Chehalis Basin Strategy

Rock Quarry Characterization
Potential RCC Aggregate Sources for Chehalis Dam

Reducing Flood Damage and
Restoring Aquatic Species Habitat

March 5, 2019

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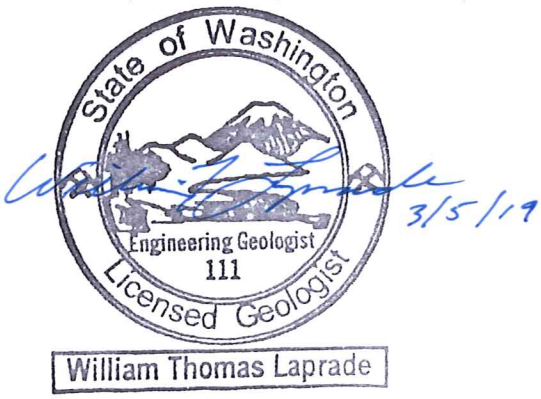
Rock Quarry Characterization
Potential RCC Aggregate Sources for Chehalis Dam

March 5, 2019

This report prepared for the Office of Chehalis Basin.

This report prepared by Shannon & Wilson, Inc.
Primary contributing authors: Bill Laprade, LEG, Stan Boyle, PhD, PE



William T. Laprade, LEG

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ACRONYMS AND ABBREVIATIONS

ASR	Alkali-Silica Reaction
EIS	Environmental Impact Statement
GDR	Geotechnical Data Report
LA	Los Angeles
RCC	roller-compacted concrete
TM	technical memorandum
VWP	vibrating wire piezometer

1 INTRODUCTION

This technical memorandum (TM) presents a summary of field explorations and laboratory testing for potential quarry sites for roller-compacted concrete (RCC) aggregate in the Chehalis River Basin in support of a potential dam on the main stem of the Chehalis River, about 1 mile south of Pe Ell, Washington (Figure 1). The exploration logs and laboratory data are presented in the Geotechnical Data Report (GDR), produced by Shannon & Wilson, Inc., dated March 5, 2019.

2 BACKGROUND

Shannon & Wilson performed a desktop study of existing commercial and abandoned rock quarries in the vicinity of the potential dam site in 2014, producing a report titled *Quarry Rock Desktop Study*. Shannon & Wilson also identified other potential rock source locations that might be developed as RCC aggregate quarries. Grab samples from the Alderbrook and Hope Creek commercial quarries and a talus pile at the eastern abutment of the potential dam site were submitted to testing. In 2016, drilling was performed at two of the sites, now called the North Quarry (QB-1, Quarry 1) and Huckleberry Ridge Quarry (QB-2, Quarry 2) and grab samples were taken from existing stockpiles at the Rock Creek Quarry. Results of the exploration programs and tests conducted on rock samples were reported in the Phase 2 Site Characterization Technical Memorandum (HDR Engineering and Shannon & Wilson, Inc., 2016). Quarry locations are shown in Figure 1.

In 2017, a Weyerhaeuser contractor improved the grade of the 1020 Road (Figure 1), west of the mainstem Chehalis River, exposing basalt that had not been visible previously. A grab sample of the rock from that road cut was tested in early 2018. Test results indicated the rock may be promising as aggregate. The grab sample test results provided an impetus to drill a boring at that site this year. This potential quarry is herein referred to as the South Quarry.

3 2018 EXPLORATIONS AND TESTING

In 2018, subsurface explorations were performed to support the Chehalis Basin s Strategy's Project-level Environmental Impact Statement (EIS) information with respect to landslides and potential quarry sites. Six borings were drilled and sampled in potential quarry sites from June through August 2018. The boring locations are shown in Figures 1 and 2. They include three borings at the North Quarry (RNQ-18-301, RNQ-18-302, and RNQ-18-303); one boring at the South Quarry (RSQ-18-301); and two borings at the Rock Creek Quarry (RCQ-18-301 and RCQ-18-302). Data for these six borings are presented in Table 1.

The borings were advanced through soil overburden that ranged from 35 to 75 feet thick, taking split-spoon drive samples at 5-foot intervals. The drillers then switched to HQ-3 triple-barrel rock coring tools for the remainder of the borehole in bedrock. A vibrating wire piezometer (VWP) was installed in each boring before leaving the site. Data from the first few months of VWP readings are presented in Appendix D of the GDR. Laboratory test results for the quarry rock samples are presented in Table 2.

