HONORABLE ROGER S. ROGOFF

SUPERIOR COURT OF WASHINGTON FOR KING COUNTY

RYAN M. PSZONKA, et al., Plaintiffs, v. SNOHOMISH COUNTY, et al., Defendants.	No. 14-2-18401-8 SEA INTERIM EXPERT REPORT OF DR. J. DAVID ROGERS, Ph.D., P.E., P.G., C.E.G., C.HG. DR. MARVIN R. PYLES, Ph.D., P.E. DR. JONATHAN D. BRAY, Ph.D., P.E., NAE DR. ARNE SKAUGSET, Ph.D., R.P.F. DR. RUNE STORESUND, D.Eng., P.E., G.E. Dr. GUNNAR SCHLIEDER, Ph.D., R.G., C.E.G. JANUARY 22, 2016
TIM WARD, et al. Plaintiffs, v. SNOHOMISH COUNTY, et al., Defendants.	
GREGORY REGELBRUGGE, et al., Plaintiffs v. STATE OF WASHINGTON, et al., Defendants	

Introduction

The State Route (SR) 530 Landslide of March 22, 2014 was a slope failure of unparalleled proportions in this country. This volume comprises the second joint report in what will be a series of reports that chronicle the progress of the expert team assembled by the Attorney General (AG) of Washington in an effort to fully understand the causes of the landslide. This report must be considered a preliminary document, because, in the opinion of the authors, there is insufficient site-specific factual information available at the present time to offer an informed opinion on some of the hypotheses regarding the proximate causes of the SR 530 Landslide of March 22, 2014. More substantial forensic opinions will emerge after completion of the geotechnical field exploration program, geotechnical laboratory testing, and engineering analyses. To date, only the geotechnical field exploration has been largely completed. The geotechnical laboratory testing is anticipated to be substantially completed by the end of May 2016. Data collection from the on-site instrumentation will continue through the spring and into summer of 2016. Forensic engineering analyses are anticipated to be completed in July 2016.

This report: (1) reviews the progress made to date on the geotechnical field exploration of the SR 530 Landslide of March 22, 2014, (2) provides a preliminary overview of the geologic setting of the SR 530 Landslide area, based on desktop reviews/overlays and in-the-field mapping, (3) updates and discussions of the five (5) contentions presented in the June 1, 2015 preliminary report, and (4) outlines of the remaining work necessary to complete a final report, so that the court may understand the nature of informed expert opinions, which adhere to the standard of practice in civil engineering, forestry, and engineering geology, and therefore present a clear understanding of the salient physical conditions influencing the SR 530 Landslide.

This report also includes a discussion of the geologic field mapping being undertaken by glacial geology expert, Dr. Gunnar Schlieder, who was added to the expert team in September 2015. The AG's expert team found that the initial information gleaned from published geologic literature, the GEER report, and other publications on the SR 530 Landslide, fell short of documenting the extreme complexity of the geological conditions underlying and surrounding the landslide, which appeared in large part to have been greatly over-simplified and, in places, to be incorrect. During a preparatory site reconnaissance to locate exploratory borings, the AG's expert team recognized these shortcomings and recommended that Dr. Schlieder be added to the team to map the landslide and such surrounding areas as necessary to correctly interpret the local and regional geology as it pertains to the landside area and the materials involved in the landslide. At this time, Dr. Schlieder's work has provided important insights, however, his detailed geologic mapping is not yet complete and cannot be completed until the weather conditions and corresponding safety concerns at the site are within reasonable limits.

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APPENDICES

Nature of Involvement

The members of the expert team that prepared this report were retained by the State of Washington's Attorney General Office to formulate expert opinions in relation to the following questions associated with the SR 530 Landslide that occurred on March 22, 2014:

1. The causation of the SR 530 Landslide;
2. The predictability of the SR 530 Landslide in the time frame of pertinent DNR FPA approvals;
3. The predictability of the runout of the SR 530 Landslide; and
4. The impact of pertinent DNR approved timber harvests on the Whitman Bench with regard to the causation of the SR 530 Landslide.

Credentials and Compensation

Dr. J. David Rogers, Ph.D., P.E., P.G., C.E.G., C.HG. holds the Karl F. Hasselmann Chair in Geological Engineering in the Department of Geosciences and Geological and Petroleum Engineering at the Missouri University of Science & Technology. He has 40 years of experience in evaluating the stability of natural slopes, embankments, stream channels, highways, and hydraulic structures. Since 1979 he has managed over 500 projects in the western United States, Hawaii, Alaska, Taiwan, the Philippines, Papua New Guinea, Japan, Korea, Taiwan, Iraq, and Afghanistan. He has served as principal investigator for scientific research funded by the National Science Foundation, U.S. Geological Survey, Federal Highway Administration, Department of Defense, and the California and Missouri Departments of Transportation, among others. Much of Dr. Rogers' research over the past 15 years has focused on regional landslide hazard mapping, in the United States, Ethiopia, Pakistan, and Nepal. He has also studied long-runout landslides in California, Colorado, Alaska, Wyoming, Montana, Washington, Pakistan, and Papua New Guinea. Dr. Rogers has served on a number of panels, including the National Academies panel on 'Levees and the National Flood Insurance Program,' the Technical Advisory Committee on Regional Geologic Studies and Slope Stability Modeling for the California Geological Survey, and the Building Codes and Dam Safety Committees of the Association of Environmental & Engineering Geologists. Rogers is a registered civil engineer, geologist, engineering geologist, and hydrogeologist in California. Dr. Rogers' hourly rates are $275/hr for straight time; $350/hr for deposition and trial testimony preparation; and $500/hr for deposition and trial testimony, without any minimum number of hours charged.

Dr. Marvin Pyles, Ph.D., P.E., F.ASCE, is a Professor Emeritus of Forest Engineering at Oregon State University. He is a registered Professional Engineer in Washington, Oregon, and California, and specializes in Geotechnical Engineering and the regulation of Forest Practices with respect to landslide and other erosional processes. Dr. Pyles rate for normal consulting is $200/hr plus expenses, and for depositions and court testimony, $400/hr plus expenses.

Professor Jonathan D. Bray, Ph.D., P.E., NAE is a registered professional civil engineer and professor of civil and environmental engineering at the University of California, Berkeley. Dr. Bray is a professor of geotechnical engineering with expertise in slope stability, soil characterization, numerical analysis, earthquake engineering, and post-event reconnaissance. Dr. Bray's consulting fee for providing engineering services on a project involved in litigation is $300.00/hr plus expenses and $450.00/hr plus expenses for work involved in preparation for and performance of deposition or trial testimony.

Dr. Arne Skaugset, Ph.D., R.P.F., is an expert on forest management and forest engineering; hydrologic impact of timber practice, landslide-prone land management in the forest environment, precipitation data collection and analysis, forest landslide hazard analysis, identification and mitigation, landslide triggers and rainfall intensity. Dr. Skaugset's consulting fee of providing technical expertise is $250/hr plus expenses and $500/hr for depositions and testimony.

Dr. Rune Storesund is a licensed civil and geotechnical engineer with 15 years of civil engineering experience and 10 years of forensic engineering experience in the areas of geotechnical, water resource, and environmental engineering. He provides civil forensics support for pre-trial review, engineering standard of care, document/data review and synthesis, engineering contract review, forensic investigations and analyses, failure mode analysis, legal visual aids & animations, and expert witness services. He also has expertise on survey methods including Total Station, RTK GPS, and LiDAR. He has a Doctorate of Engineering in Civil Systems and a Masters in Geotechnical Engineering from University of California, Berkeley. Dr. Storesund is the Executive Director of University of California, Berkeley's Center for Catastrophic Risk Management, a group of academic researchers and practitioners who recognize the need for interdisciplinary solutions to avoid and mitigate tragic events. This group of internationally recognized experts in the fields of engineering, social science, medicine, public health, public policy, and law was formed following the tragic consequences of Hurricane Katrina to formulate ways for researchers and experts to share their lifesaving knowledge and experience with industry and government. Dr. Storesund serves as a technical reviewer for the National Academy of Forensic Engineers (NAFE). In the past 10 years, he has participated in the following forensic investigation: Mississippi River Gulf Outlet Wave-Induced Erosion, St. Bernard Parish, Louisiana; Investigation of the Greater New Orleans Area Flood Defense System Failure, New Orleans, Louisiana; Upper Jones Tract Levee Failure, San Joaquin County, California; East Bank Industrial Area (Lower 9th Ward), New Orleans, Louisiana; Tumbi Long-Runout Landslide, Papua New Guinea (underlined indicates expert witness-related cases). Dr. Storesund is compensated at a rate of $175.00/hr for engineering consultations, $262.50/hr for testimony preparation, and $350/hr for expert testimony/depositions, plus incurred expenses.

Dr. Gunnar Schlieder is an Oregon Registered Geologist (RG) and Certified Engineering Geologist (CEG) with 29 years of professional experience specializing mostly in geotechnical assessments for slope stability related projects and development of foundation design parameters. He has extensive experience in forensic geotechnical investigations related to slope stability, including long-run-out slides, expansive soils, and settlement issues. He has provided expert testimony for both plaintiffs and defendants. Clients have included government agencies (Oregon Department of Forestry, Oregon Department of Geology and Mineral Industries, City of Eugene), industry (mostly timber- and quarry-related cases), and private parties. He received a Ph.D. from Lehigh University for his work on the glacial geology and chronology of a portion of the Patagonian Andes. Dr. Schlieder is compensated at a rate of $150.00/hr for his work on the SR-530 slope movement, plus incurred expenses.

Requirement of a Complete Site Characterization Program

It is not possible to formulate expert opinions substantiated by site-specific facts regarding causation or potentially contributing factors to the March 22, 2014 SR 530 Landslide without a site-specific program of site characterization. Site-specific characterization programs include evaluation of topography, geology, subsurface seepage, weather, subsurface exploration, geotechnical laboratory testing, and instrumentation (1) (2). Our work focuses on characterization of geology, seepage and groundwater, rainfall and associated throughfall, subsurface geotechnical exploration, geotechnical laboratory testing, and site-specific data captured via the instruments installed on Whitman Bench, as well as within the main body of the 2014 SR 530 Landslide.

As of submission of this report, the geotechnical field exploration work has largely been completed, instruments have been installed, and a substantial amount of the geologic field mapping has been conducted. The outstanding items that remain incomplete, in order to develop more complete expert opinions, include: (a) completion of the geotechnical laboratory testing to establish the engineering properties of the onsite-soils, (b) collection of site-specific data on groundwater response (via vibrating wire piezometers and standpipes) and slope movements (via traversing-type inclinometers and extensometers previously installed by WSDOT), (c) completion of the site-specific geologic mapping, and (d) the forensic analyses necessary to fully inform our expert opinions.

Slope stability analyses (whether limit equilibrium or finite element) require definition of the site-specific landslide geometry, likely groundwater regime, soil unit weights, and soil shear strengths of key units to calculate a global slope stability factor of safety (FS) (3). The completed geotechnical exploration program has identified the location of the surface of rupture of the landslide at several locations, as well as in visible exposures in vicinity of the 2014 slide's toe of surface of rupture. Installed piezometers are providing information on the groundwater regime and subsurface flow, both of which may have exerted a significant influence on slope stability. Previous and ongoing soil classification and soil index testing are providing information on the soil's unit weight, specific gravity, plasticity, gradation, as well as other diagnostic soil properties. However, at this time, there are insufficient geotechnical laboratory test results to evaluate the in-situ shear strength (peak, softened, and residual) of the key geologic units involved in the SR 530 Landslide. Geotechnical laboratory testing could only be initiated after completion of the field exploration program, which provides the physical soil samples upon which the geotechnical laboratory testing will be conducted. This testing requires specialized test equipment due to the high pressures required to capture the in-situ stress conditions along the surface of rupture, which is deep within the landslide. Unlike routine geotechnical tests, these tests also require significant durations (weeks to months) to evaluate relevant responses (such as fully-drained behavior) of the test specimens.

Issuing a final expert opinion that is predicated on information not yet available would be speculative at best and inconsistent with the standard of professional practice we are bound to uphold by our licensure. We have full intention of following through with our commitment to determine the proximate cause(s) of the SR 530 Landslide. The geotechnical laboratory testing is anticipated to be completed in May 2016. Data collection from the on-site instrumentation will continue through the spring and into the summer of 2016. Forensic engineering analyses are anticipated to be completed in July 2016. However, we submit this interim report in order to comply with the court-imposed case management order.

Field Exploration Program

The field exploration program was generally outlined in May of 2015 and consisted of a series of exploratory borings on Whitman Bench, borings in Upper Headache Creek Basin, and borings within the main body of the SR 530 Landslide. The exploratory borings are listed in Table 1. Site reconnaissance efforts were conducted in June and July 2015 to identify potential access routes onto the body of the SR 530 Landslide. Specific site access challenges are described below (Site Access Logistics).

One drill rig began drilling on Whitman Bench in mid-July 2015. Simultaneous drilling by two drill rigs shifted to the main body of the slide in mid-September 2015 and continued through early October 2015. Drilling activities included in-situ soil testing (sample retrieval, blow counts, etc.), soil sample collection, installation of vibrating wire piezometers (for measurements of groundwater levels), and installation of slope inclinometer casings (necessary to record slope movements). Drilling with one drill rig resumed on Whitman Bench following completion of drilling on the main body of the SR 530 Landslide in October 2015 and was completed in December 2015. Preliminary geologic field mapping was initiated between September 2015 and December 2015.

An overview map of proposed locations versus as-drilled locations is presented in Figure 1 and an overview map of the as-drilled locations are shown in Figure 2. Note that Figure 2 also shows the location of H-1vwp-14, which was a deep exploratory boring completed by WSDOT in 2014, prior to initiation of this field exploration program.

Table 1: Summary of exploration points for SR 530 Landslide

Boring Location	Exploration Point	Ground Elev (ft)*	Boring Depth (ft)	Start Date	End Date
EB-01	EB-01vwp-15	865.34	129.7	7/24/2015	7/26/2015
EB-01	CPT-01-15		32.6	7/27/2015	7/27/2015
EB-02	EB-02vwp-15	867.40	594.0	10/15/2015	12/10/2015
EB-02	SP-01vwp-15		116.0	10/13/2015	10/14/2015
EB-03	EB-03vwp-15	890.30	141.4	7/14/2015	7/16/2015
EB-04	EB-04si-15	535.85	281.5	9/16/2015	9/22/2015
EB-04	EB-14vwp-15	539.45	280.0	9/24/2015	9/29/2015
EB-04	CPT-17-15	537.67	157.3	10/1/2015	10/1/2015
EB-05	EB-05si-15	497.08	155.0	10/6/2015	10/8/2015
EB-06	EB-06vwp-15	867.54	279.0	10/27/2015	11/3/2015
EB-07	EB-07si-15	412.25	151.0	10/1/2015	10/2/2015
EB-07	H-18vwp-15	412.37	60.5	10/7/2015	10/7/2015
EB-08	EB-08vwp-15	847.29	240.0	10/20/2015	10/22/2015
EB-09	EB-09si-15	378.94	145.5	9/16/2015	9/18/2015
EB-09	H-13vwp-15	379.53	120.5	9/21/2015	9/23/2015
EB-09	CPT-19-15	378.28	53.3	10/7/2015	10/7/2015
EB-10	EB-10vwp-15	863.32	140.7	7/16/2015	7/21/2015
EB-11	EB-11vwp-15	832.53	76.5	7/22/2015	7/22/2015
EB-12	H-12si-15	438.06	176.0	9/23/2015	9/24/2015
EB-12	H-15vwp-15	437.59	131.0	9/29/2015	9/29/2015
EB-12	CPT-16-15	438.05	100.9	9/30/2015	9/30/2015

**Vertical datum is NAVD88, units of feet (see "osobh102315 revised.xlsx" for WSDOT Survey Results)*

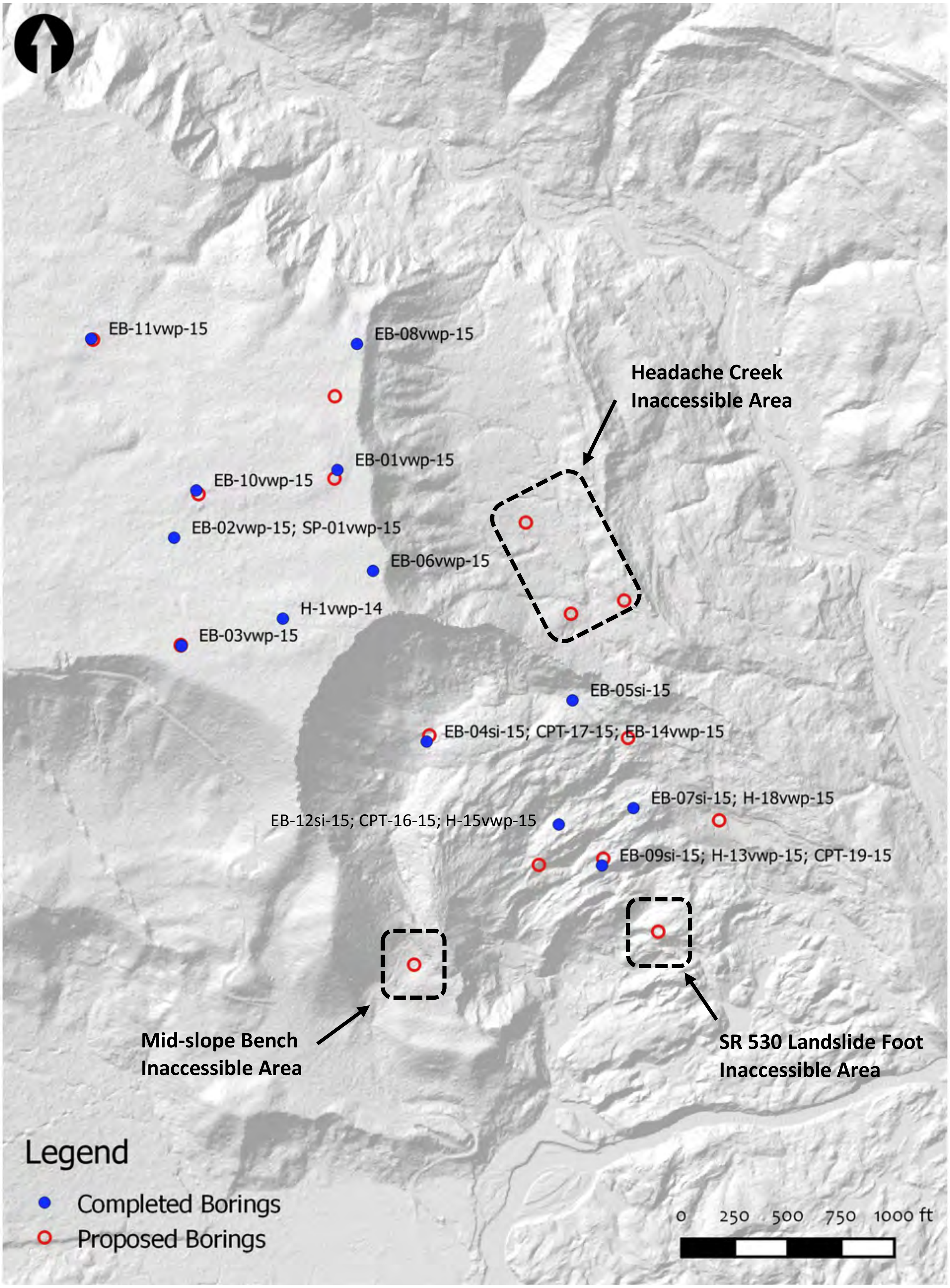

Figure 1: Overview of originally proposed (red) exploratory borings vs. actual (blue) as-drilled locations.

