

20 October 2025

Mike Kaputa, Director
Chelan County Department of Natural Resources
SEPA Responsible Official
missionridgeeis@outlook.com
411 Washington St. Suite 201
Wenatchee, WA, 98801

Re: Draft Environmental Impact Statement, Mission Ridge Expansion Master Planned Resort

Dear Mr. Kaputa:

Thank you for the opportunity to comment on the draft EIS (DEIS) for the proposed development at Mission Ridge Resort.

The first time I skied at Mission Ridge Resort was in the late 1970s. I have been a season pass holder for many years. In 2018 I moved to the Wenatchee area in large part to be closer to the Ridge. I am a fan of the Resort and want it to succeed. I am also a recently retired research geologist with expertise in the geology of the Pacific Northwest, geologic mapping, the interpretation of lidar topography, and the mapping of landslide deposits.

In the following pages I comment on landslide hazard in the proposed development and its treatment in the DEIS. Topics are: (1) landslides at the site of the proposed development; (2) discussions in the DEIS of landslides; (3) planned wastewater disposal and snowmaking will exacerbate the landslide hazard; (4) inadequate mapping of surficial geology; (5) analysis, evaluation, and monitoring are not mitigation; (6) significance of block fields; and (7) how the magnitude and frequency of landslide hazard might be evaluated. I also comment on (8) geology beneath the proposed public access road.

I wish I could suggest how to safely site roads, commercial space, housing, and wastewater disposal for the development the Resort owner believes is needed. However, my conclusion is that there is no convincing, positive, evidence that landslides in the project area are currently inactive and unlikely to be reactivated in the near future. My reading of the landscape, site geology, and the DEIS is that the proposed development is likely to expose Chelan County, owners and tenants of property within the development, and Tamarack Saddle, LLC to large risks that would be extremely difficult, if not impossible, to mitigate. The development as currently proposed should not be permitted.

Sincerely,

Ralph Haugerud
Wenatchee, WA 98801
rhaugerud@gmail.com

(1) LANDSLIDES AT THE SITE OF THE PROPOSED DEVELOPMENT

When I look at lidar topography ([Washington Lidar Portal](#)) (Fig. 1) of the area of the proposed Mission Ridge expansion, I see two significant landslides. The first landslide (L1) occupies much of the W½ of Section 19, T21N R20E and extends downhill into the eastern edge of Section 24, T21N R19E. Most of the development (commercial buildings, residences, maintenance facilities, residential access roads, utility distribution lines) proposed as part of the Mission Ridge expansion is in this landslide. Tabor and others (1982) fairly accurately mapped this landslide as unit Qls (Landslide deposits, undifferentiated). The morphology of this landslide is complex: large rotational blocks in its upper region transition downslope into debris flows that reached Squilchuck Creek. The SW margin of the landslide may be located along a recent fault (Fig. 1).

The second landslide (L2), partly mapped in Fig. 1, is mostly in the NE¼ of Section 25, T21N R19E, east of Chak Chak ski run, and extends downhill to the NW into the SW¼ of the SE¼ of Section 24. The proposed public access road to the development crosses this landslide. Tabor and others (1982) mapped most of this landslide as unit Qrg (Rock glacier deposits—Angular locally derived boulders forming bulbous tongue) and mapped the lowermost part as Qa (Alluvium).

Topographic details of both landslides are crisp, which suggests to me they are recent. Section 4.1.3 of the DEIS describes a young scarp and tilted trees which clearly demonstrate that part of L1 has been active recently. As I discuss below, planned snowmaking and onsite disposal of wastewater by infiltration can only increase the likelihood of L1 moving. Downcutting by Squilchuck Creek provides a measure of relative age, with older features more deeply and widely incised. By this measure, the little-incised toe of L2 is amongst the youngest geomorphic features along the Squilchuck valley.

(2) DISCUSSIONS IN THE DEIS OF LANDSLIDE HAZARD

The DEIS describes and discusses the landslide hazard in several places: section 4.1 of the main text; Volume III, Appendix A (the 2020 USFS Draft Environmental Analysis); a report by GeoEngineers, Inc. that is the 1st part of Volume III, Appendix B; and a number of reports by GN Northern, Inc. and its subcontractors (GNN) that form the remainder of Appendix B. These descriptions and discussions are inconsistent regarding the extent of landslides, probable age(s) of landslide activity, and the consequent severity of the landslide hazard.

Section 4.1, to its authors' credit, does recognize that there is significant landslide hazard in the area proposed for development. Section 4.1.2.1, *Impacts from Construction*, concludes with the statement that "...there are probable significant adverse construction-related impacts on landslide hazards and earthquake-induced landslides from the Proposed Project. These impacts can be partially mitigated for as described in Section 4.1.3.3." Section 4.1.3.1, *Impacts from*

Operation, concludes with a similar statement. I share the concerns expressed in section 4.1 of the DEIS that construction and operation of the proposed development may increase landslide risk¹. However, the EIS should be clearer that the landslide hazard is significant even without construction and operation. Please see my comments below about proposed mitigation.