4 QUARRY DESCRIPTIONS AND SUBSURFACE CONDITIONS

4.1 North Quarry

The North Quarry location is shown in Figures 1 and 2 (Page 1 of 4). It is comprised of two narrow ridges to the east of the mainstem Chehalis River, about 1.2 miles southeast of the potential dam site (or about 2.14 road miles). The southern ridge has an upper elevation of 825 feet, and the northern ridge tops out at approximately elevation 700 feet. The 1000F Road circles around the eastern edge, through the middle of the two ridges, and down the western flank of the southern ridge at the potential quarry site. Except for this road, the site is wooded with mature timber.

Boring QB-1 (RNQ-16-301) was drilled at the site in 2016. A seismic refraction survey was completed by Global Geophysics at the site in 2016. Three more borings were drilled and sampled in 2018 to the south, east, and north of boring QB-1 (RNQ-16-301). A subsurface profile is presented in Figure 3. It indicates variable thicknesses of colluvium, weathered bedrock, basalt, siltstone, and breccia, all of which have been observed in Weyerhaeuser rock pits in the vicinity. As shown in Figure 3, the maximum thickness of basalt is about 94 feet at QB-2 (RNQ-16-301). Below the basalt, layers of siltstone and breccia were encountered. To the south, extending down the narrow ridge, the rock is weathered to a depth of about 75 feet, below which is basalt. To the north, the upper about 45 feet is colluvium or weathered rock, below which is basalt.

The test results, summarized in Table 2, indicate four of the seven tests on basalt exceeded the minimum of 2.55 for specific gravity and the other three tests were below, but near 2.55. All the tests exceeded the standard of 3.0 percent for absorption. All the tests were less than the upper limit of 35 percent for the Los Angeles (LA) Abrasion test. Four of the five Alkali-Silica Reaction (ASR) tests were innocuous, and one would have required additional testing per ASTM (2014).

In conclusion, the data show that the North Quarry basalt is likely to be adequate qualitatively, with some wastage for lower quality pockets or seams; however, a significant amount of overburden would require removal, and the siltstone and breccia zones would have to be wasted.

4.2 South Quarry

The South Quarry is on a nose protruding from a high ridge about 2.5 miles south of the potential dam site (or about 4.3 road miles) (see Figure 1 and Figure 2, Page 2 of 4). The upper level of the nose is about elevation 1,040 feet, with steep slopes down to the east and south. A slope to the west rises up sharply to about elevation 1,340 feet. The 1020 Road traverses the eastern and southern sides of the

topographic nose, and the upper level is accessed by an unnamed logging road off the 1020 Road. Except for the roads, the site is covered with mature timber.

Basalt is exposed in a road cut along the 1020 Road. One boring (RSQ-18-301) was drilled and sampled to a depth of 180 feet on a logging road at about elevation 980 feet. Boring RSQ-18-301 encountered 35 feet of overburden, below which was basalt down to approximately 133 feet. Basalt breccia extended down to about 144 feet and then a 2-foot-thick layer of siltstone was encountered. Below 146 feet, basalt has slightly higher strength than the upper basalt stratum; however, the lower basalt contains multiple lenses of siltstone and weathered zones.

As indicated in Table 2, most of the laboratory test results for samples from boring RSQ-18-301 and the 1020 Road cut met or were near the standards. All of the specific gravity tests were greater than the minimum standard of 2.55. Two of the four absorption tests were less than the maximum standard of 3.0 percent. All of the LA Abrasion tests were significantly less than the maximum of 35 percent. Three of the four ASR tests were innocuous; only the grab sample from the 1020 Road that was moderately weathered requires additional testing per ASTM (2014).

In conclusion, the data show that the South Quarry basalt is likely to be adequate qualitatively in the upper zone between 35 and 144 feet, with little wastage. The zone below the 146-foot depth may also be suitable, as indicated by its test values, but more processing may be necessary to remove the siltstone.

4.3 Rock Creek Quarry

The potential Rock Creek Quarry site is on a narrow ridge west of an existing, but abandoned, Weyerhaeuser quarry (see Figure 1 and Figure 2, Page 3 of 4). The highwalls around three sides of the existing quarry expose basalt, and several stockpiles on the quarry floor are comprised of basalt. The site is about 10 miles west of the potential dam site. Rock from the stockpiles was tested in 2016 and found to be suitable for use as aggregate, so two borings were drilled in 2018 on the western ridge. Borings were not sited on the southern slope because a stream with a waterfall presently occupies part of that highwall and getting permits to excavate near the stream could be difficult, even if rock of sufficient quality is present.