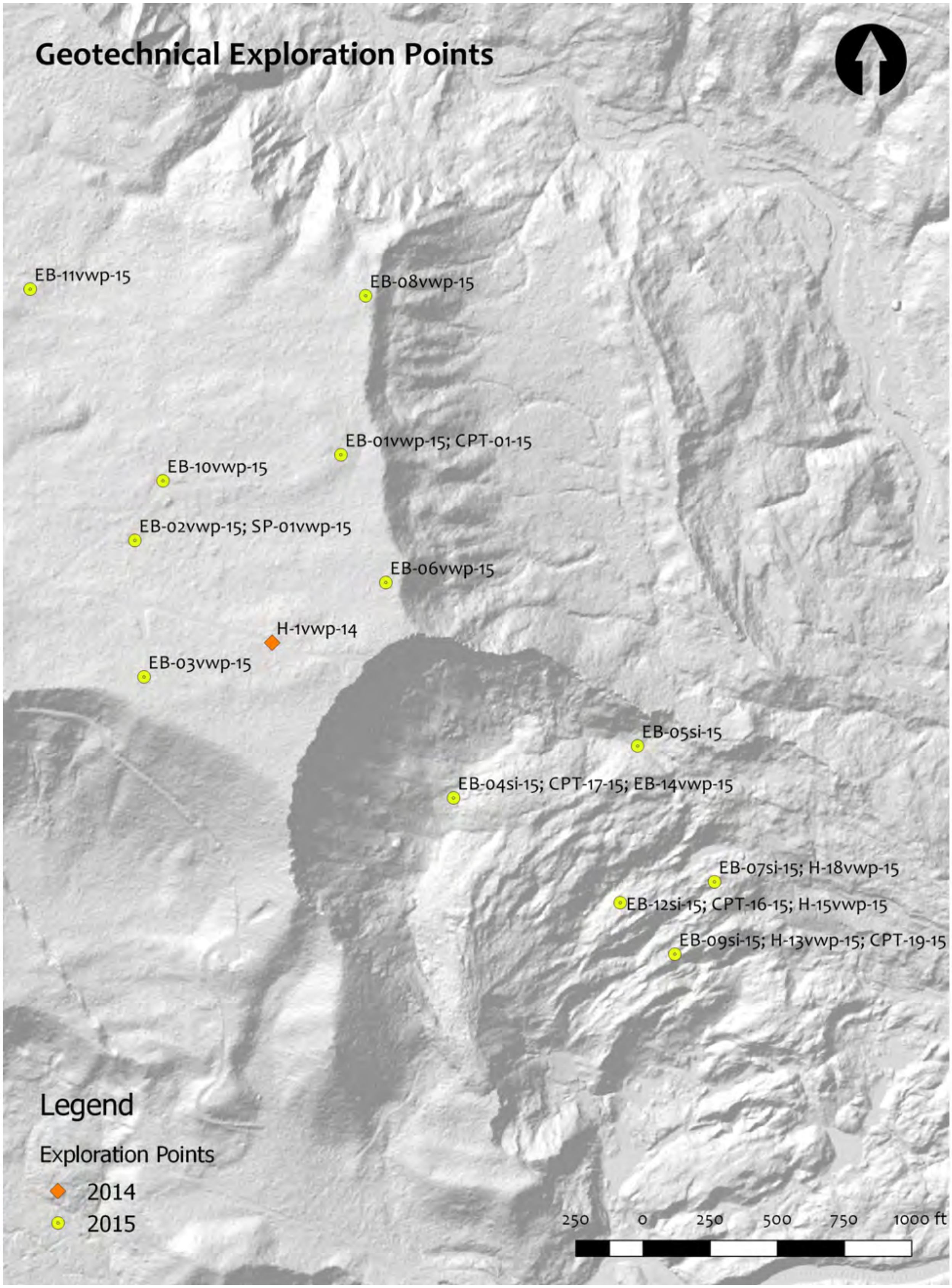

Figure 2: Locations of completed exploratory borings and CPTs.

Program Formulation

The field exploration program was generally outlined during an expert meeting in May of 2015. Exploratory borings were planned to be performed on Whitman Bench, in the Upper Headache Creek Basin, and within the main body of the SR 530 Landslide. The purposes of these borings included the following: (a) obtain samples for geotechnical laboratory testing to ascertain engineering properties; (b) delineate the site-specific soil stratigraphy, including identification of the surface of rupture; (c) obtain estimates of in-situ unit density information via sampler blow counts; and (d) enable the installation of instrumentation at selected stratigraphic horizons below the ground surface.

The field exploration program was developed based on input from the Washington State Department of Transportation's (WSDOT) previous experience conducting subsurface exploration in 2014 on Whitman Bench, as well as other locations in the immediate vicinity. The expert team also considered input from the other defense experts, as well as input submitted by plaintiff experts via the State of Washington's Attorney General Office.

Site Access Logistics

An initial site reconnaissance was undertaken in mid-June 2015. Proposed boring locations were loaded in GPS field books so that access to each location could be evaluated and shifted as necessary, and stakes placed in the ground to mark the intended exploration points. Several additional trips were made in June and July 2015 by various parties to examine potential access routes to the borings on the main body of the SR 530 Landslide.

Three boring locations were planned for the Upper Headache Creek Basin. It was anticipated that conventional drilling equipment would not be able to access these sites, so a portable tripod system was envisioned. This system would have required transport via helicopter. Challenges included: providing a landing area; transporting the tripod system from one location to the next; shuttling daily supplies and drilling crews to and from the drill sites, and transporting the recovered samples from the site.

One boring was also envisioned on top of the remaining segment of the mid-slope bench. The mid-slope bench appears to be a remnant erosional feature of past slide movement(s) emanating from Whitman Bench. This boring would have provided information on the composition of the mid-slope bench, including geologic structure and groundwater conditions. Access to this location was constrained by steep slopes within the main body of the slide to the east and private property to the west.

Finally, one boring was intended to be performed through the foot of the SR 530 Landslide to characterize the landslide debris and gain insights as to composition and overlay of 2014 slide debris vs. 2006 slide debris. During the field reconnaissance, it was determined that access to this location, due to the soft soils and amount of grading required, was not feasible.

Two separate access routes were required to execute the drilling program: access to Whitman Bench and access to the main body of the SR 530 Landslide. Access to Whitman Bench was accomplished via State of Washington Department of Natural Resources (DNR) logging roads as well as private land owned by Grandy Lakes (Figure 3). This access route is approximately 13 miles long and, due to the condition of the road, requires about 45 to 60 minutes to traverse each way.

Developing access to the main body of the SR 530 Landslide required significantly more effort, and the preparation and submission of a grading permit to Snohomish County and DNR to enable the construction of temporary access paths to the exploration points (the permit was submitted in mid-August 2015 by WSDOT). A separate, much shorter, access route was identified from the east, using C-Post Road, traversing private property to a staging area just east of Rollins Creek. This location, however, required negotiation of an access agreement with the private landowners, construction of a temporary crossing of Rollins Creek (Figure 4) and grading of an access route, so that the drill equipment could reach the proposed boring locations (Figure 5).

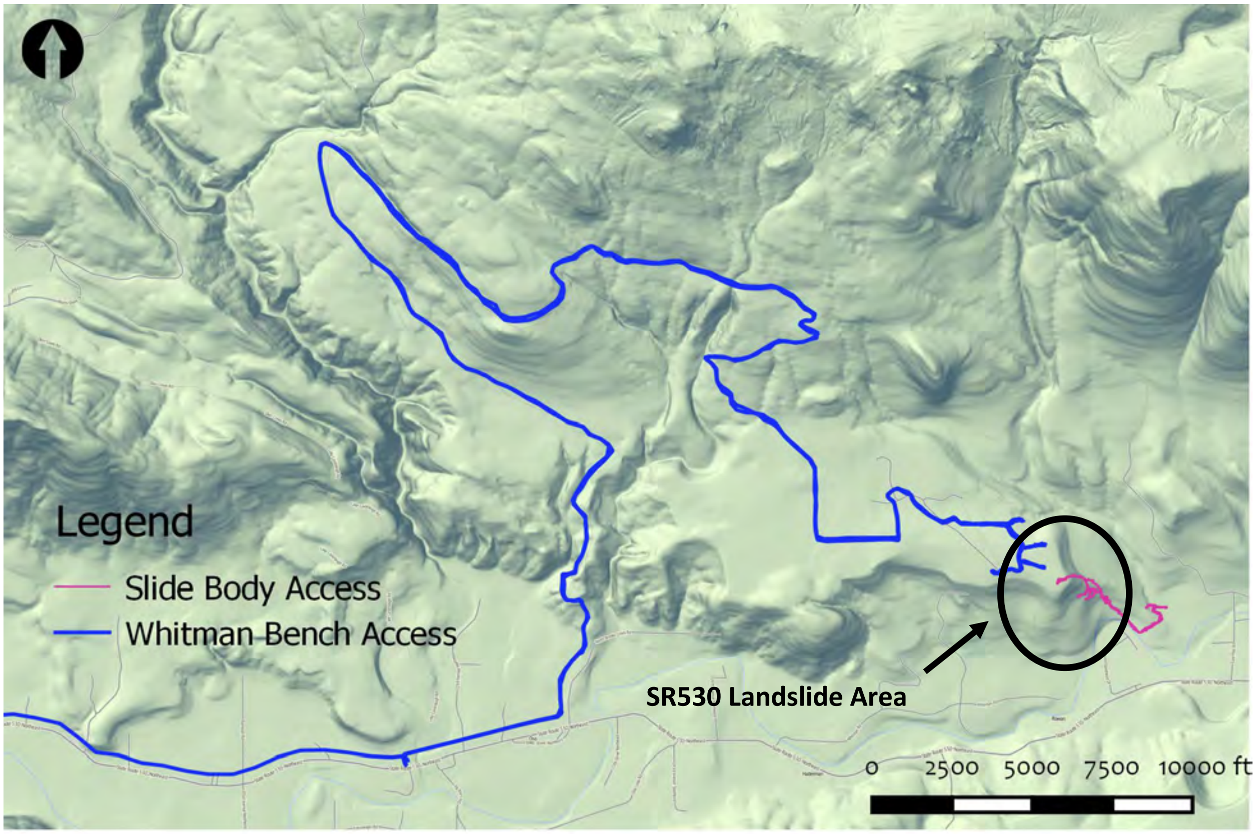

Figure 3: Access routes for Whitman Bench (in blue) and SR 530 Landslide main body (in purple) during exploratory drilling.

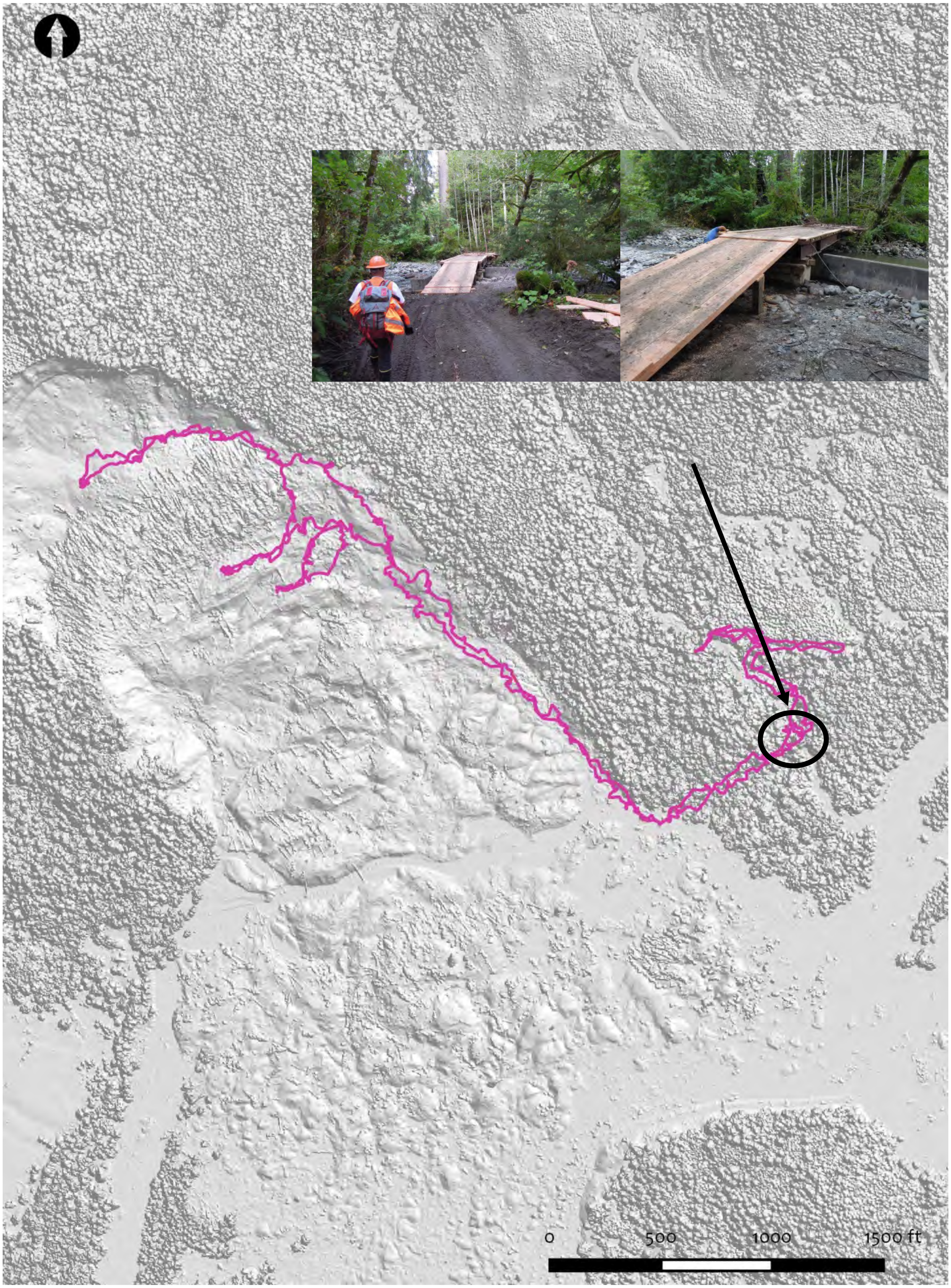

Figure 4: Enhanced view of access paths for exploratory work on main body of the SR 530 Landslide.

Figure 5: Tracked excavator grading an access path to the drill pad for EB-04 on the main body of SR 530 Landslide.

Exploratory Borings & Surface of Rupture

The exploratory borings on the SR 530 Landslide were advanced using a CME-850 tracked drill rig (Figure 6). Two drilling techniques were used; hollow stem auger and rotary wash. The hollow stem auger technique was used in the Recessional Outwash sands so that soil samples could be obtained and moisture content testing performed, to ascertain representative values of in-situ soil moisture content (rotary wash methods typically saturate sandy materials during the drilling/sampling process). Hollow stem auger drilling was employed on EB-01vwp-15 and SP-01vwp-15. The remaining borings were advanced using rotary wash methods.

Exploratory boring EB-05 was terminated early due to inclement weather and safety concerns by WSDOT. This boring was advanced to a depth of 155 feet; the anticipated target depth was approximately 200 feet.

Figure 6: CME-850 drill rig setup at EB-04 on the main body of SR 530 Landslide (drill rods supported on stands).

A suite of samplers were used to recover soil samples. These samplers included: Standard Penetration Test (SPT) sampler; an oversize sampler; a Dames & Moore (DM) sampler; a core barrel sampler without brass liners; a core barrel sampler with brass liners; and a punch-core sampler devised by WSDOT. The SPT, oversize, and DM samplers were advanced with drill rod segments. The core barrel and punch core samplers were advanced using wireline techniques. An automatic 140 lb. drop hammer was used to obtain blow counts on the SPT, oversize, and DM samplers. No blow count information was collected via the core barrel sampler because this sampler is advanced by drilling, whereas the SPT, oversize, and DM samplers are mechanically driven into the ground.

WSDOT provided the drill rigs and support crews. Each drill crew typically included an inspector who would log the stratigraphic units encountered and catalog the collected samples.

Figure 7: WSDOT Inspector examining soil core sample and packaging in core box.

Field logs with field notes from each soil boring are presented in Appendix A. The field notes associated with each boring are listed in Table 2. Photographs of soil samples extracted in the field are presented in Appendix B. Formal exploratory boring logs will be produced following completion of the geotechnical laboratory testing. These logs will present finalized interpretations of stratigraphy, blow counts, laboratory testing, and associated boring metadata (i.e. location and elevation). Finalized logs are anticipated to be produced in May 2016.

The surface of rupture was found exposed in the lower western portion of the slide source area, and was found in the borings installed in the slide area. In some of the borings, identification of the location of the surface was unequivocal, as the surface represented the transition from high stratigraphic units (recessional outwash) into much lower stratigraphic units (glacio-lacustrine silt and clay), as shown in Figure 8. In other borings, the determination was made on the basis of an abrupt transition from disturbed/distorted laminae in the fine-grained glacio-lacustrine units to horizontally laminated material.

At other borings, the determination was more difficult. However, in no case was any evidence of shearing or disruption consistent with the presence of the surface of rupture evident in the materials obtained from below El. +310 feet.

In the exposures in the lower western source area (Figure 9 & Figure 10), the surface of rupture is located on and barely within the Bear Lake Sand, transitioning upslope into the lowermost portion of the glacio-lacustrine silt and clay. In some exposures of the SR 530 Slide Surface of Rupture, Recessional Outwash is found on undisturbed Bear Lake Sands or on horizontally laminated fine-grained glacio-lacustrine unit. At other exposures, other stratigraphic units are found in contact with the Bear Lake Sands. These exposures are also all located above El. +310 feet.

Figure 8: Surface of rupture delineated at contact of recessional sand and glacio-lacustrine silt and clay at boring EB-04-si-15.

Figure 9: View of surface of rupture exposure with clay shear zone at top of Bear Lake Sands (photo taken on 10/23/2015 at 48.282N;121.848W, looking SW).

Figure 10: View of glacio-lacustrine silt and clay exposure of surface of rupture (photo taken 10/23/2015 at 48.282N; 121.848W, looking N).

Table 2: Correspondence between field logs and exploration point IDs.