Despite referencing “Geologic Map of the Wenatchee 1:100,000 Quadrangle, Central Washington” (the title of the map by Tabor and others, 1982), the geologic mapping reproduced in Figures 4.1-1a and Figure 4.1-1b is from a state-wide digital compilation maintained by Washington DNR, which conflates unit Tabor and others’ unit Qls (Landslide deposits, undifferentiated) of Holocene and Pleistocene age with unit Qdy (Diamicton) entirely of Pleistocene age. The former is indicative of potential landslide hazard; the latter, less so.

Figure 3-17 of Appendix A shows the entirety of the proposed development as having high risk of both shallow and deep landslides.

The 2016 report by GeoEngineers (the 1st part of Appendix B) is exemplary. Discussing the 2016 landslide off Castle Peak and a 2006 landslide above Skookum, the authors state on p. 8:

The 2006 and 2016 landslide events indicate that future landsliding within the site area is possible, if not likely when weather conditions similar to the spring of 2006 and 2016 occur.

Reports by GNN in September 2017 (Preliminary Geologic Site Reconnaissance), November 2017 (Reconnaissance-Level Evaluation of Geologic Hazards Report), and December 2019 (Review of Revised Expansion Plans by GNN) reached different conclusions about landslide hazard. Significant conclusions in these reports are unsupported by evidence; some are demonstrably wrong.

The November 2017 report by GNN (Executive Summary, p. 4; re-affirmed in the memo of December 2019, written after GNN’s examination of lidar topography) states:

We believe the landslide events occurred under notably different geologic and climactic conditions during the end of the Pleistocene Epoch. The noted slump-block failures and surrounding mass wasting deposits from older landslide events appear to be relatively stable under the modern day geologic and climate conditions.

No direct evidence for the assertion that landslides are end-Pleistocene is given. On page 9 it is suggested, though not stated outright, that landslides in the vicinity of the proposed expansion resulted from undercutting cutting of slopes by late Pleistocene Missoula floods. This is very

¹ The U.S. Geological Survey has defined risk and hazard as follows: Risk—the potential loss of things we care about as a society caused by hazards and current or proposed human actions in hazardous areas. Hazard—the physical process or condition that can do harm to things we care about as a society.
(<https://www.usgs.gov/media/images/what-difference-between-hazard-and-risk>)

unlikely. Highest Missoula flood inundation in the Wenatchee area was around 1,600 ft (O'Connor and others, 2020). The toes of L1 and L2 are much higher, at approximately 4,000 ft and 4,400 ft elevation. Undercutting could not have occurred at these elevations. Flood velocities in alcoves such as (much lower) Squilchuck valley would have been low, with little undercutting. On page 13 the assertion that landslides occurred at the end of the Pleistocene is repeated, again without evidence, and then the authors also suggest that slump-block failures were possibly triggered by a Holocene earthquake, partially contradicting this assertion.

The next assertion is “deposits from [these] older landslide events appear to be relatively stable under the modern day geologic and climate conditions.” Note the qualifications appear to be and relatively. No evidence for this assertion is presented in the November 2017 GNN report. Recent movement of landslides onto Skookum ski run (2006), off Castle Peak onto Mimi ski run (2016) (GeoEngineers, Inc., 2016, in volume III, Appendix B of the DEIS), and along the Whispering Ridge Road farther down valley (e.g., KOMO NEWS, 2016; NCWLIFE NEWS, 2017) demonstrate how wrong this assertion is.

(3) Planned wastewater disposal and snowmaking will exacerbate the landslide hazard

I am taken aback by the apparent disconnect between consideration of landslide hazard and plans for snowmaking and wastewater disposal. GNN, in their November 2017 memo, (p. 21) emphasized that

- ... Drainage design for the proposed project should direct stormwater runoff away from the identified slide mass ...
- Development on sloping ground poses an inherent risk related to global and local stability of site slopes. The proposed project site development will require careful design and construction including slope stabilization and drainage/erosion control measures to mitigate the observed geotechnical and geologic site constraints. [my emphases]

This wisdom appears to have been ignored in the discussion of groundwater.

The DEIS states the majority of domestic-use and landscape water is likely to be imported from outside the boundaries of the new development. Unless and until a possible wastewater treatment plant is built, it is estimated that about 90% of the imported water will be disposed of onsite by infiltration, using OSS (Onsite Sewage System) or LOSS (Large Onsite Sewage System).

Snowmaking is planned for approximately 62 acres of new ski trails. Maps in the DEIS suggest that all these trails are in or upslope of landslides L1 and L2. Water for snowmaking would be pumped from elsewhere in the Resort area, outside of these landslides and their contributing areas, resulting in a net increase of local groundwater.