Borings RCQ-18-301 and RCQ-18-302 were drilled and sampled on the A5008 Road, at the locations shown in Figure 2. Overburden (soil and weathered rock) was 70 and 45 feet thick, respectively, on the ridge. At the northern end, in RCQ-18-301, breccia was encountered to the bottom of the boring. The breccia contained an abundance of calcite fillings down to about 100 feet. Below 100 feet, the rock was good quality. At the southern end of the ridge, in RCQ-18-302, siltstone extended down to 101 feet, below which basalt and siltstone alternated to the bottom of the boring.

RCQ-18-302 was drilled first, and contained multiple layers and lenses of siltstone, so little testing was performed there due to unfavorable stratigraphy. When the abundance of calcite joint fillings was identified in RCQ-18-301, little testing was performed there also. Test results are presented in Table 2.

4.4 Huckleberry Ridge Quarry

The Huckleberry Ridge Quarry was called Quarry 2 in the Phase 2 Site Characterization report (HDR Engineering and Shannon & Wilson, Inc., 2016). It is just south of the F1000 Road, about 7 miles (8.4 road miles) southwest of the potential dam site, as indicated in Figure 1. It is on a low ridge with a very steep eastern face that exposes basalt (Figure 2, Page 4 of 4). An unnamed logging road traverses the eastern side of the ridge and another road accesses the top of the ridge on which boring QB-2 was drilled and sampled to a depth of 150 feet in 2016.

Relatively high quality basalt was encountered in boring QB-2 to a depth of 94 feet. No soil overburden was encountered in boring QB-2. Beneath the basalt was a 37-foot-thick sequence of alternating claystone/siltstone with basalt and basalt breccia in a claystone/ siltstone matrix. Competent basalt was encountered from 131.5 to the bottom of the boring. The exposed rock in the road cut was also high quality.

Test results for the Huckleberry Ridge Quarry site, shown in Table 2, indicate that absorption was slightly higher than the standard, but the results for specific gravity, LA Abrasion, and ASR met the standards. In conclusion, the basalt in the upper 94 feet at this potential quarry site is favorable for exploitation for the RCC aggregate. Below the basalt is 37 feet of unsuitable rock that would have to be wasted. Basalt below the unsuitable rock is likely to be suitable, but it has not been tested yet.

5 OVERALL CONCLUSIONS

In our opinion, the North, South, and Huckleberry Ridge sites should be carried forward as potential RCC aggregate quarry sites. We do not recommend retaining Rock Creek as a viable quarry site for RCC aggregate.

The North Quarry has a substantial, but not prohibitive, thickness of overburden, but (1) the rock is of good quality, (2) the area for expansion to the north of the existing explorations may provide even more acreage, (3) the site is the closest of the potential quarry sites to the potential dam site, and (4) the site is in the reservoir footprint.

The South Quarry (1) has good quality rock, (2) has a reasonable thickness of overburden, and (3) is relatively close to the potential dam site, and (4) is in the reservoir footprint.

The Huckleberry Ridge Quarry has the longest haul distance of the three identified potential quarries, but (1) has good quality rock and (2) little to no overburden.

The North, South, and Huckleberry Ridge quarry sites would require construction of, or improvements to, roads to haul rock from the quarry sites to the location of processing facilities at the proposed dam site. Existing logging roads would likely need to be widened and reconfigured to accommodate haul trucks. No public roads would need to be used. The Huckleberry Ridge Quarry would require the longest haul route and the most road improvements.

The 2018 borings at the Rock Creek site indicate that there is too much siltstone in the ridge to be viable as a source of RCC aggregate. That fact, combined with the calcite joint fillings in the rock in boring RCQ-18-301, that otherwise appears to be useful, render this ridge unfavorable for an RCC aggregate source, in our opinion.

6 RECOMMENDATIONS

The three potential quarry sites identified require additional drilling and testing, including borings, laboratory testing, and field reconnaissance. The recommended boring locations are shown in Figure 2, Pages 1, 2, and 4.

At the North Quarry, we recommend that two borings be drilled on the ridge to the north of boring RNQ-18-303. Field reconnaissance should also be carried out to determine the feasibility of a direct road or conveyor connection from this ridge to the potential dam site.

At the South Quarry, we recommend that five borings be drilled to further explore this resource. Borings should include (1) one boring on the existing logging road, north of boring RSQ-18-301, (2) two angle borings into the hillside on the 1020 Road, (3) one boring upslope of RSQ-18-301, near the upper limit of the nose, and (4) one boring on the slope below boring RSQ-18-301. This last-mentioned boring may or may not be feasible owing to the steepness of the slope and the difficulty in permitting a drill access road there.