Boring Location	Exploration Point	Ground Elev (ft)*	Boring Depth (ft)	Field Log
EB-01	EB-01vwp-15	865.34	129.7	EB-01-15 field notes.pdf
EB-01	CPT-01-15		32.6	CPT-01-15 Data.txt
EB-02	EB-02vwp-15	867.40	594.0	EB-02vwp-15 field notes_DRAFT.pdf
EB-02	SP-01vwp-15		116.0	SP-01-15 field notes.pdf
EB-03	EB-03vwp-15	890.30	141.4	EB-03-15 field notes.pdf
EB-04	EB-04si-15	535.85	281.5	EB-04si-15 field notes.pdf
EB-04	EB-14vwp-15	539.45	280.0	EB-14vwp-15 field notes.pdf
EB-04	CPT-17-15	537.67	157.3	CPT-17-15 Data.txt
EB-05	EB-05si-15	497.08	155.0	EB-05si-15 field notes.pdf
EB-06	EB-06vwp-15	867.54	279.0	EB-06vwp-15 field notes.pdf
EB-07	EB-07si-15	412.25	151.0	EB-07si-15 field notes.pdf
EB-07	H-18vwp-15	412.37	60.5	H-18vwp-15 field notes.pdf
EB-08	EB-08vwp-15	847.29	240.0	EB-08vwp-15 field notes.pdf
EB-09	EB-09si-15	378.94	145.5	EB-09si-15 field notes.pdf
EB-09	H-13vwp-15	379.53	120.5	H-13vwp-15 field notes.pdf
EB-09	CPT-19-15	378.28	53.3	CPT-19-15 Data.txt
EB-10	EB-10vwp-15	863.32	140.7	EB-10-15 field notes.pdf
EB-11	EB-11vwp-15	832.53	76.5	EB-11-15 field notes.pdf
EB-12	H-12si-15	438.06	176.0	EB-12si-15 field notes.pdf
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EB-12	CPT-16-15	438.05	100.9	CPT-16-15 Data.txt

**Vertical datum is NAVD88, units of feet (see "osobh102315 revised.xlsx" for WSDOT Survey Results)*

Cone Penetration Tests

Cone Penetration Tests (CPTs) were attempted at four of the exploratory borings locations: EB-01, EB-04, EB-09, and EB-12. The CPT was advanced using the CME-850 rig (Figure 11). The CPT crew experienced significant challenges advancing the CPT at the EB-01 location. The drilling crews were able to advance the CPT with a series of push-drill-push sequences at EB-04, EB-09, and EB-12. The reported CPT results are presented in Appendix C.

Figure 11: Pushing CPT with the CME-850 at the EB-12 exploratory location.

Instrumentation

Two instrumentation approaches were employed as part of our geotechnical exploration program: groundwater levels based on vibrating wire piezometers (vwp), and slope movement detection using traversing-type inclinometers. Details regarding specific instruments, configuration of data collectors and data transmission, and calibration sheets, are presented in Appendix D. VWP instruments generally collect data every two hours. Weekly updates are extracted from the data logger by WSDOT personnel and then distributed to the State of Washington Attorney General's office for distribution to the designated parties (State of Washington Expert Team being one of the designated parties).

WSDOT initiated the process of instrument installation during execution of the exploratory borings as part of the 2015 campaign (WSDOT previously installed instruments as part of the 2014 work performed on Whitman Bench). The WSDOT instrumentation team then connected the individual stations to central data loggers, after the majority of the installations were complete. The first batch of data came online in late October 2015. The last set of instruments was connected to the base stations in late December 2015. We note that a formal quality control check on the instrumentation data (e.g. verifying correct surface elevations, instrument depths, and calibration factors) has not been completed yet. This quality control will need to be completed before the data can be used in formal analyses. We anticipate the quality control phase to be completed by early March 2015.

Upper Headache Creek Basin Mapping

As noted earlier, we were unable to mobilize drilling equipment to explore the Upper Headache Creek Basin. As a result, we spent several days field mapping springs and seeps, creeks, drainages, exposures, hand auguring, and digging shallow test pits to ascertain near-surface conditions (Figure 12).

Inspection of high resolution LIDAR images of the Whitman Bench and Landslide area (4) shows obvious signs of surface water erosion on the escarpment to the east of the Whitman Bench – specifically into the Headache Creek Basin. No such surface water erosion signature is visible on the 2013 LIDAR image in the escarpment above the earlier Hazel slide, nor is there a surface water erosion signature in the escarpment on the edge of the Whitman Bench to the west of the area of the SR 530 Landslide. This led to a field mapping traverse of the Headache Creek basin to verify that the surface erosion channels evident on the LIDAR images were in fact, just that. There were numerous springs emanating from the slope at approximately the level of the top of the till.

The fact that springs emanating from the level of the top of the till are only evident in the Headache Creek Basin, suggests that lateral groundwater flow trends to the north and east, and not to the south, where the SR530 landslide occurred. During our traverse through the Headache Creek Basin, we encountered native glacio-lacustrine silt and clay in an exposure in Headache Creek (Location #1 in Figure 12; see Figure 13). This clay was discovered at approximately El. +530 to El. +570 feet. We were able to verify the presence of native glacio-lacustrine silt and clay at the northern end, as well as the eastern margin of Headache Creek Basin. At all locations, the glacio-lacustrine silt and clay was situated above El. +500 feet. This means that the Headache Creek Basin does not appear to be a large, deep-seated landslide ((5) (6) (7)); rather, the surface of rupture is likely situated above El. +500 to +550 feet.

Within the Headache Creek Basin, we performed seven shallow (3-15 feet) hand auger probes to examine the surficial soils. These borings encountered olive-gray clayey sand to sandy clay, until we hit refusal due to the presence of gravels/cobbles (Figure 14). The hand auger probes on the ridge between Headache Creek Basin and the Hazel Landslide encountered material consisting of well graded sand to silty sand. “Blue” sandy clay was encountered at a depth of 14 feet at the ridge location. Water was also encountered at a depth of 14 feet (on 9/27/15).

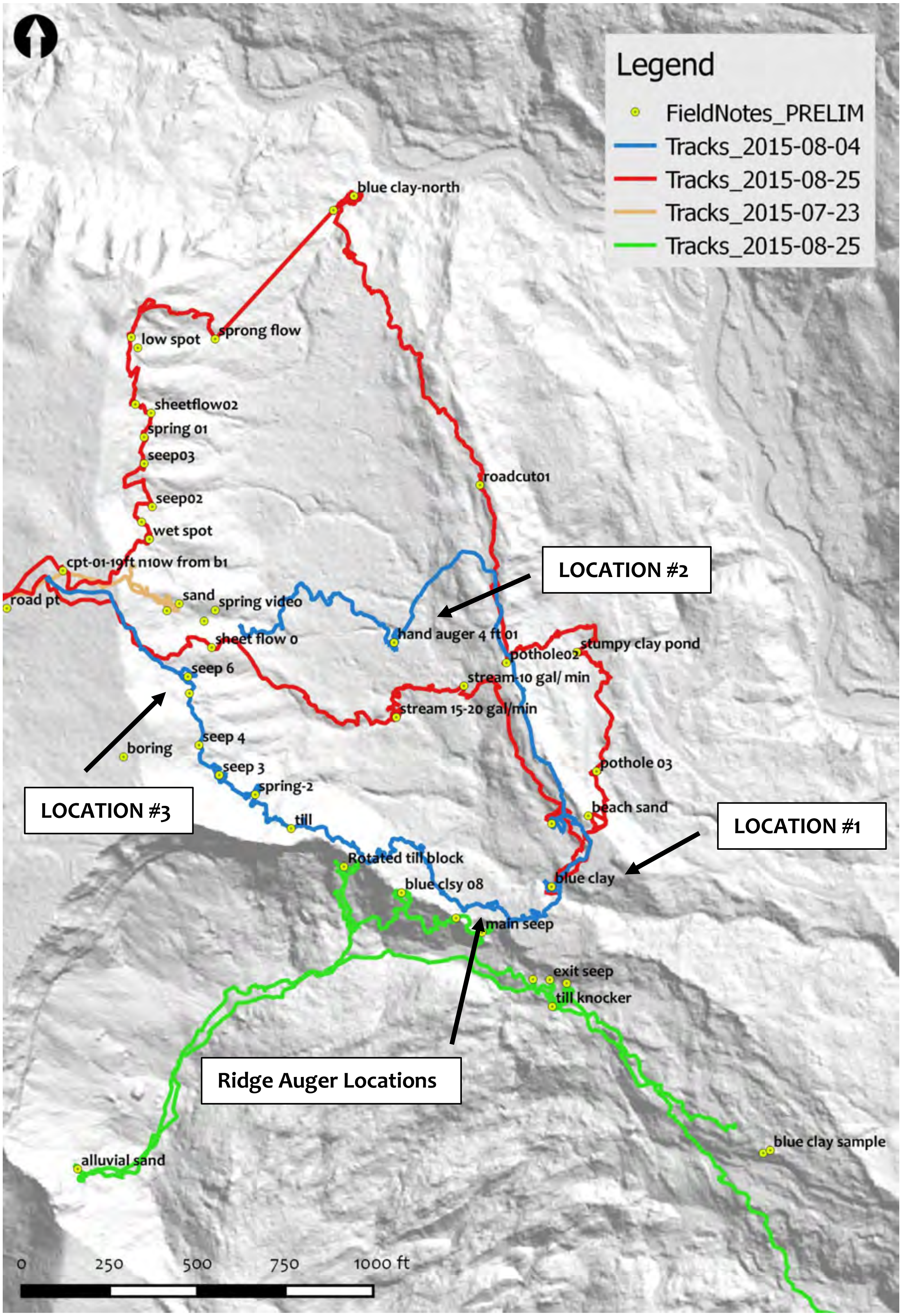

Figure 12: Field mapping tracks from Headache Creek Basin.

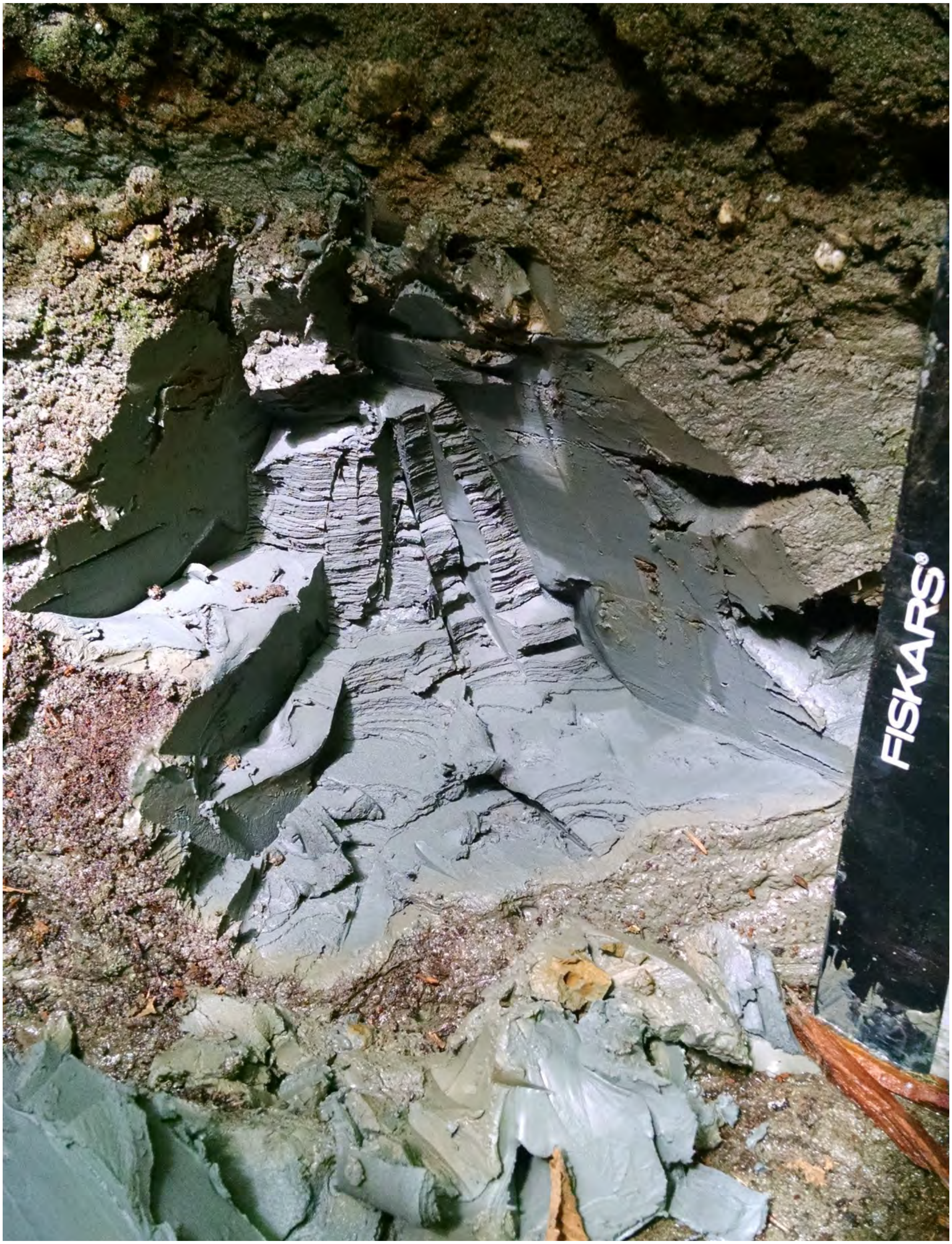

Figure 13: Native glacio-lacustrine silt and clay encountered in Headache Creek ("blue clay" location #1 in Figure 12).

Figure 14: Hand auger within Headache Creek encountered sandy clay (location #2 in Figure 12).

We mapped several seeps and springs (Figure 15) along the western margin of Headache Creek Basin. We observed that approximately 1/3 of the Upper Headache Creek Basin drains to the north; the other 2/3 drains down to Rollins Creek via Headache Creek. We were unable to locate any similar discharges within the main scarp of the SR 530 Landslide.

Figure 15 Spring emanating from Whitman Bench (~10 gal/min) (location #3 in Figure 12).

Terrestrial LiDAR Scanning

We performed a terrestrial (ground based) LiDAR scan campaign of the western exposures and main scarp on September 24 and 25, 2015, using a Faro Focus 3D X series (Figure 16). Temporary control points were set and positions were determined using a Trimble R8 GNSS receiver. The purpose of this scan campaign was to obtain higher resolution point cloud data to enable draping of high-resolution photographs onto a high-resolution digital elevation model (DEM) and thereby determine high-accuracy contact elevation of exposed stratigraphic units.

Traditional Aerial LiDAR only has the perspective of 'top-down,' so augmenting the available aerial LiDAR surveys with the terrestrial LiDAR provides the ability to generate high resolution of oblique surfaces, such as that of the landslide main scarp (evacuation scar).

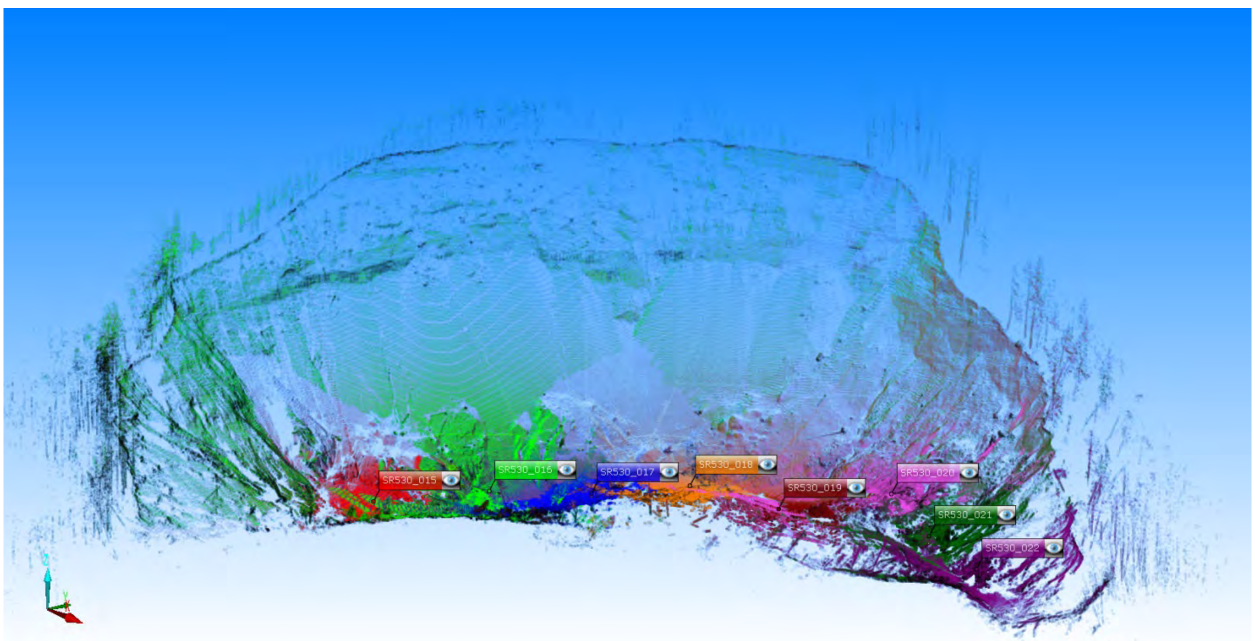

Figure 16: Terrestrial LiDAR mapping of the main scarp of the SR 530 Landslide.

Rainfall & Throughfall Monitoring Program

A network of 28 tipping bucket rain gages was installed on Whitman Bench in the vicinity of the SR 530 Landslide main scarp to quantify the effect different aged forest canopies have on the delivery of rainfall to the soil surface (throughfall). The rain gages are arranged in three transects of eight rain gages in the different aged forest stands, and one transect of four rain gages in a small (2004) clear-cut north of the SR 530 Landslide main scarp.

Twenty-two of the rain gages were installed on November 20, 2014. These rain gages were installed in three transects of seven rain gages each in the different aged forest stands, and one rain gage was installed in the clear-cut. On December 4, 2014, one rain gage was added to the end of each of the three transects and an additional rain gage was installed in the clear-cut. In April 2015, two additional rain gages were installed in the 2004 clear-cut. All of the rain gages were removed in July 2015, for re-calibration. Once they were re-calibrated they were reinstalled at the site on September 26, 2015. The last download for the rain gages for which data has been reduced is December 5, 2015.

During the summer of 2015 the rain gage locations were determined using a total station theodolite by the Washington State Department of Transportation. Figure 17 through Figure 20 show the surveyed locations of the rain gages in the three different age class forests on the Whitman Bench in the vicinity of the 2014 landslide.

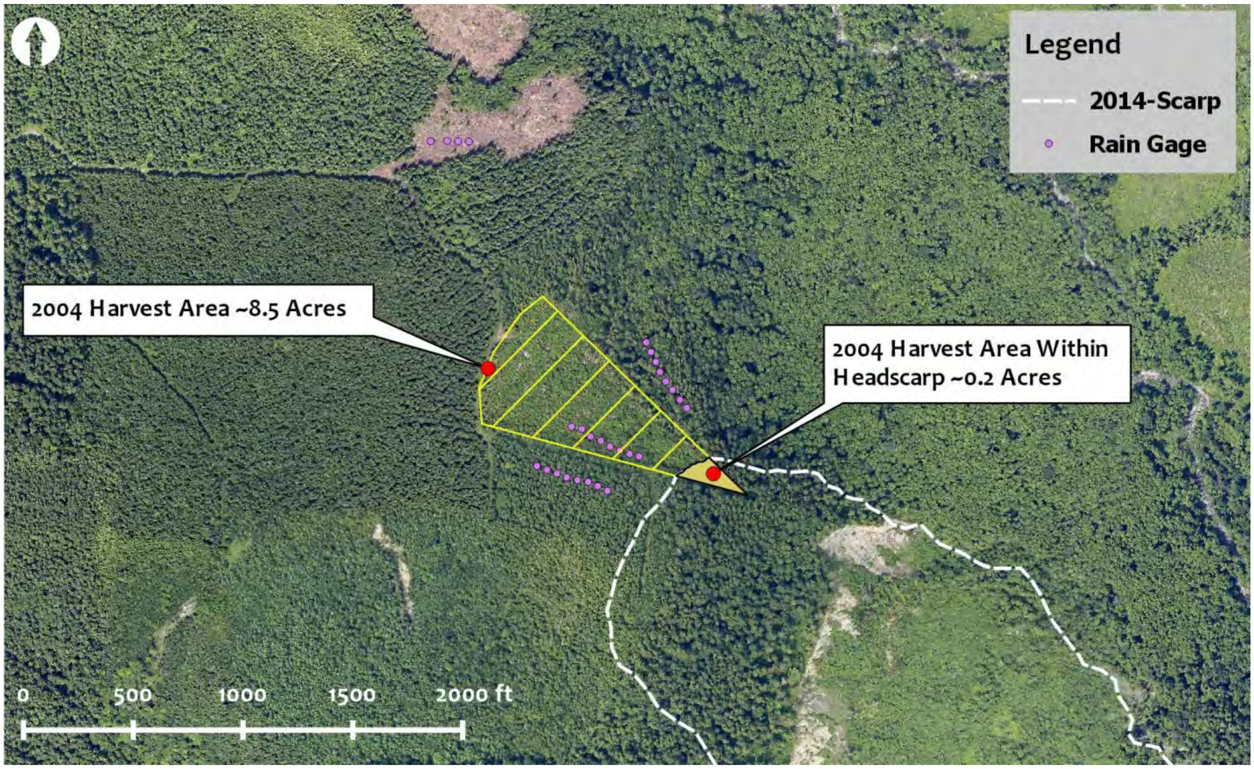

Figure 17: Overview of rain gage locations with 2012 aerial image base map.

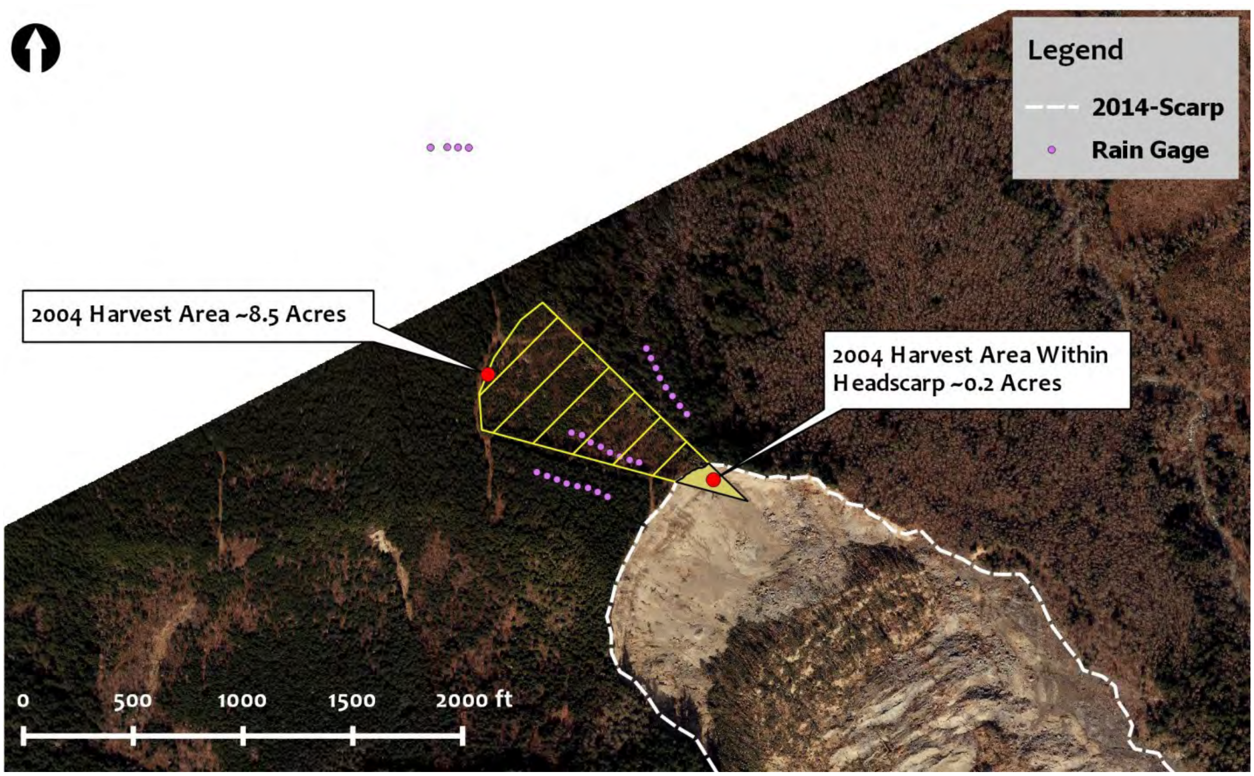

Figure 18: Overview of rain gage locations with 2014 (post slide) aerial image base map.

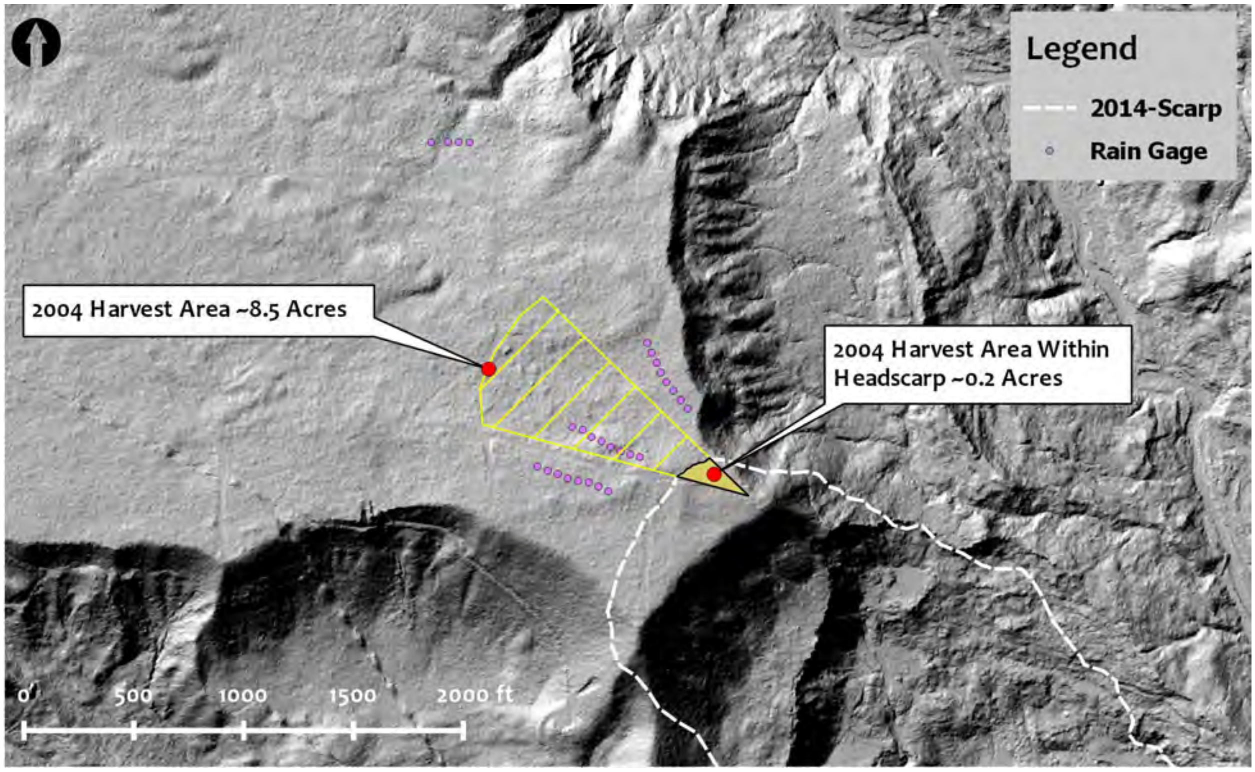

Figure 19: Overview of rain gage locations with 2013 Aerial LiDAR hill shade base map.

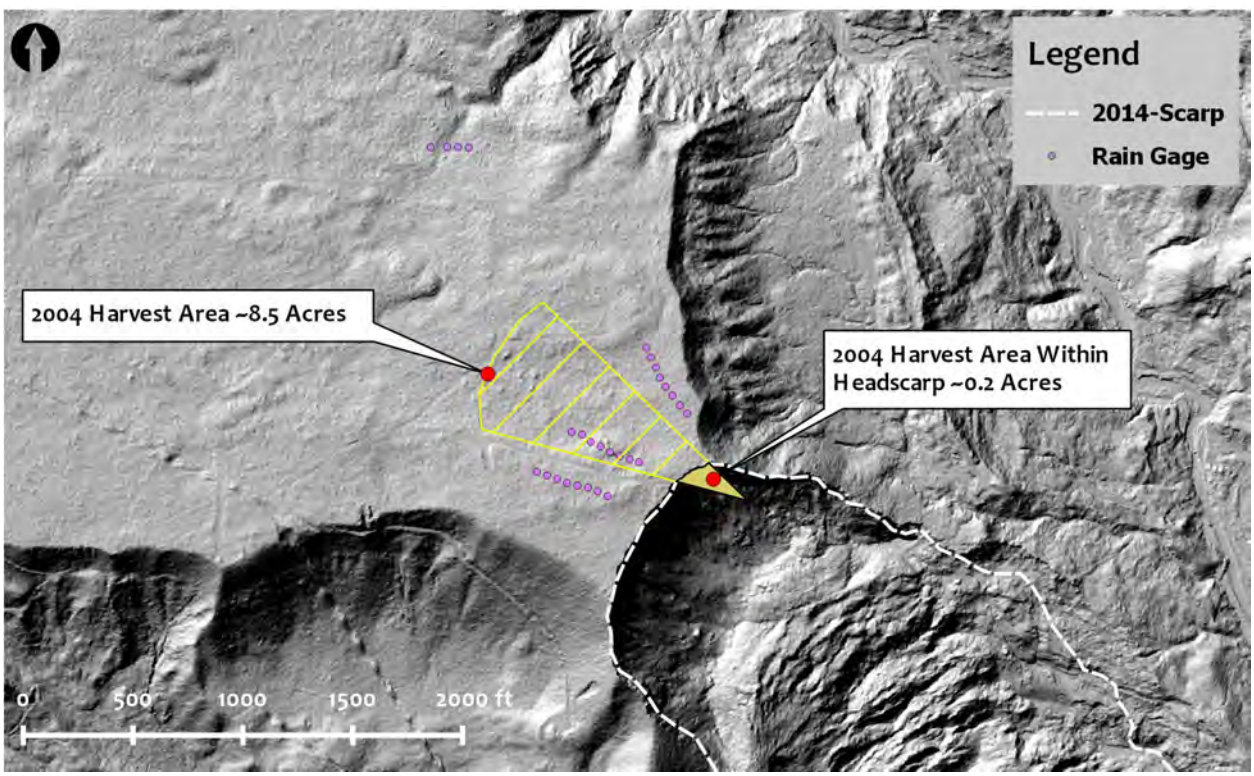

Figure 20: Overview of rain gage locations with 2014 Aerial LiDAR hill shade base map.

The average and the range of throughfall measured for each of the different aged forest stands and the clear-cut are summarized in Table 3 and depicted in Figure 21 and Figure 22. The clear-cut, as expected, has recorded the most rainfall. The different age classes of forest all received roughly the same amount of throughfall. The throughfall for the 12- and 27-year old stands are essentially the same. The throughfall for the 80+ year old stand is numerically less than the other two stands. The trend in throughfall exhibited in water year (WY) 2015 has continued in WY 2016.

The throughfall values calculated for the different age forest stands are averages gleaned from the rain gages in each stand. There is high variability among the throughfall values for each stand. There is less variability in the clear-cut. The variability is represented by the range of the throughfall values for each age stand listed in the table and illustrated in the graph. There was missing data for each of the two rain gages in the clear-cut in WY 2015, thus a range cannot be calculated. A range of values was available for WY 2016.

In each forest stand sampled, the variability in throughfall between the rain gages within a given stand is large. The variability in throughfall between rain gages within a forest stand is greater than the difference between the average throughfall among the stands. Thus, for all practical purposes, no difference exists in throughfall between the three different aged forest stands.

Table 3: Summary of throughfall data collected on Whitman Bench

	WY 2015		**WY 2016 (to 12/5/15)**	
Stand Age	**Avg. rainfall (in)**	**Range**	**Avg rainfall (in)**	**Range**
Clear cut	53.16	-	23.39	23.6 – 23.1
12 years	42.85	53.49 – 31.53	19.34	26.9 – 17.04
27 years	41.45	49.83 – 33.72	17.46	20.37 – 14.16
80 years	35.86	46.54 – 26.11	17.42	20.46 – 15.56

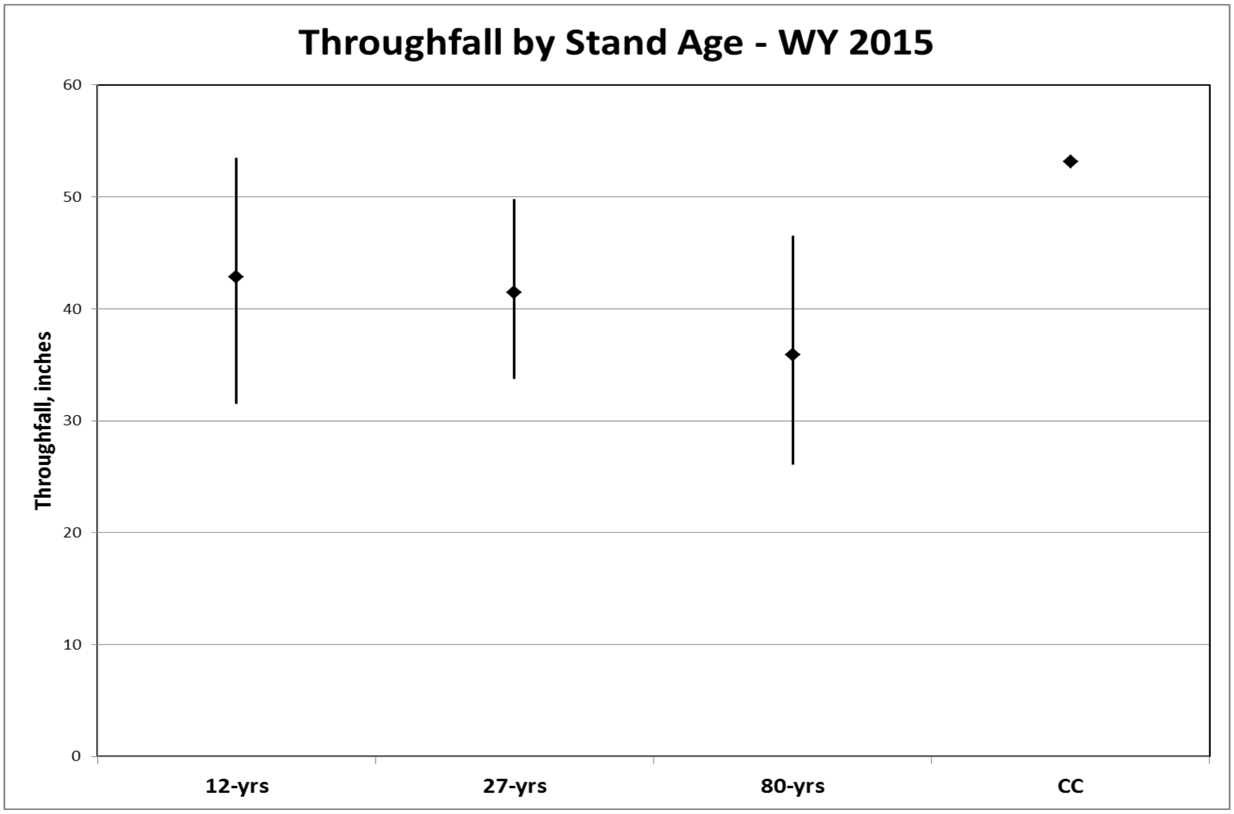

Figure 21: Summary of precipitation throughfall results for water year 2015.

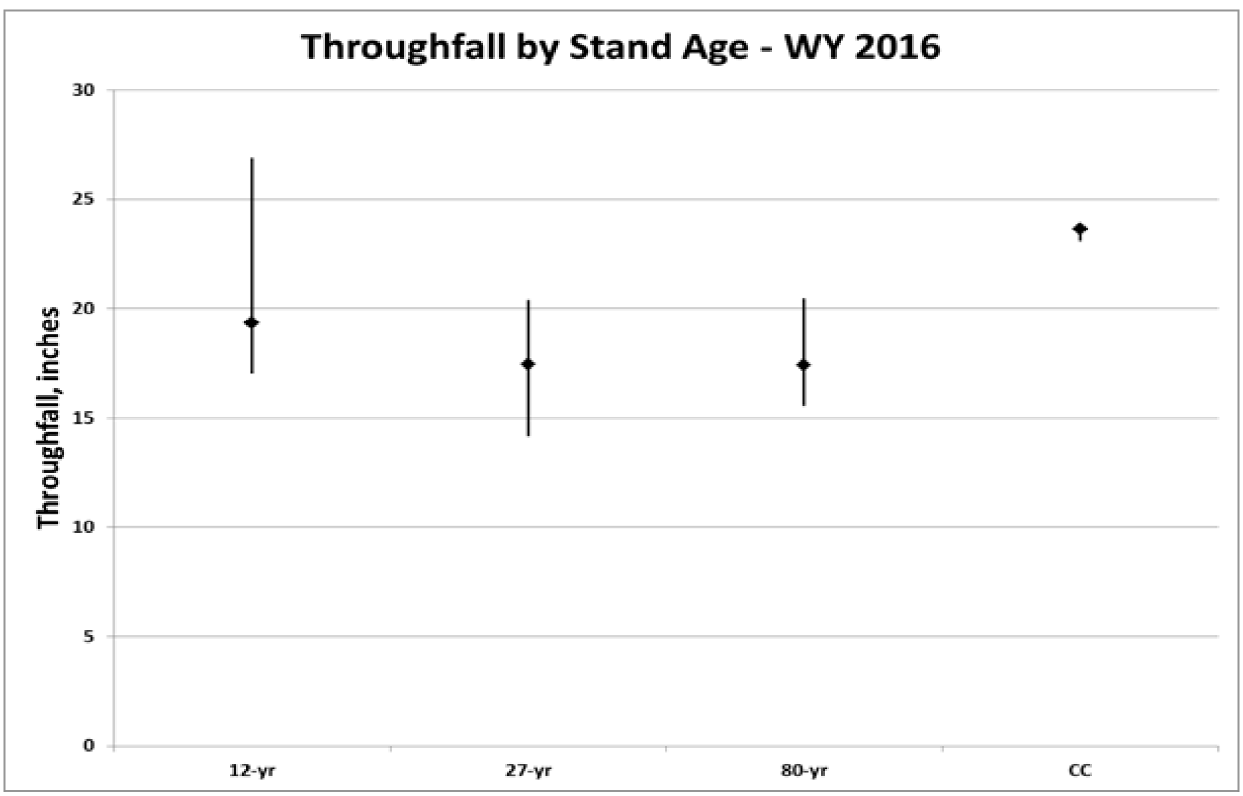

Figure 22: Summary of precipitation throughfall results for water year 2016 (through 12/5/2016).