At the Huckleberry Ridge Quarry site, we recommend that two borings be drilled and sampled. One boring would be on the ridge to the west of boring QB-2, and another boring would be an angle boring on the road adjacent to the logging road rock outcrop.

7 CLOSURE

This quarry characterization TM was prepared to present new and existing geologic/geotechnical data for use in the Chehalis Basin Strategy Project-Level EIS and to aid team members in engineering decisions regarding RCC aggregate sources. The raw data, such as boring logs and laboratory test result, were presented in the GDR (Shannon & Wilson, 2018). This TM should be used in tandem with that GDR.

This TM should be made available for information on factual data only. Subsurface conditions, such as those that may be interpreted from exploration logs and profiles included in this TM, may not be construed as a guarantee or warranty of any subsurface conditions.

We appreciate the opportunity to be of service. Questions or comments regarding this TM should be directed to the undersigned at wtl@shanwil.com.

8 REFERENCES

ASTM, 2014, Standard test method for potential alkali reactivity of aggregates (mortar-board method), C1260-14: West Conshohocken, PA., ASTM International, Annual book of standards, v. 04.02, concrete and aggregates (I): C29/C29 M-E329, 5 p., available: www.astm.org.

HDR Engineering and Shannon & Wilson, Inc., 2016, Phase 2 Site Characterization Technical Memorandum, prepared for State of Washington Office of Financial Management and Chehalis Basin Work Group, 39 p.

Shannon & Wilson, Inc., 2019, Phase 3 Chehalis Dam Geotechnical Data Report, Chehalis Basin Work Group, Pe Ell, Washington.

Table 1

2018 Quarry Geotechnical Explorations

																INSTRUMENTATION NOTES	
BORING NUMBER	LOCATION	PURPOSE	EASTING	NORTHING	ELEVATION (FT.)	DRILLING DEPTH (FT.)	SOIL/ WEATHERED ROCK DEPTH (FT.)	ANGLE OF HOLE FROM HORIZONTAL	DRILLING METHODS SOIL/ WEATHERED ROCK	ROAD BUILD	ROAD LENGTH (FT.)	TRACK/ TRUCK	DRILLING METHODS SOUND ROCK	SAMPLING METHODS	BACKFILL/ COMPLETION REQUIREMENTS	PIEZOMETER	INCLINOMETER
RCQ-18-301	Rock Creek Quarry	Quarry Site	911015.285	451209.330	1108.28	149.8	70.3	Vertical	Mud Rotary	Yes	145	Track	HQ3	SPT/coring	Grout	Yes	No
RCQ-18-302	Rock Creek Quarry	Quarry Site	910980.444	450774.285	1159.24	200.0	45.0	Vertical	Mud Rotary	No		Truck	HQ3	SPT/coring	Grout	Yes	No
RNQ-18-301	North Quarry	Quarry Site	939359.003	448526.788	752.79	120.0	75.0	Vertical	Mud Rotary	Yes	305	Track	HQ3	SPT/coring	Grout	Yes	No
RNQ-18-302	North Quarry	Quarry Site	939866.449	448996.851	786.20	100.2	47.5	Vertical	Mud Rotary	No		Truck	HQ3	SPT/coring	Grout	Yes	No
RNQ-18-303	North Quarry	Quarry Site	939280.220	449373.655	696.97	100.0	45.0	Vertical	Mud Rotary	No		Truck	HQ3	SPT/coring	Grout	Yes	No
RSQ-18-301	South Quarry	Quarry Site	939397.505	440775.917	979.91	180.0	35.0	Vertical	Mud Rotary	No		Track	HQ3	SPT/coring	Grout	Yes	No
Total No.						Total:	Soil/ Weathered Rock										
6	Total Boring Depths					850	317.8										