Geologic Setting

The data developed during this field exploration program to date suggest that the stratigraphy and distribution of geologic materials are extremely complex. This complexity is illustrated in a mapping of units exposed in the main scarp of the SR 530 Landslide (see Figure 23 and Figure 24; Appendix E). As outlined below, much of the complexity of the site is related to the geomorphic origin of the Whitman Bench, which was formed either close to ice margins or in direct contact with the ice. In these environments, extremely complex geology develops. Thus, overly simplistic "layer cake" geologic interpretations, as has often been done at the SR 530 Landslide site, should not be relied upon to characterize the site.

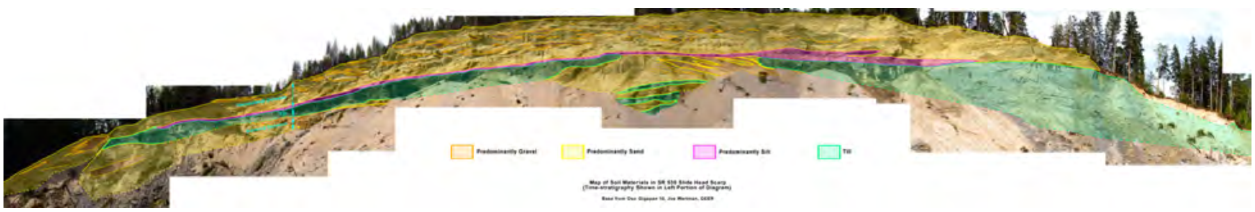

Figure 23: Mapping of geologic units on the SR 530 Landslide main scarp.

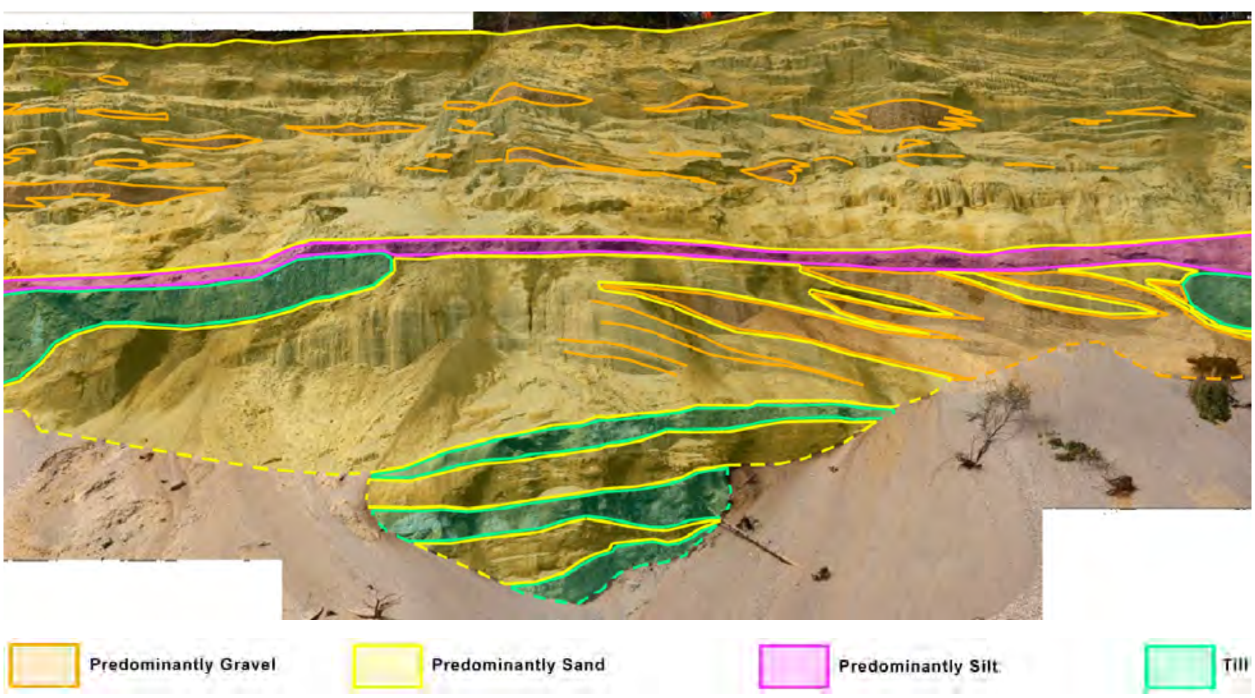

Figure 24: Close-up view of the central portion of the SR 530 Landslide main scarp, showing significant stratigraphic complexity.

The following discussion of the regional and more site-specific glacial geology and stratigraphy is based on a suite of available information. For the regional context, the interpretation of glacial features was gleaned from remote sensing data, consisting of LiDAR and Digital Elevation Model (DEM) hill shade images ((4) (8) (9) (10)), augmented at times by observations on Google Earth. The geomorphology of the vicinity of the SR-530 slide was also developed largely from LiDAR hill shade images and aerial photos. Utilization of such methods for initial surficial geologic mapping is standard practice for geologists. To date, the time requirements of the subsurface exploration program have not permitted extensive verification of these interpretations of the surface exposures. However, in the immediate vicinity of the slide, some of these interpretations - such as the presence of kettles on the Whitman Bench and on its counterpart in the southern part of the North Fork Stillaguamish Valley, where eskers were also identified, have been confirmed by field observations of exposures at key locations.

In addition, the stratigraphy at the slide area was developed from direct observations of exposures in the main and lateral scarps of the 2014 slide (both in the field and on earlier Gigapan images which are included in the GEER report (6)), in the blocks which have moved, and from observations of the materials penetrated by the exploratory borings in 2014-15. Due to onset of inclement weather, detailed mapping of the displaced blocks has not yet been completed. Information on shallow geology in the valley of the North Fork Stillaguamish River in the vicinity of the slide was also obtained from water well logs on file with the Washington Department of Ecology (11), although this information has not yet been fully processed and interpreted.

Where appropriate (such as with all the samples from the borings), recovered soil samples were classified according to the Unified Soil Classification System (USCS) using ASTM method D-2488 (Visual-Manual Procedure), which, in many cases was, or will be, augmented or superseded by laboratory classification, using ASTM Method D-2487.

Glacial Context

Based on our recent mapping of glacial geomorphic features in the area, including the Cultus Mountains, Skagit, Sauk, and North Fork Stillaguamish Valleys; the stratigraphy of the Whitman Bench and surrounding area appears to be the result of complex interaction of several ice streams/sources during the Fraser Glaciation (approximately 30,000 to 10,000 years before present [YBP]), and possibly, only the latest significant glacial advance of that glaciation (the Vashon Stade, 18,000 to 13,000 YBP).

The idea that several independent sediment sources were active at the time of the deposition of the sediments underlying the Whitman Bench was first developed when it became apparent that the composition of the gravel-size component in the till at the SR-530 Landslide area differed from that of the gravel component of the overlying "recessional outwash" materials. The till contains an overwhelming majority (estimated at 80%+) of relatively local lithologies, whereas the overlying outwash contains a similarly overwhelming majority (also around 80%) of exotic lithologies, thought to be derived in large measure from bedrock sources in British Columbia.

This observation prompted a more in-depth geomorphic study of the area surrounding the 2014 SR 530 Landslide, which included the Cultus Mountains, Skagit, and Sauk Valleys, and the Puget Sound Lowland, west and northwest of the site. Due in large part to the recent availability of higher-quality LiDAR-derived digital elevation models of the surrounding area, it has been possible to map glacial scour features resulting from the interaction of glaciers with the landscape. These features mainly include moraines, flutes, drumlins, eskers, and otherwise glacially "streamlined" substrate.

Based on the distribution and orientation of lateral moraines on the northern side slopes of the North Fork (NF) Stillaguamish Valley, during the last glacial episode, it appears that glacial ice flowed in a westerly direction east of Whitman Bench, and in an easterly direction west of Whitman Bench (Figure 25). In addition, significant ice sources reaching the NF Stillaguamish River Valley were the White Horse Mountain massif southeast of the site (just under 7,000' elevation), and the top of Skadulgwas Peak and Mount Higgins, located immediately northeast and east-northeast of the site (maximum elevation 5,171 feet). The "alpine" glaciers from White Horse Mountain appear to have flowed down the valleys of Boulder and French Creeks, while the western portion of the glacier from Skadulgwas Peak initially flowed northwestward, and spilled southwestward, into Rollins Creek Valley, lower down.

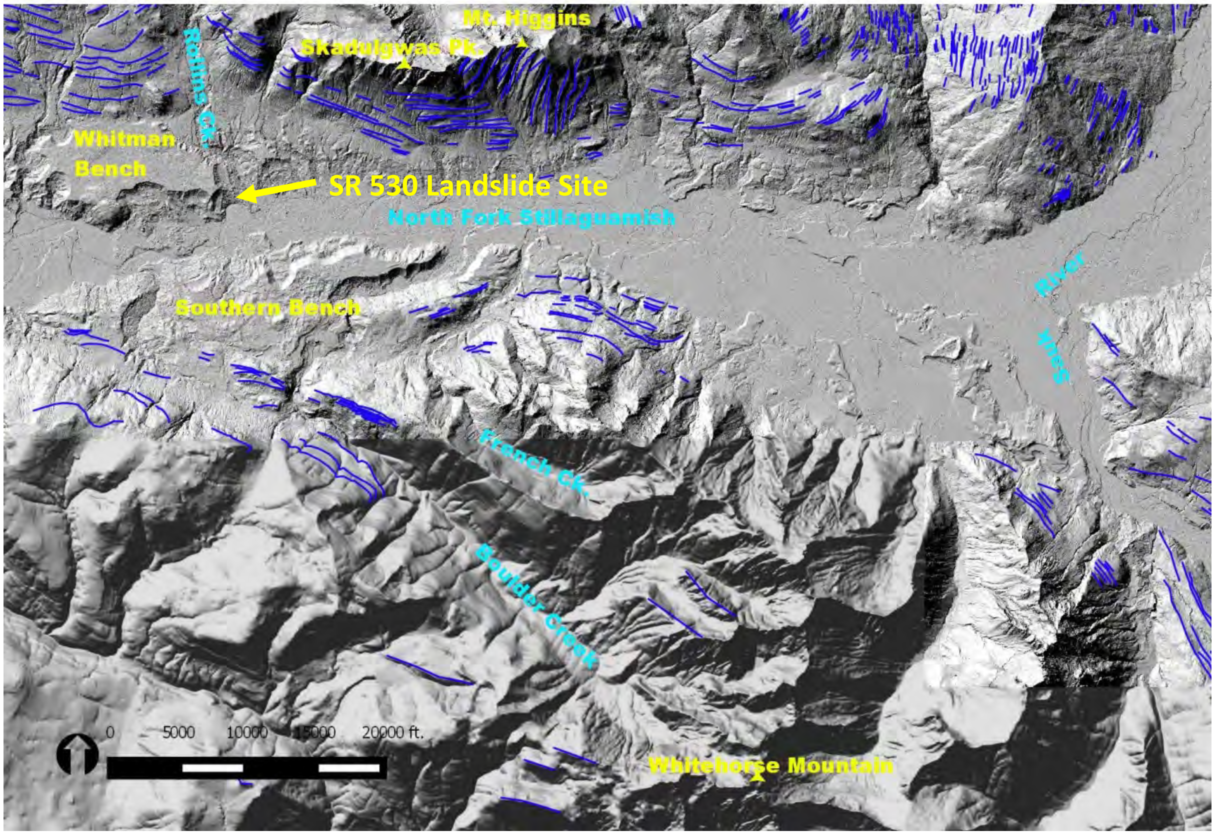

Figure 25: Linear glacial geomorphic features in the vicinity of Whitman Bench.

Based on the location of the highest lateral moraines exposed along the south flank of Skadulgwas Peak, and on the preservation of sharp divides exposed near the top of the peak, at the last glacial maximum the ice elevation on the north side of the NF Stillaguamish Valley was at least 4,500 feet. At Mt. Higgins, the ice deposited steeply plunging lateral moraines, which very nearly reached the peak of the mountain.

The higher lateral moraines along the south face of Skadulgwas Peak are essentially flat-lying, indicating that there was very little surface slope on the glacial ice mass, at least in an East-West direction. Farther to both the east and the west, the lateral moraines appear to be sloping; with the moraines east of Skadulgwas Peak sloping westward, and the moraines on the valley sides west of Whitman Bench decreasing in elevation, eastward. This suggests that two arms of the Cordilleran Ice Sheet, flowing mostly around and partly over the Cultus Mountains, essentially 'met' at Whitman Bench.

Based on the orientation of glacial streamlining in the area around and north of Lake Cavanaugh, the source of the ice entering the NF Stillaguamish Valley from the west and northwest was the eastern side of the Puget Sound Lobe. The source of the ice moving westward from the eastern portion of the NF

Stillaguamish Valley would have been located east, north, and northeast of the present-day valley. It is not clear whether at times of significant glaciation, the Glacier Peak massif contributed ice to the NF Stillaguamish Valley through the Sauk drainage. The glacial moraines on the mountain directly southeast of Darrington indicate that the last glaciers in that vicinity flowed in a southerly direction, up the Sauk Valley. However, there is also geomorphic evidence, albeit more subdued, of ice moving northward through the Sauk Valley southeast of Darrington, likely during the earlier part of the last glaciation.

Based on the direction and cross-cutting relationships between the lower lateral moraines on the south flank of the Skadulgwas Peak- Mt. Higgins massif, the western ice source appears to have outlasted the eastern ice source by a short time, and may have undergone minor re-advances during late Vashon Time. This is also indicated by evidence exposed along the south side of the NF Stillaguamish Valley in the vicinity of Boulder and French Creeks, where eskers (englacial tunnel fills) were deposited on top of the outwash bench which forms the southern counterpart of the Whitman Bench in that area. An approximately 2% eastward slope of this depositional bench suggests that the youngest outwash there was deposited from the west, along the margins of the retreating western glacier.

Kettle holes, which are closed-contour depressions resulting from melting of “dead ice” buried by outwash, are present on the Whitman Bench and its southern counterparts. This is evidence that most of the “recessional outwash” was deposited along the glacial margins.

There is a strong possibility that Whitman Bench and its southern counterpart formed as “kame terraces,” where the glacier was occupying the central portion of the valley, with ice extending to current river level or even lower (there is some evidence of till in some of the water well logs in the valley). The upper portion of the benches would have been deposited along the margins of this glacier. This scenario would obviate the necessity of evacuating an average of approximately one million cubic yards of material from a 10-mile stretch of the NF Stillaguamish Valley every year for the last 13,000 years. This represents the volume of material that would have been present if the benches were continuous across the valley, as inferred in papers recently published by some researchers ((7), (6)).

Of interest in this context is a C-14 date reported in Lahusen et al. (7) for a log buried in the fluvial terrace of the NF Stillaguamish River, which was over-run by the Rowan Landslide. The log was dated

11,692+/-286 YBP, which would allow only approximately 1,300 years between final recession of the ice and the river reaching its current level in the valley. This appears to be an impossibly short time-frame for evacuation of so much material filling the valley, if the Whitman Bench and its southern counterpart were continuous across the valley, at the end of the Vashon Stade.

A kame terrace origin would also explain the apparent collapse of some portions of the till deposit in the eastern portion of the main scarp, where the collapsed blocks are buried under essentially flat-lying sand-and-gravel outwash, which is at a lower level than the exposed surface of Whitman Bench.

For these reasons, we are currently favoring a kame terrace origin for the Whitman Bench and its counterpart on the south side of the NF Stillaguamish River Valley.

Geologic Units

The scenario involving two main ice sources from two "arms" of the Cordilleran Ice Sheet coming both down and up the North Fork Stillaguamish River Valley serves to explain the stratigraphic and geomorphic evidence gleaned from the site and immediate vicinity for the youngest unit deposited on and around the bench (the "recessional outwash"). However, in addition, it also provides an explanation for the stratigraphic relationships between the older units underlying the Whitman Bench.

Bear Lake Sands

The oldest of the stratigraphic units penetrated by some of the exploratory borings on the Whitman Bench and in the 2014 slide area consists of a deposit of sand which, at EB-09, is at least 90 feet thick (the boring was terminated prior to reaching the bottom of the unit). This same unit is exposed at several locations, including extensive portions of the lower left lateral scarp of the slide, along the lower right lateral scarp of the slide, and at the base of the steeper slope in dormant slide deposits, in the west-central portion of the source area.

At all locations where this unit is exposed, the cross-bedding dips to the north and west, or towards the northern valley side. The sand also contains interbeds of laminated silt and clay, in some cases, significantly far down in the deposit.

Whereas this sand unit appears initially to have been interpreted (12) to be of "Olympia" age, meaning it was deposited during the interglacial period pre-dating the Fraser Glaciation, this origin now seems questionable. During an interglacial period (such as today), the Stillaguamish River is transporting large quantities of gravel, some of which is 2+ feet in diameter. One would expect the river to have moved similar material during the last interglacial period. However, no such material is to be found at that level in this vicinity. Instead, there is a thick deposit of sand with minor laminated silt and clay interbeds, which is suggestive of a deltaic deposit formed in a standing body of water. The USCS soil classifications for these materials vary from poorly graded Sand (SP) to well-graded Sand (SW), silty Sand (SM), with more minor Silt (ML), elastic Silt (MH), and lean Clay (CL). The deposit lies well above the current sea-level (top at 310 to 325 feet elevation) to preclude deposition in an estuarine environment. We have concluded, therefore, that these sandy soils must have been deposited in a lake, which we refer to as the "Bear Lake Sand."

Deposition in a lake requires the presence of a lake, and also a dam to form the lake. Several hypotheses can be presented for such a dam. These include, at a minimum, a landslide dam, a moraine dam, an ice dam farther down the NF Stillaguamish River Valley by the Puget Sound Lobe, or an ice dam formed by a local alpine glacier extending across the NF Stillaguamish River Valley. Of these, the first two appear implausible.

The only significant landslides in the valley originate in the deposits along the sides of the valley formed by glacial drift, which would not have been present at the time of the deposition of these sands (which underlie and therefore, pre-date deposition of the Whitman Bench).

A moraine dam is similarly implausible, as the NF of the Stillaguamish River is a powerful river, which would likely have removed such a dam in short order, draining the lake. Therefore, glacial damming is the most likely scenario for damming the valley to form lake in which the sand was deposited. This, however, cannot have occurred during a significant interglacial period. The lake is, therefore, thought to have been impounded relatively early during the onset of the Fraser Glaciation, or even the Vashon Stade.

The main evidence contrary to this hypothesis are three radio-carbon dates obtained from wood fragments, possibly within these sands by Dragovich (12), and one very small wood fragment found near the top of the deposit in EB-04. The samples collected by Dragovich produced C-14 ages for the deposit of (35,040 +/- 450 and 38,560 +/- 640 YPB), and the fragment from EB-04 indicates an indeterminate age older than approximately 43,500 years (13). A possible solution to this discrepancy is re-mobilization of older "Olympia Age" interglacial slough deposits containing woody debris by the glaciers advancing down the NF Stillaguamish River or Sauk River Valleys at the onset of the Fraser Glaciation. The "old" wood was then deposited in the younger deltaic sediments.