Notes:

ft. = feet

SPT = Standard Penetration Test

Table 2

Prospective Quarry Lab Test Results

BORING	SAMPLE DEPTH (FT.)	SPECIFIC GRAVITY	SLAKE DURABILITY (%)	ABSORPTION (%)	LA ABRASION (%)	ASR (16 DAY) (% LENGTH CHANGE)	ROCK TYPE
BNQ-18-301							
	93.5-95.9						altered amygdaloidal BASALT
	105.0-105.2						altered amygdaloidal BASALT
	80-100	2.50		6.8	19.8		
	100-120	2.69		4.8	21.5		
RNQ-18-302							
	64.6-64.8						altered amygdaloidal BASALT
	81.5-82.5		26.5, Type III				SILTSTONE
	75-92.4	2.51		8.85	18.5	0.055	
RNQ-18-303							
	80.3-80.5						altered amygdaloidal BASALT
	50-64.6	2.72		5.08	18.9	0.049	
QB-1, North Quarry							
	38-50	2.60		6.46	27.1	0.08	
	84-95	2.65		4.69	26.8	0.076	
	127-140	2.49		8.26	27.5	0.124	
QB-2 Huckleberry							
Ridge	15-27	2.69		4.04	24.8	0.034	
	45-55	2.71		3.72	24.1	0.036	
RSQ-18-301							
	55.7-55.9						altered amygdaloidal BASALT
	154.0-154.2						altered amygdaloidal BASALT
	50.2-70	2.71		3.3	20.5	0.042	
	100-118.2	2.80		2.9	18.9	0.047	
	149.8-171.2	2.63		4.9	20.4	0.042	
1020 Road Cut							
	GRAB	2.72		2.35	18.4	0.254	

Table 2 (continued)

BORING	SAMPLE DEPTH (FT.)	SPECIFIC GRAVITY	SLAKE DURABILITY (%)	ABSORPTION (%)	LA ABRASION (%)	ASR (16 DAY) (% LENGTH CHANGE)	ROCK TYPE
RCQ-18-301							
	75.6-75.9						altered BASALT
	120.95-121.2						altered mafic VOLCANICLASTIC
RCQ-18-302							
	160.5-160.7						altered amygdaloidal BASALT
	51.6-52.5		87.7, Type II				SILTSTONE
	83.3-84.2		86.8, Type II				SILTSTONE
	151-167.7	2.52		3.21	19.2	0.31	

Notes:
0-0.10 innocuous, 0.11-0.20 acceptable if supplemental testing confirms expansion is not due to Alkali-Silica Reaction (AST), >0.20 requires additional testing.
Bolded quarry names from previous years' testing.
ft. = feet

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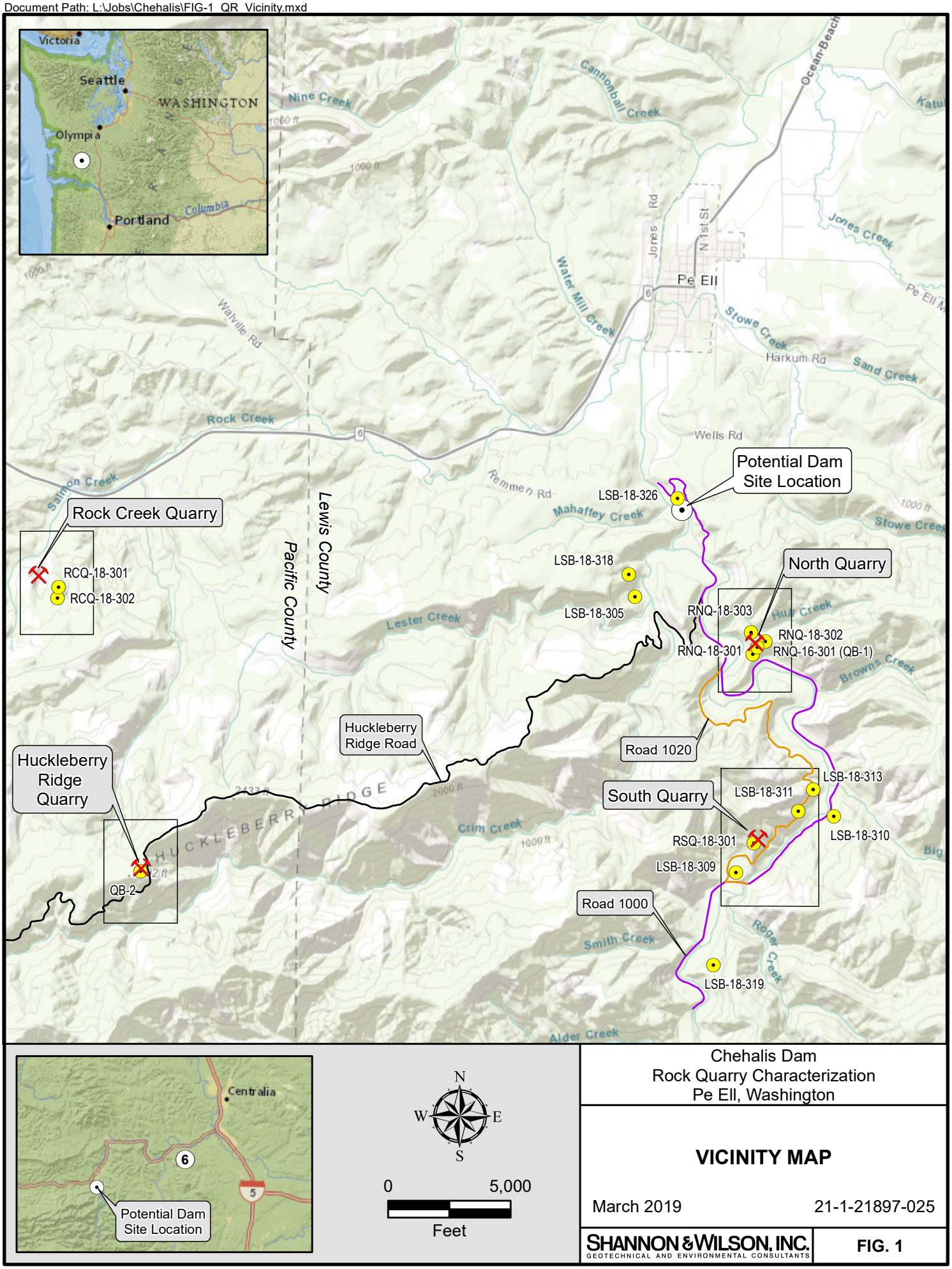