One point which might support the re-sedimentation hypothesis is that the wood collected by Dragovich et al (12) was reportedly obtained from deposits located very close to river level (around elevation 260') (personal communication). The wood fragment in EB-04 was found very close to the top of the sand unit, at an elevation around 310', or 50 feet higher than former river elevation. Yet, the material obtained from higher (presumed younger) deposits provided an older C-14 date than the wood from lower (presumed older) strata.

There are two possible ice sources for damming the NF Stillaguamish River Valley. One is the local alpine glaciers which would have advanced from the Whitehorse Mountain area, and could well have reached and crossed the North Fork valley. This ice dam would not have been high, which would explain the dominance of sand in the deposits. Where a river enters a lake, gravel is the first material to be deposited as the water velocity decreases. Sand is transported farther out into the standing water, and suspended sediments, such as silt and especially clay, is usually dispersed across the lake, settling onto the floor of the lake.

In this case, for much of the time, sand was the dominant material deposited at the location of what later became the Whitman Bench, which suggests that the location of sediment input into the lake was not very far removed, but sufficiently far to have dropped its gravel bedload closer to its source. The time frame required for deposition of more than 90 feet of sand with some intercalated silts and clays is not possible to determine with the available information.

The reason a local ice dam appears more likely during deposition of the sand than an ice dam at the mouth of the Stillaguamish River by the Puget Sound Lobe is the fact that the deposit consists mostly of sand, which would imply a relatively shallow, smaller lake.

Given that the sand is likely not part of the Olympia Interstade, our expert panel decided it was appropriate to give the unit a local stratigraphic name and, for purposes of this assessment, it has been termed the “Bear Lake Sands.”

Fine-grained Glacio-Lacustrine Unit

The next younger unit exposed at the site is a nearly 300-foot thick deposit of rhythmically bedded or mostly laminated silt and clay. Laminations are layers mostly on the order of 1/32nds to 1/8-inch thick. Some portions of the unit are rhythmically bedded, with individual beds on the order of 1/8 to 1/2-inch thick. Each bed is usually a fining-upward couplet, with silt near the bottom and clay near the top. The overall characteristics of the material range from an elastic Silt (MH), to a lean clay (CL) and, especially in the lower portions, a fat Clay (CH). However, it appears that individual laminae may well range from Silt (ML) at the bottom to fat Clay (CH) at the top of the lamina. The unit also contains isolated “drop stones,” which are pebbles or cobbles ice-rafted on the lake and then dropped into the fine-grained deposits, as the ice-floes either capsize or melt. The unit has often been referred to in previous reports (14) as “Blue Clay.”

Given the thickness of the unit (which is around 300 feet), and the thickness of individual laminae (which is on average probably less than 1/8"), it is unlikely that each lamination represents a year, as that would imply a time of deposition around 28,800 years. Therefore, these laminations most likely do not represent “varves” (annual laminae). Instead, each lamina probably represents an individual depositional event in the lake. The latter deduction is also supported by the fact that, in some portions of the unit, the laminae consist of interbedded lighter greenish-gray and darker gray layers. The distinctly different colors imply at least two sediment sources “feeding” the shallow lake.

It is possible that deposition of the Bear Lake Sands ceased in this vicinity when the water level of the lake deepened as a result of the Puget Sound Lobe blocking the mouth of the Stillaguamish River. Given the fact that elevation of the Puget Sound Lobe ultimately reached an altitude of around 4,100 feet near the mouth of the Stillaguamish River, it was capable of damming a lake with a relatively high pool elevation. The lake level was controlled by the elevation of the lowest available spillway. No effort has yet been made to determine the location of such spillways.

Raising the lake level in the NF Stillaguamish River Valley would have resulted in moving the depositional delta of the lake far up-valley. As a result, under this scenario, deposition of sand would have ceased at the current location of Whitman Bench once the lake level rose significantly, to be replaced by deposition of finer-grained, suspended components of the outwash flow. This situation would have been altered as the glaciers advanced both up and down the valley toward Whitman Bench, moving the sediment source (outwash streams) closer to its current location.

Advance Outwash

This unit is located between the fine-grained glacio-lacustrine silts and clays and the overlying till. It is also the most laterally variable unit, as far as composition is concerned. In the borings on the Whitman Bench, the unit consists mainly of silty sand, silt, and sand. However, in the extensive exposures of the 2014 Landslide main scarp (Figure 23), the unit consists predominately of sand and gravel. With the exception of the western portion of the main scarp, much of this unit is covered by collapsed material from the main scarp above and by sand "talus" cones forming below the recessional outwash.

In the western main scarp, the unit consists of cross-bedded coarse-grained poorly-graded sand with frequent thin and discontinuous layers of pebbles and cobbles. At one location in the west-central portion of the exposure, a deposit of well-sorted light-colored pebbles to small cobbles more than 10 feet thick terminates against the sand along a surface dipping at 80 degrees. Similar off-sets are found throughout the deposit, indicating that this unit was deposited as ice-contact stratified drift, where the shifting and melting ice caused collapse of the material deposited on or against the ice. Large-scale cross beds in the western portion of the main scarp appear to dip at shallow angles to the southeast. Similar apparent dips (eastward component) were observed in silty coarse gravel beds located directly beneath the till in the west central portion of the 2014 main scarp. The constant raveling of the younger recessional outwash materials lying above the till negates access to much of the 2014 main scarp because of safety concerns, so no direct measurements of the of these unit's attitudes (strike and dip) were possible.

In the center of the main scarp, the lowermost exposed "Advance Outwash" consists of a couple of layers of what appears to be till, a few feet thick, separated by thin bands of sandy outwash. These tills occur several tens of feet below the general elevation of the principal till unit prominently exposed along much of the 2014 Landslide main scarp. It is possible that these till layers represent "flow till" which forms when previously formed, cohesive till "mud" located on, or right next to the ice flows, or slides off of the ice, or is pushed into a standing body of water. It then forms a layer of debris with the general grain-size distribution of till, but in an irregular layer form or in individual "blobs."

Above the apparent flow tills exposed near the center of the 2014 main scarp is a thick pile of sand and gravel, which has a high point near the center of the main scarp (Figure 24), with apparent dips on individual layers toward the east on the east side of the pile, and to the west on the west side of the scarp. The actual dip appears to be to the north-northwest. This part is interpreted as a delta deposit. Given the dip direction of the foreset beds, the sediment source had to be on the valley side, and likely was the northern ice-marginal drainage of the glacial lobe extending up the Stillaguamish River Valley from the Puget Sound Lobe. The latter inference is based on the prevalence of light-colored "exotic" pebbles and cobbles in the deposit, which does not appear to have been sourced up the NF Stillaguamish River Valley.

In the central and east-central portion of the main scarp, this sand-and-gravel delta replaces the main deposit of lodgment till present both to the east and west of those exposures. However, this coarse-grained deltaic deposit was not found in either of the borings drilled by WSDOT in late 2014, less than 300' behind the 2014 main scarp. Given the slope angle of the beds forming the deposit, and its thickness, the top of the delta could not have extended significantly farther to the northwest (under the Whitman Bench) than the present main scarp.

Till

The till at the site consists almost exclusively of subangular to well-rounded gravels and cobbles with few angular boulders in a medium-gray matrix consisting of sand, silt, and clay. Identifiable rock types are generally meta-sedimentary units, ranging from meta-graywacke and argillite/phyllite to schist, gneiss, and greenstone. Many of the cobbles are rather dull in color, ranging from greenish-gray to pinkish-brown, with few light-colored lithologies, some of which turn out to be quartz veins from foliated metamorphic rock units. Local (i.e. within about 20 miles) lithologies appear to dominate the pebble and cobble fraction of the material. The few large boulders often consist of granite or granodiorite. No actual random pebble counts of lithologies have been performed to date to establish geomorphic provenance.

The thickness of the till is highly variable across the 2014 main scarp and in the recent borings extended through the unit on the Whitman Bench. In the eastern portion of the main scarp, the unit is in excess of 80 feet thick. In H-1VWP-14, the till was 86 feet thick; in EB-02 it consisted of two layers of diamict separated by interbedded sand and gravel, with the entire package totaling 100.5 feet. In EB-06 the unit was approximately 53 feet thick, and in EB-08 it also consisted of two layers separated by bedded sands and gravel, totaling 139 feet. As discussed above, no till is present for approximately 150 to 200 feet laterally across the center of the 2014 main scarp, and immediately to the east. To the west of the center of the main scarp, the till layer is never more than 30 feet thick, with the predominant thickness between 20 and 25 feet. It thins to less than 20 feet in the westernmost portion of the 2014 main scarp.

In EB-05, below the obvious failure surface found at a depth of 50 feet, 25 feet of a gray silt and clay unit was encountered, which contains chaotically contorted veinlets and seams of a light gray silt with some very fine-grained sand. This unit was not observed in any other borings. One possible origin for this unit is that it represents fine-grained glacio-lacustrine deposits "bulldozed" by the ice, in which case, this material would be classified as till. The typical diamict till found elsewhere on the site consists of mixture of grain sizes, including silt and clay, which were probably in part derived from fine-grained glacio-lacustrine deposits over-ridden and scoured by the ice and mixed with the coarser grained components of the till.

The upper elevation of the till decreases both to the east and west from its high point located slightly west of the 2014 Landslide main scarp center. The total drop in elevation from the high point to the east end of the exposure is 39 feet, and to the end of the exposure on the west side is 67 feet.

As determined in the borings, under the remaining eastern portion of Whitman Bench, the elevation of the till generally slopes to the northeast, towards Upper Headache Creek Basin.

Recessional Silt

At most places along the exposed 2014 main scarp and in the borings on the Whitman Bench, a Silt/Sandy Silt/Silty Sand unit was encountered either directly above the till or, in the center of the main scarp, lying upon the sand-and-gravel delta. The unit is dark brown to dark gray in color and appears to form an aquitard, where active seeps were observed in the main scarp of the 2014 Landslide. It is probable that this unit formed in a relatively small ice margin lake above the Whitman Bench, prior to the time when the sand-and-gravel delta of the recessional outwash had pro-graded (filled in the lake) at this location.

Recessional Outwash

The youngest unit at the site consists of what has been called "Recessional Outwash." This unit consists mostly of sand with localized concentrations of gravel. The stratification of the unit appears to be near-horizontal, but many of the strata are internally cross-bedded. Apparent dips of the crossbeds are generally to the east. Gravel is present mostly in the western and central portions of the main scarp, and is essentially absent in the exposures along the eastern part of the 2014 main scarp.

Discussion of the Geologic Setting

Based on our current understanding of the regional geomorphology and site stratigraphy, the Whitman Bench and its depositional counterpart on the south side of the NF Stillaguamish River Valley (Figure 26) likely formed in the area where two ice streams of the Cordilleran Ice Sheet met during the Fraser Glaciation, or during the Vashon Stade of that glaciation. The interaction of the two glaciers, combined with the fact that much of the sediments above El. +550 to +600 feet appear to have been deposited as ice-contact stratified drift, has resulted in stratigraphy that is highly complex.

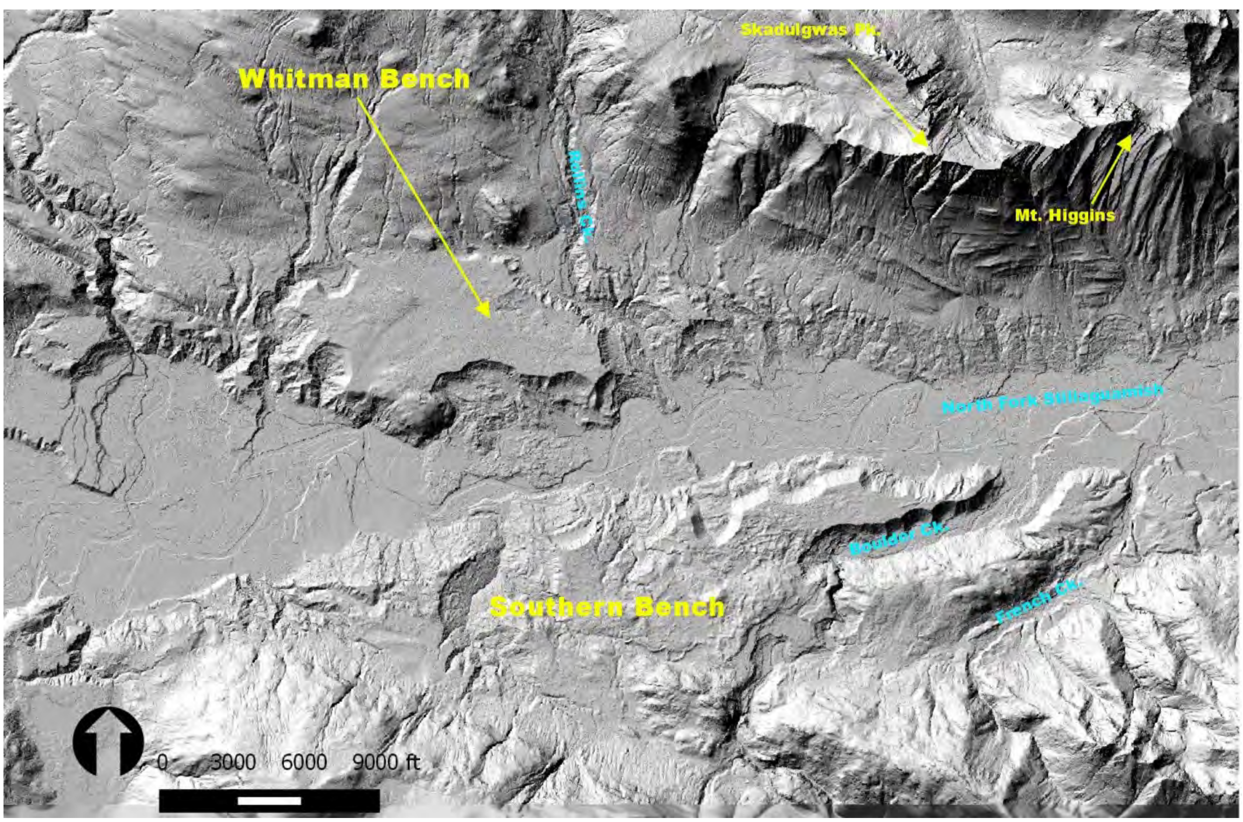

Figure 26: Overview of Whitman Bench and Southern Bench.

Conceptual illustrations of the advance and retreat of the glaciation in the Stillaguamish and Skagit valleys is presented in Figure 27 through Figure 32. The complete figures, including cross-sectional profiles across the valley and up the valley, are presented in Appendix F. Figure 27 represents conditions during the Olympia Interstade, prior to the onset of the Fraser Glaciation. At that time, normal fluvial processes are assumed to have been active in the North Fork, Skagit, and Sauk valleys. Alpine glaciers were likely present on high mountain peaks, similar to today's conditions.

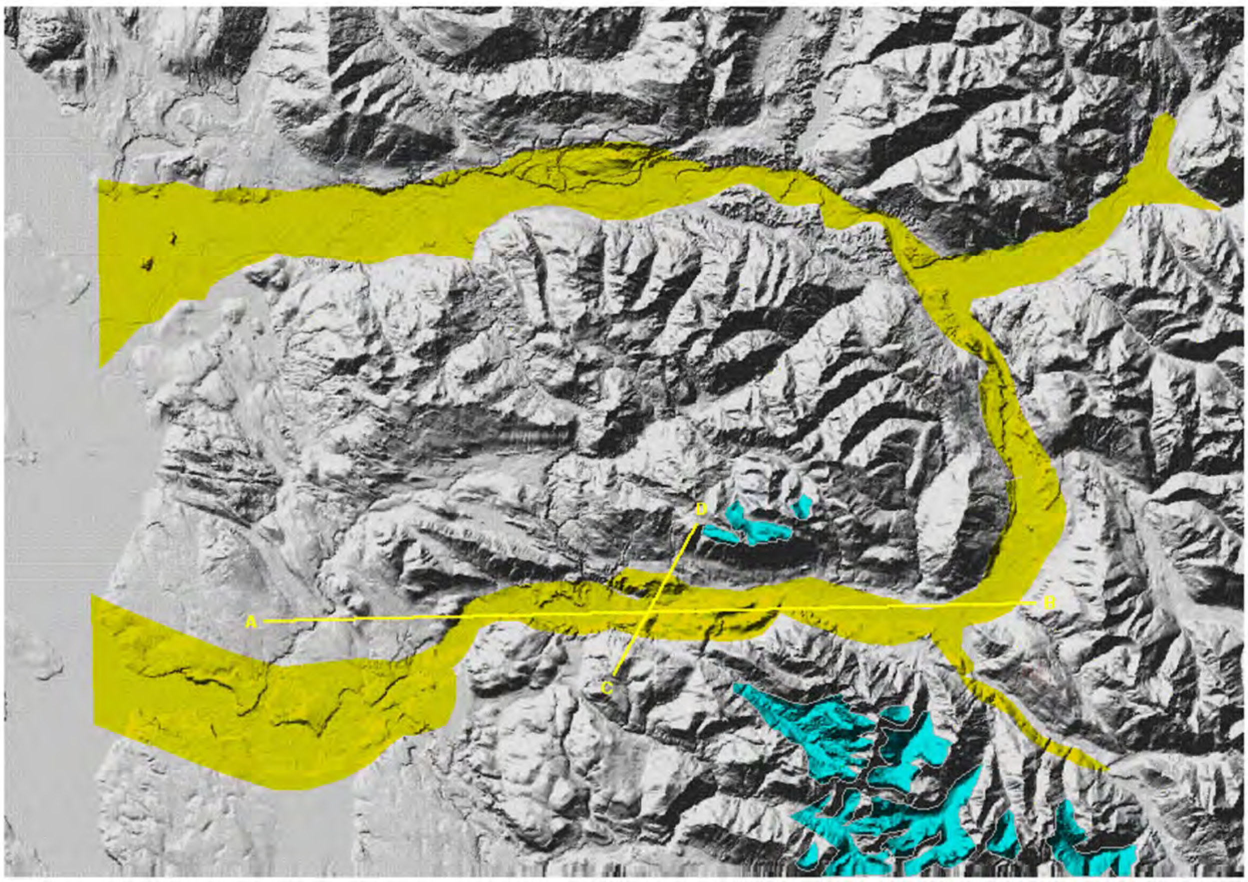

Figure 27: Conceptual map of glacier (turquoise) and sediment (yellow) distribution during the Olympia non-glacial Interstade.

With the onset of the Fraser "ice age," these mountain glaciers would have grown both in size and in numbers. The geologic evidence at the SR-530 Landslide site indicates that, with the exception of the till and portions of the "recessional outwash," all materials deposited at the site are of a glacio-lacustrine origin. This is also true of the Bear Lake Sands, which consist of 90+ feet of foreset bedded sand with interbedded laminated silt and minor clay, typical of lacustrine deltaic deposition. The lake into which these sands were deposited was likely caused by damming of the river by a local alpine glacier advancing through Boulder and French creeks from the Whitehorse Mountain massif, or a dam located at the mouth of the Stillaguamish River Valley, formed by the advancing ice of the Puget Sound Lobe. Given that the deposit consists mostly of sand, it is likely that the NF Stillaguamish entered the lake not far from the site of the 2014 SR 530 Landslide. The gravel fraction was likely deposited up gradient (i.e. farther up the river valley). The evidence suggests that the water level of this initial lake was likely around El. +200 to El. +300 feet (above present sea level). Figure 28 illustrates the damming of the North Fork by the Whitehorse glacier.

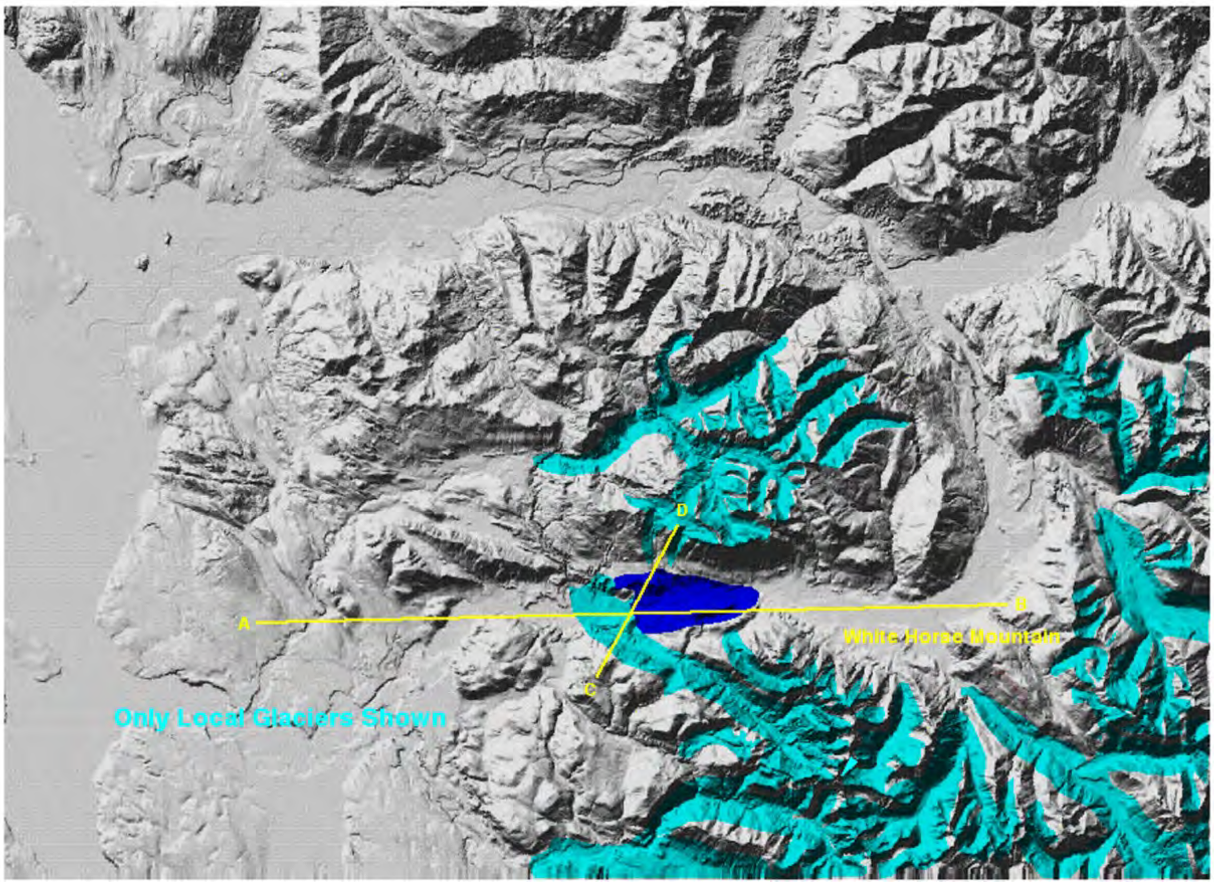

Figure 28: Conceptual map of ice distribution (turquoise) and the lake (blue) in which the Bear Lake Sands were deposited.

At some point, deposition of sand ceased abruptly, and was replaced by deposition of fine-grained laminated lacustrine sediments, consisting of clay and silt. This would have resulted if the lake level were raised fairly rapidly to a much higher elevation, probably around El. +820 feet, forcing all rivers and creeks to form deltas at higher elevations and farther up the tributary valleys (Figure 29). This condition persisted for some time; although the decrease in clay content and increase in silt content upwards indicates that the sediment source(s) was/were advancing toward the SR 530 Landslide site.

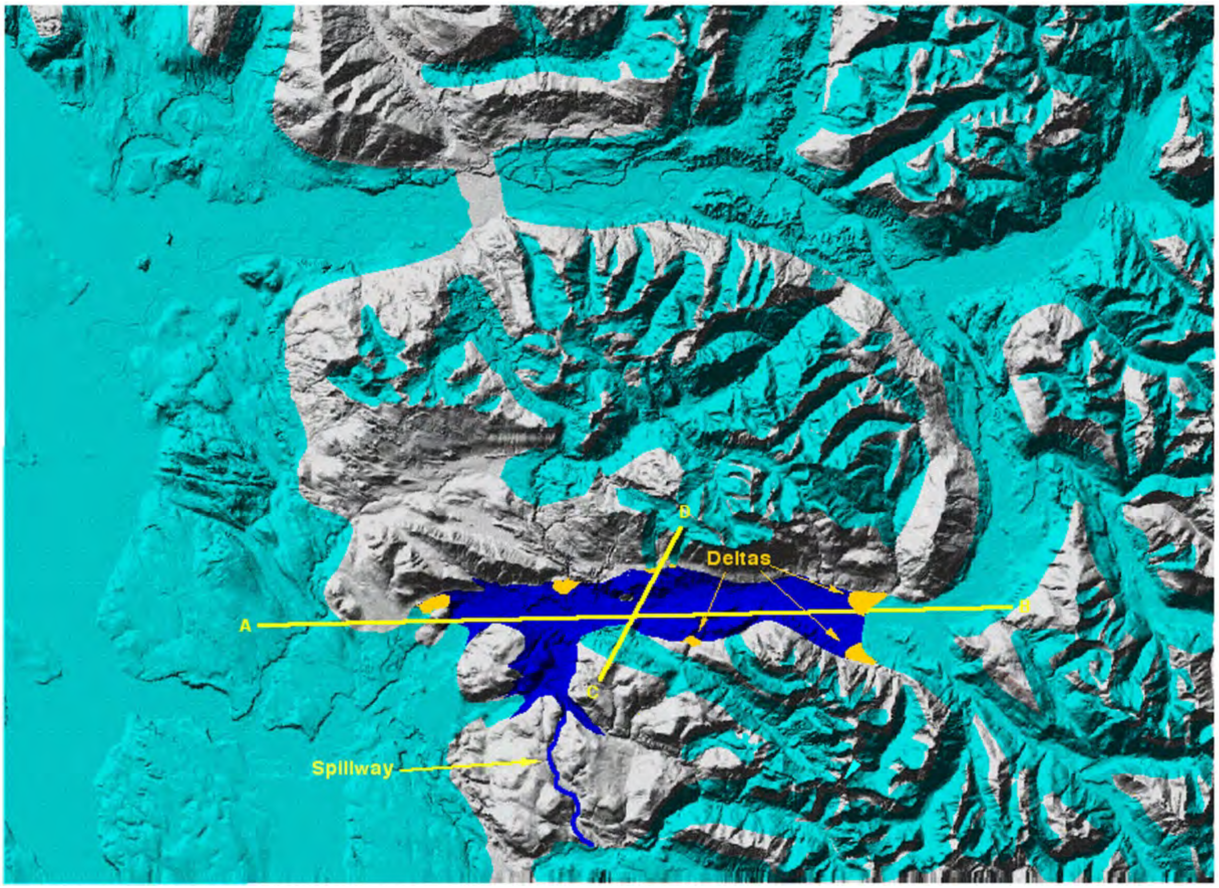

Figure 29: Conceptual map of lake (blue) resulting from damming of the mouth of the Stillaguamish by the Puget Sound Lobe.

The two glaciers, one advancing westward down the NF Stillaguamish River Valley, and one extending eastward from the Puget Sound Lobe (up the valley), appear to have met in the general vicinity of what later became the southeastern end of the Whitman Bench (Figure 30). The fact that the fine-grained glacio-lacustrine silt and clay and silt can be shown to have been significantly disturbed in the vicinity of boring EB-05 (which is located near the eastern end of the bench) suggests that the local glacier (sourced up-valley) reached this area first. This may also be the reason that the till is significantly thicker on the east side of the 2014 SR 530 Landslide main scarp, as compared to the west flank.

Significant amounts of ice-contact stratified drift, consisting mostly of coarse sand and gravel, were deposited near the center of the 2014 SR 530 Landslide main scarp and west flank. These gravels contain a significant volume of "exotic" lithologies, suggesting that the glacier extending up valley from the Puget Sound Lobe was at or near the western end of the Whitman Bench at the same time the North Fork Lobe arrived at the east end of the Whitman Bench.

The presence of the northward-deposited sand-and-gravel delta in the center of the main scarp suggests that another sediment source was located immediately south of the Whitman Bench just prior to that portion of the bench being overridden by ice. It is possible that this material was delivered by the eastern ice-marginal drainage of the Whitehorse Lobe, which must have merged with the Puget Sound Lobe glacier.

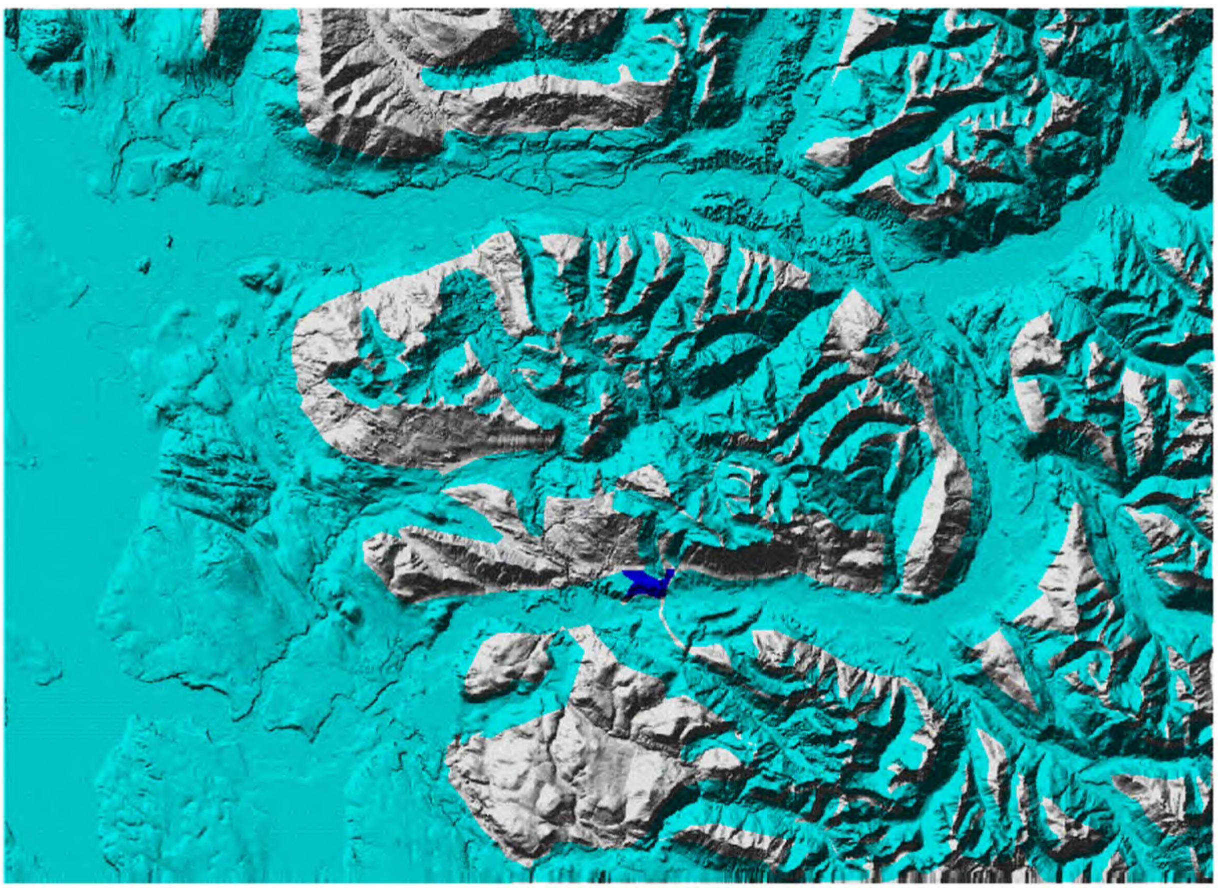

Figure 30: Conceptual map of ice distribution immediately prior to the convergence of the Puget Sound and North Fork Stillaguamish glacial lobes.

The advancing snouts of the two glaciers must have arrived in the immediately vicinity of the 2014 SR 530 Landslide area at approximately the same time, resulting in essential cessation of ice flow at ground level, despite the fact that ice was still being delivered, likely from both sides.

Although the Bear Lake Sands and glacio-lacustrine silt and clays may have originally been present across the entire valley floor, preliminary water well information (11) indicates that they are now absent in the center of the valley. This will have to be verified. If found to be true, it is probable that the Bear Lake Sands and glacio-lacustrine silt and clays would have been removed either by the advancing ice, or by sub-glacial drainage.

Ultimately, the ice reached an elevation of at least +4,500 feet immediately northeast of the site, as evidenced by lateral moraines on the south face of the Skadulgwas Peak/Mt. Higgins massif. These lateral moraines are near horizontally aligned along the side of the mountain, indicating equilibrium between the two glaciers at the time of deposition of the moraines (Figure 31). This equilibrium appears to have been maintained for much of the time during which deglaciation occurred, and may have lasted until at least some of the recessional sand and gravel had been deposited.

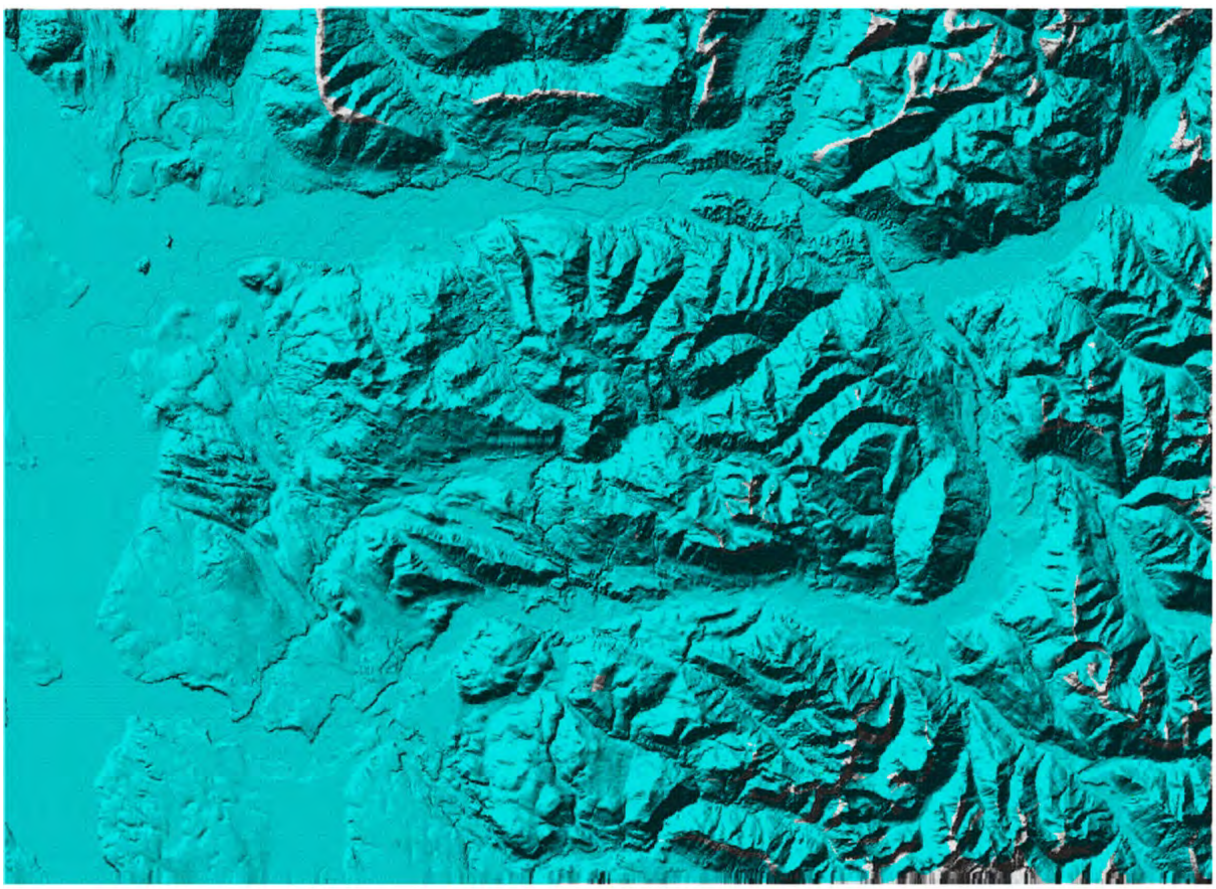

Figure 31: Conceptual map of maximum ice distribution during the Vashon Stade.

At the very end of the glacial presence in the river valley, the western glacier may have experienced one or more minor re-advances, while the eastern glacier was already disintegrating (Figure 32). Evidence for this is present on the south side of Skaduldgwas Peak, at elevations between +1,000 and +1,500 feet in the form of east-sloping lateral moraines, and are observed on the bench on the south side of the valley, in the form of eskers. Since the eskers were deposited over outwash, which could not have been deposited under the ice, the ice must have re-advanced over the outwash to drop the contents of the englacial tunnels onto the outwash bench. Kettles present on both Whitman Bench, and its counterpart on the south side of the river valley, suggest that this outwash was deposited over and around dead ice blocks which subsequently melted, leaving the kettle holes.