Chehalis Dam
Rock Quarry Characterization
Pe Ell, Washington

VICINITY MAP

March 2019

21-1-21897-025

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FIG. 1

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RNQ-18-303

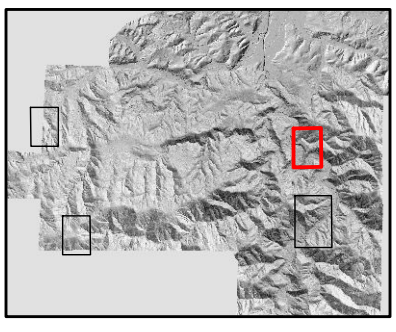
NORTH QUARRY

RNQ-18-302

RNQ-16-301(QB-1)

RNQ-18-301

Chehalis River



LEGEND

Landslide Location and Designation

LS-26

Quarry Site Location

Profile Location

Potential Dam Site Location

Completed Boring Locations

Recommended Boring Locations

NOTE:
Hillshade generated using ESRI 3D Analyst from LiDAR data provided by HDR. NAVD 88, Illumination 315

N
W E
S

0 300

Feet

Chehalis Dam
Rock Quarry Characterization
Pe Ell, Washington

SITE PLAN

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FIG. 2

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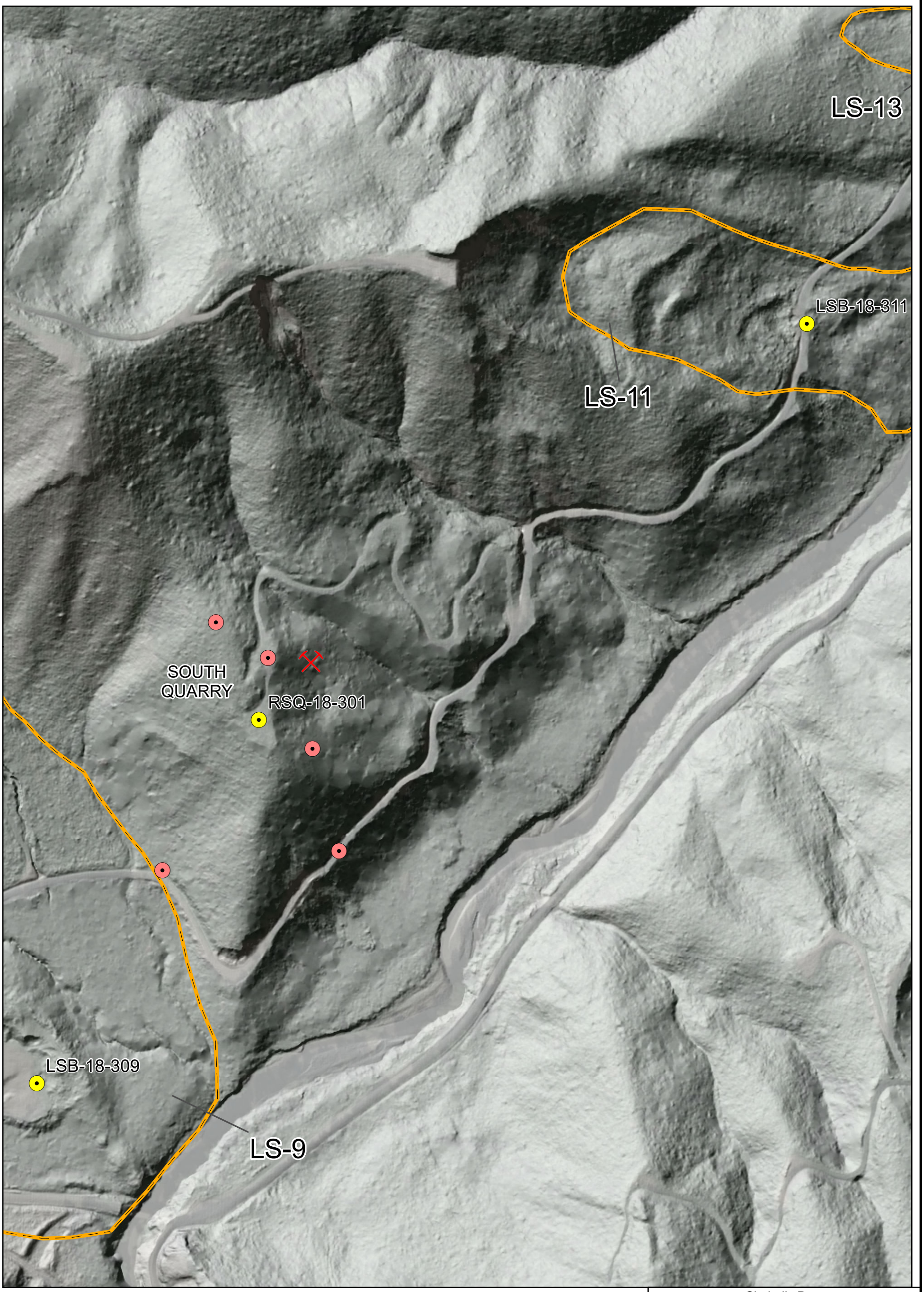

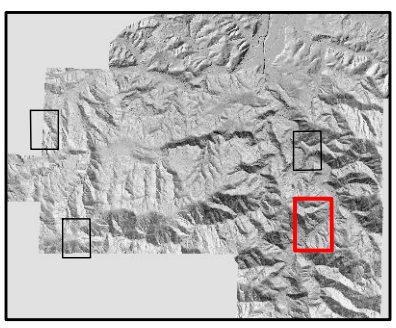

LEGEND

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Hillshade generated using ESRI 3D Analyst from LiDAR data provided by HDR. NAVD 88, Illumination 315

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Chehalis Dam
Rock Quarry Characterization
Pe Ell, Washington

SITE PLAN

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FIG. 2

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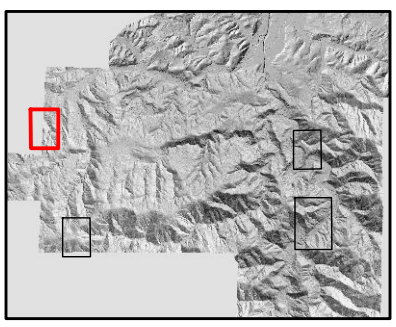
RCQ-18-301

RCQ-18-302

EXISTING
ROCK CREEK
QUARRY



LEGEND

Landslide Location and Designation

LS-26

Quarry Site Location

Profile Location

Potential Dam Site Location

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Recommended Boring Locations

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Hillshade generated using ESRI 3D Analyst from LiDAR data provided by HDR. NAVD 88, Illumination 315

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Chehalis Dam
Rock Quarry Characterization
Pe Ell, Washington

SITE PLAN

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FIG. 2

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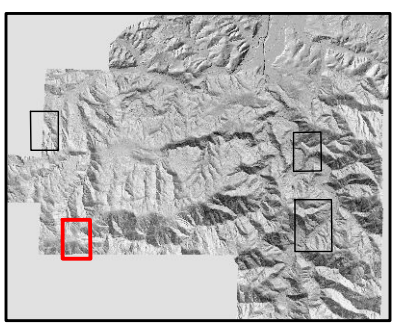
HUCKLEBERRY RIDGE QUARRY