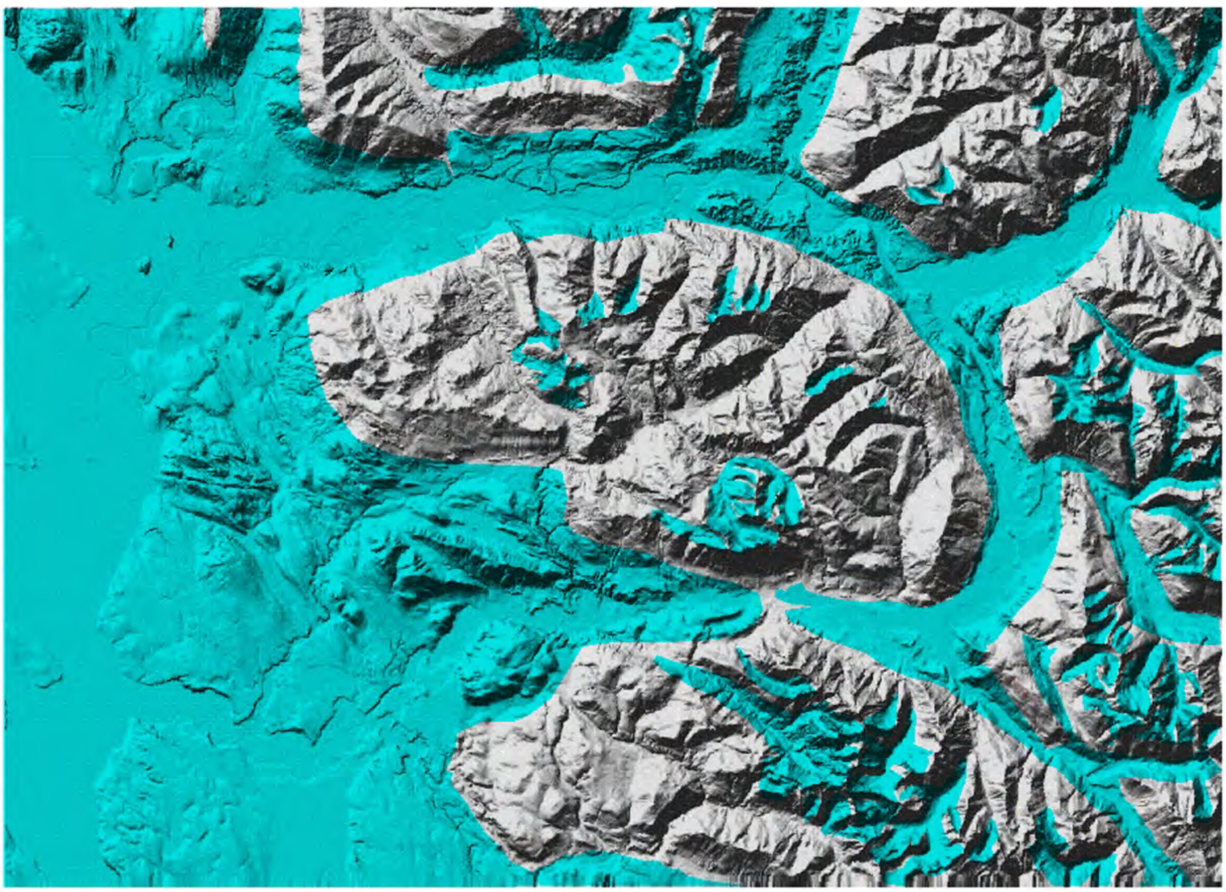

Figure 32: Conceptual map of the interior ice sheet recession/collapse.

In this scenario, much of the depositional benches on both sides of the valley were built as kame terraces, with ice occupying the central portion of the valley to some, as yet unknown depth (see last figure in Appendix F). Such a kame terrace origin for the Whitman Bench is also supported by till-collapse features observed in the eastern head scarp of the SR-530 slide. The collapsed till blocks in that vicinity are covered by horizontally bedded outwash, which is at a significantly lower elevation than the rest of Whitman Bench. Therefore, the till collapse must have occurred while outwash was still being deposited by meltwater.

This hypothesis obviates the need to remove enormous quantities of sediment from the valley in a very short time following deglaciation around 13,000 years ago (described previously). Radio-carbon dates on woody debris in the Holocene fluvial terraces of the NF Stillaguamish River suggest (7) that the river was flowing at approximately its current level just 1,300 years after deglaciation.

However, it must again be emphasized that at this stage, the foregoing concepts are simply a hypothesis which is capable of explaining the stratigraphy observed to date at the site of the SR 530 Landslide and the geomorphic features observed via remote sensing images (i.e. Aerial LiDAR) of the NF Stillaguamish Valley area. More field work is required to test this hypothesis.

Geotechnical Laboratory Testing

As noted previously, it is not possible to perform meaningful slope stability analyses without a sound basis to delineate the site-specific shear strength of the key stratigraphic units that failed during the landslide in 2014. It is therefore crucial that the shear strength of the stratigraphic units through which the surface of rupture passed be appropriately characterized. Geotechnical laboratory strength data for several of the intact stratigraphic units outside of the SR 530 Landslide area remain unavailable from the ongoing USGS/WSDOT Phase 1 Investigation of the SR-530 landside hazards study (15). These data, when they become available, will be a useful complement to the strength parameter testing that we are performing.

The high plasticity, over-consolidated fine-grained glacio-lacustrine unit beneath the upper sand/gravel, till, and outwash sand units is the primary stratigraphic unit to be tested in terms of shear strength, because much of the surface of rupture of the SR 530 Landslide appears to lies within this unit. Thus, this unit is the primary focus of the geotechnical laboratory testing program. Over-consolidated, high plasticity glacial silts and clays are particularly susceptible to strength loss, which could help explain the cause of the rapid movement and long runout length of the SR 530 Landslide. The stability assessment of the SR 530 Landslide is largely governed by the shear strength of the soil materials that failed during the SR 530 Landslide movement. Thus, strength data of the soil materials collected along the surface of rupture and within the SR 530 Landslide mass are essential to perform realistic slope stability analyses.

We are employing several strength tests to comprehensively evaluate the shear strength of over-consolidated silt and clay materials. Torsional Ring Shear (TRS) tests are used to evaluate fully softened and residual effective friction angles of the glacio-lacustrine silt and clay, which defines its effective shear strength. When combined with Direct Shear (DS) test data that captures the peak friction angles of the silt and clay materials, a nearly complete picture of the effective shear strength of the fine-grained glacio-lacustrine unit can be discerned. The shear strength of the rhythmically bedded, mostly laminated, glacio-lacustrine deposit is likely anisotropic. Thus, some of the Direct Shear (DS) tests will be performed with non-horizontally oriented test specimens to evaluate anisotropy. The stress-strain responses of these soil materials are important as well, because the materials potentially involved in the 2014 Landslide likely achieved their peak, fully softened, and residual strengths at different times as the landslide deformed. Therefore, a series of triaxial (TX) tests are being performed to characterize the nonlinear, stress-dependent stress-strain response of the key stratigraphic horizons. Stress-strain strength anisotropy will also be evaluated by performing TX compression and TX extension tests. The stress-strain responses of the fine-grained glacio-lacustrine materials along the basal surface of rupture of and within the SR 530 Landslide mass are required to perform reliable finite element/finite difference numerical simulations of the initiation and evolution of the SR 530 Landslide.

In addition to strength testing of the fine-grained glacio-lacustrine unit, stress history is being investigated through a series of consolidation tests. Soil response depends significantly on the soil's stress history (i.e., whether it has never felt a higher stress than it is feeling currently, or if it is over-consolidated because it once felt a stress higher than what it is feeling currently). These test results, along with estimates of the in situ state of the fine-grained glacio-lacustrine unit, are essential components of the numerical simulations of the SR 530 Landslide.

Lastly, soil units other than the fine-grained glacio-lacustrine unit, also require strength characterization. In particular, the surface of rupture was found within the sand unit beneath the fine-grained glacio-lacustrine unit at one location. The Cone Penetration Tests (CPT) and index testing will be used to estimate the shear strength of these units, because "undisturbed" sampling of sands and tills was not possible, because of the unusually high overburden pressures (up to 600 vertical feet of confinement).

However, our team believes there are sufficient field data and robust correlations available to develop reasonable estimates of the strength of these soil units.

Cursory preliminary geotechnical laboratory testing data received from WSDOT's geotechnical testing laboratory is presented in Appendix G. Appendix H presents a summary of proposed geotechnical laboratory testing to be performed.

Discussion of Plaintiff Contentions

The Plaintiffs have put forth a suite of theories and hypotheses. The State of Washington Attorney General's expert team extracted those theories as best they could be interpreted from the submitted complaints and stated them as hypotheses in the June 1, 2015 preliminary report (16). At this stage, we have not completed our geotechnical study, hence we are not able to put forth a conclusive expert opinion regarding causation. However, based on information gathered to date, there are some elements that have been eliminated as potential contributors to causation for the SR 530 Landslide. These eliminated factors are discussed below. Formal causation opinions will be forthcoming, following completion of the geotechnical study.

Contention No. 1

As we interpret it, the Plaintiffs contend that the increase in precipitation throughfall that results from clear-cut timber harvesting results in a direct increase in groundwater.

This contention actually includes a number of components. The contention implies that an increase in groundwater level was the proximate cause of the SR 530 Landslide. In order for an increase in groundwater to occur as a result of clear-cut timber harvesting, there must first be an increase in the amount of water that reaches the ground, and second, this increased amount of water must be transmitted downward in the soil profile in such a way as to change the effective stress in the soil along the surface of rupture on the base of the landslide, resulting in shearing of the soil and the ultimate failure of the slope that occurred.

Numerous studies throughout the Pacific Northwest ((17) (18) (19) (20) (21)) have shown that there is an increase in throughfall to the ground surface following clear-cut timber harvesting. In an effort to understand the potential influence of the actual clear-cut harvest on the Whitman Bench, we investigated: (1) the amount of precipitation that reaches ground level in the area of the 2004 clear-cut, which is now a well-stocked plantation of 12-year old trees; we also evaluated throughfall in the 27–year old reforested stand adjacent to and southwest of the clear-cut, and within the 80+ year old tree stand to the east of the 2004 clear-cut; (2) evidence of lateral groundwater flow paths evident in topography and the presence of seeps and springs; and (3) the stratigraphy exposed beneath the Whitman Bench.

Since the area of the Whitman Bench adjacent to the SR 530 Landslide is not a clear-cut, but rather, stands of 12-years, 27-years, and 80+ years of age, we undertook the rainfall study discussed above. The site-specific study showed that the variability in throughfall between rain gages within a forest stand is greater than the difference between the average throughfall among the stands. Thus, for all practical purposes, no difference exists in throughfall between the three different aged forest stands.

The Whitman Bench borings all succeeded in locating the top surface of the till, which acts as an aquitard (groundwater barrier) for the percolation of water through the recessional outwash materials blanketing much of the Whitman Bench. The till is also blanketed with a very low permeability sandy silt, which also behaves as an aquitard. The piezometer measurements show a gravitational water table perched near the base of the recessional sands and slopes to the east (Figure 33), which is consistent with the observation of springs along the Upper Headache Creek Basin erosional escarpment; not southerly toward the SR 530 Landslide.

The groundwater monitoring data collected to date suggests that shallow groundwater percolating through the recessional outwash gravels and sands flows off to the east, concentrating to the center of the Upper Headache Creek Basin. The groundwater data does not support flow towards the SR 530 Landslide main scarp. Therefore, the Miller-Sias model (22) (23) of assumed groundwater flow is not supported by site-specific data.

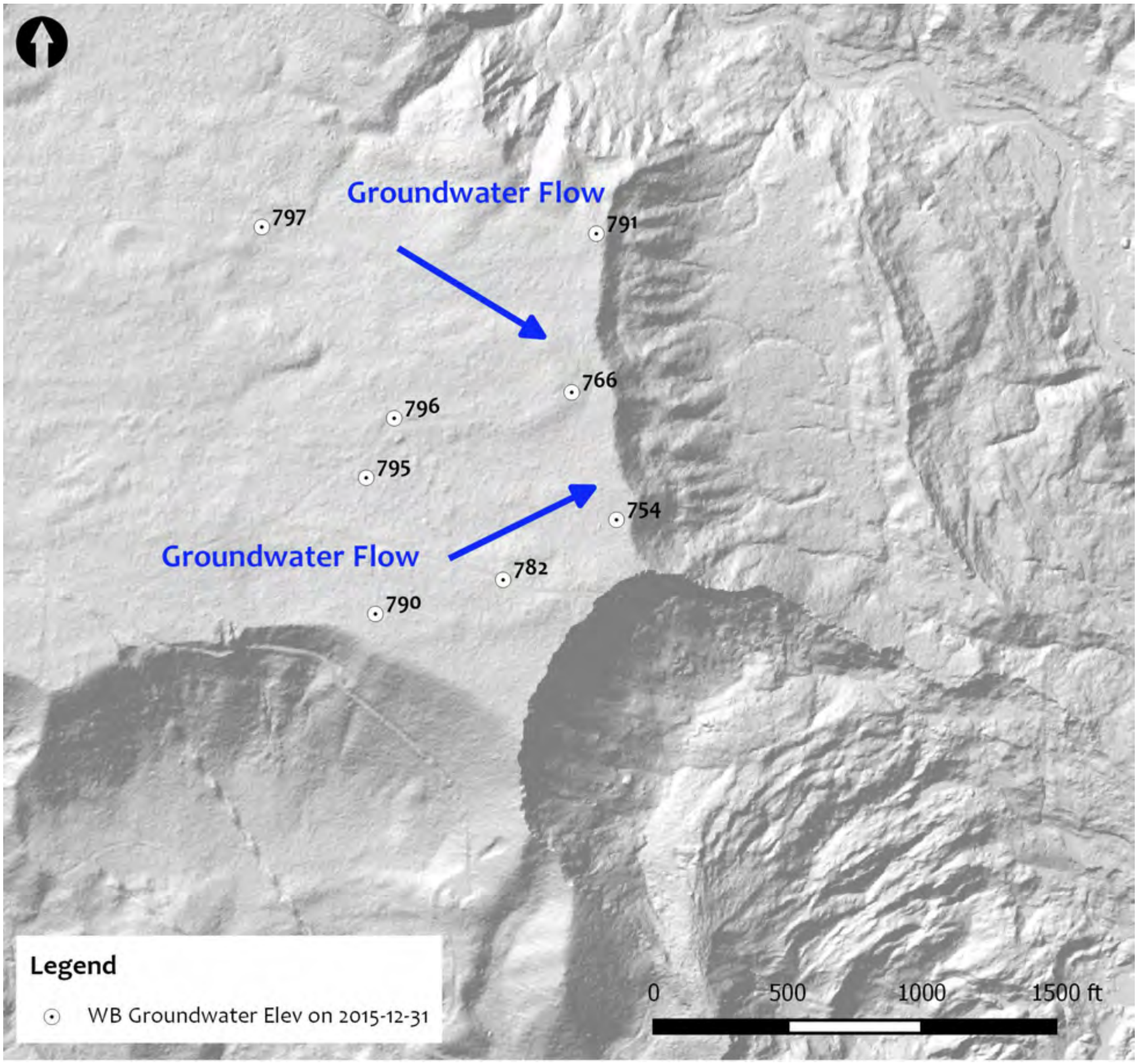

Figure 33: Groundwater flow based on elevations of groundwater surface from instruments installed in Whitman Bench (elevations reported at noon on 12/31/2015).

Additional evidence of the lateral, rather than downward movement of groundwater can be gleaned from the response to precipitation recorded by the piezometers installed in the recessional outwash sands and gravels that cap the Whitman Bench and piezometers installed below the silt/till.

The WSDOT boring H-1vwp-14 indicates that the piezometric pressure below the till is less than that above the till, which confirms that the silt/till serves as an aquitard, perching groundwater within the base of the Recessional Outwash on Whitman Bench. The silt and till layers form an effective aquitard, which restricts downward percolation and redirects said seepage off towards the east, likely flowing upon the low permeability horizons. Hence, precipitation landing on Whitman Bench and percolating down to the groundwater table will drain towards Headache Creek Basin, not downward through the till, and not toward the SR 530 Landslide.

We note that the work of Millar and Sias (23) (22), specifically invoked in the Plaintiff's complaints, which purported to be specific to the SR 530 Landslide site, equated water that reached the ground to groundwater, and considered modeled increases in groundwater to occur everywhere. That is, the entire area analyzed by Miller and Sias, which included the area of the SR 530 Landslide, was considered to be forested on the one hand, and clear-cut on the other. The reason for pointing this out should be apparent in that the clear-cut timber harvest that occurred in the fall of 2004 on the Whitman Bench was only ~8.5 acres in area, out of a total area of some 1100 acres comprising the Whitman Bench. This means that the 2004 harvest only involved about eight-tenths of one percent of the bench area.

Two problems are apparent from the deficiencies in the work of Miller and Sias. One problem is that associated with the timing of clear-cut harvesting, with respect to the occurrence of the SR 530 Landslide. Since only a small portion of the area of the Whitman Bench was clear-cut harvested, any increase in rainfall reaching the ground surface in the area of the clear-cut, must be dispersed laterally, toward the landslide, in order to determine its impact. Second, in order for any increase in infiltrated water to influence the stability of the SR 530 Landslide mass, it must flow downward, through the soil profile to depths as great as the elevation of the surface of rupture at the base of the 2014 Landslide mass. Neither of these factors was considered in the work of Miller and Sias, making their work irrelevant to the actual cause of the SR 530 Landslide.

Contention No. 2

As we interpret it, the Plaintiffs contend that the SR 530 Landslide failure mechanism was driven by unconfined gravitational seepage.

Insufficient data has been collected to comment on this contention at this time. By monitoring the series of installed piezometers through the balance of the current water year, the site-specific data will be obtained to aid in evaluating this contention.

Contention No. 3

As we interpret it, the Plaintiffs contend that erosion by the North Fork of the Stillaguamish River at the toe of the SR 530 Landslide foot destabilized the slope, which resulted in the SR 530 Landslide.

We concluded, as explained in the Declaration of Dr. J. David Rogers of November 5th, 2015 (Appendix I), that the North Fork (NF) of the Stillaguamish River had no impact on triggering of the SR 530 Landslide because (a) the surface of rupture of the SR 530 Landslide is located around El. +310 to +320 feet, which is well above the river level of approximately El. +270 to +280 feet; and (b) the NF Stillaguamish River was laterally disconnected by approximately 600 feet from the SR 530 Landslide main body's toe of surface of rupture.

Contention No. 4

As we interpret it, the Plaintiffs contend that construction of settling ponds in the foot of the SR 530 Landslide, for the purposes of reducing sediment input to benefit fisheries, destabilized the slope, resulting in the SR 530 Landslide.

We concluded, as delineated in the Declaration of Dr. J. David Rogers of November 5th, 2015 (Appendix I), that the settling pond had no impact on triggering the SR 530 Landslide, because (a) the toe of the surface of rupture of the SR 530 Landslide is located around El. +310 to +320 feet, well above the settling pond, situated at approximately El. +275 feet, (b) the presence of permeable "Bear Lake Sands," abuts the settling pond would not have resulted in saturated conditions to propagate 'uphill' into the glacio-lacustrine silt and clay deposits; rather any hydrostatic pressures resulting from the settling ponds would 'drain' on either side of the settling pond; and (c) groundwater data from the 2014 WSDOT piezometer indicates groundwater levels consistent with river level, so there is no viable physical mechanism by which surface runoff in the settling pond could have elevated pore water pressures within the 2014 SR 530 Landslide mass. We also note that isolated ponds of standing water, situated well above the maximum elevation of the settling pond, were present at the site before and after the SR 530 Landslide. These ponds are the result of the very low permeability glacio-lacustrine units, and not representative of groundwater levels. Instruments installed within the main body of the SR 530 Landslide as part of our geotechnical study will provide insights on groundwater fluctuations and relationship between river levels.

Contention No. 5

As we interpret it, the Plaintiffs contend that stability analyses performed before the SR 530 Landslide, with subsurface information available at the time, demonstrated, within the standard of practice, that the landslide was going to occur and endanger the Steelhead Haven neighborhood.

To date, we have been unable to identify any previous stability analyses for the Hazel Landslide of the SR 530 Landslide that were based on site-specific data, as required for a meaningful slope stability evaluation. We have only seen speculative slope stability analyses utilizing hypothetical site characterization models.

Reservation

We reserve the right to clarify, amend and/or supplement our observations and forthcoming opinions based on development of additional information as this case proceeds. We reserve the right to provide rebuttal opinions at the appropriate time to contentions or expert opinions that may be disclosed by the Plaintiffs in this case.

This Interim Report submitted on behalf of AG Experts submitted on January 22, 2016 by:

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