QB-2



LEGEND

Landslide Location and Designation

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Hillshade generated using ESRI 3D Analyst from LiDAR data provided by HDR. NAVD 88, Illumination 315

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Chehalis Dam
Rock Quarry Characterization
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SITE PLAN

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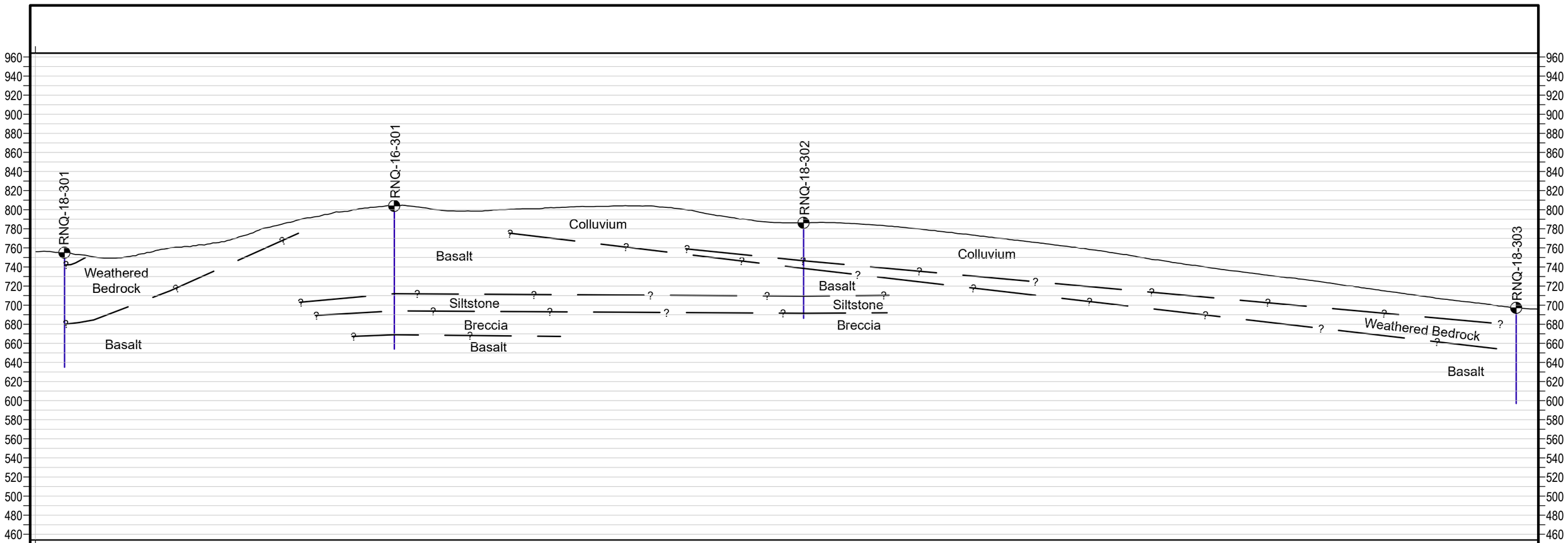
FIG. 2



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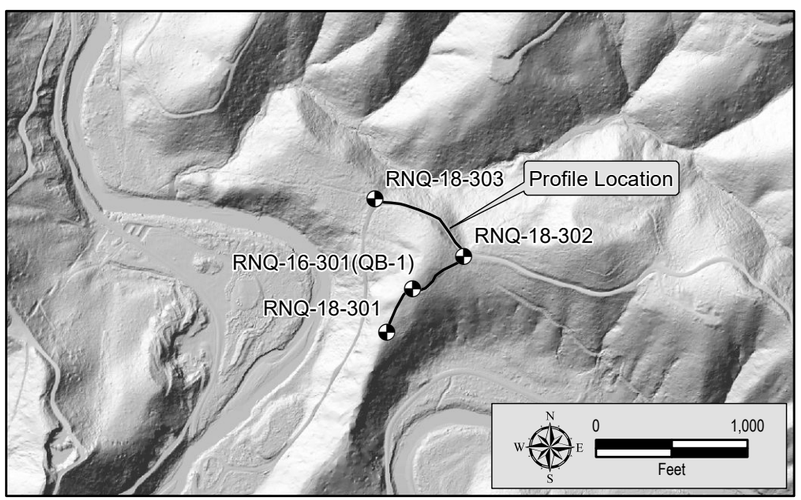

Chehalis Dam
Rock Quarry Characterization
Pe Ell, Washington

NORTH QUARRY PROFILE

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FIG. 3