These increases in local groundwater input are summarized on page 5-30, where it is stated that the water budget for the project would include:

- Importing potable water from outside the basin coupled with treated effluent discharge to groundwater via OSS/LOSS and/or to Squilchuck Creek via WWTP (year-round).
- Snowmaking activities that divert surface water to a reservoir during the fall and winter, eventually storing that water [as] snow, and effectively extending the spring snowmelt season (seasonal).

Increased groundwater recharge will decrease the stability of landslide masses and consequently increase the landslide hazard. See, for example, the GeoEngineers report (DEIS v. III, 1st part of Appendix B) on the April 2016 Castle landslide, which on page 8 states:

It is our opinion that the chief mechanism of landslide movement was significant water flow into and through the very permeable basalt talus on top of the relatively impermeable and steeply inclined sandstone bedrock.

Stormwater (roof and road runoff) disposal may present a similar issue, but I could not ascertain how stormwater is proposed to be handled.

(4) INADEQUATE MAPPING OF SURFICIAL GEOLOGY

Section 4.1 of the DEIS presents a geologic map derived from the 1:100,000-scale map by Tabor and others (1982, 2005). Locations of features (e.g., solid-line contacts and faults) shown on this map are accurate within about 100 meters. This limitation derives from the scale at which the map was prepared and does not reflect any lack of care by the authors. For surficial deposits which are mapped largely on the basis of landforms, the accuracy with which deposits could be identified was limited by forest cover. To address questions of exactly where landslide deposits are, and whether a given deposit is of a landslide, mapping at a larger scale with a more detailed depiction of landforms is both possible (e.g., Haugerud, 2014) and necessary.

In the early 2000s the earth science community became aware that detailed topographic models derived from airborne lidar surveys could revolutionize our mapping of geomorphic features, including landslides (e.g., Haugerud et al., 2003). This is especially true for features under forest cover (e.g., Haugerud and Harding, 2001). In 2008 the Oregon Lidar Consortium began collecting lidar data partly to support better landslide mapping. After the 2014 Oso landslide the state of Washington began a similar lidar acquisition and interpretation program (see <https://dnr.wa.gov/washington-geological-survey/publications-and-data/lidar>).

Public-domain lidar topography for a small part of the proposed Mission Ridge expansion became available in 2014 (Colockum 2014 survey, <https://lidarportal.dnr.wa.gov/>). Lidar topography for the remainder of the proposed expansion became available in late 2018 (Yakima Basin North 2018 survey, <https://lidarportal.dnr.wa.gov/>). Failure to use this lidar topography for detailed mapping of surficial geology in the area proposed for development is a serious omission in the DEIS.

(5) ANALYSIS, EVALUATION, AND MONITORING ARE NOT MITIGATION

Table 2.4, Phase and Mitigating Conditions Summary, and Section 4.1.3.3, Proposed Mitigation Measures, in the DEIS identify a number of mitigation measures, including:

- A. ... global slope stability analysis with explorations for the DNR-mapped landslide to evaluate the actual stability of slopes in and near the Project Area and to determine the risk of construction and operation of the Proposed Project to drive future slope failures. (p. 4-14)
- B. ... periodic LiDAR flights (at least once every 3 years) to provide high resolution topographic mapping of the Project Area and nearby vicinity. LiDAR data shall be analyzed for the purpose of enabling early detection of any changes over time and finding will be reported to Chelan County. (Table 2.4, p. 4-16)
- C. ... install 10 new monuments across the Project Area. These monuments will be surveyed regularly (at least once every 3 years) and used as a second method for tracking slope movement. Findings will be reported to Chelan County concurrently with the LiDAR analysis. Additional monuments may be required to be installed and monitored following completion of field exploration and design. (p. 4-17)

Mitigation is about reducing or avoiding risk, not merely identifying landslide movement as it occurs. Measures A, B, and C will do nothing to reduce the magnitude or frequency of possible landslides. Though these efforts are worthwhile, they are not mitigation².

Given the obvious potentially large landslide hazard, I'm surprised the applicant hasn't performed slope stability analysis (item A) before investing in this proposal.

Periodic lidar flights (item B), unless carefully designed, are not guaranteed to detect distributed deformation in advance of impacts to infrastructure. Vertical accuracy of a few cm or better is likely required. Relative vertical errors within a single swath of airborne lidar can be as low as 1-2 cm, but swath-to-swath errors can be an order of magnitude larger. I suspect that surveys should include nearby (same swath), stable (over the years) reference surfaces to reduce inter-survey errors to useful levels.

Repeat surveys of monuments (item C) may not have the density of measurements needed to identify partial mobilization of a landslide.

² In the case of a very slowly accelerating landslide, measures B and C might identify the need to abandon structures and thereby minimize potential damage to portable property, injury, and(or) loss of life. Perhaps this is called mitigation?

(6) SIGNIFICANCE OF BLOCK FIELDS

Section 4.1 and reports in Appendix B note the occurrence of fields of angular basaltic blocks and call these “talus”. Many of these fields are shown as “Basalt Cobble / Boulder Rubble (Talus)” on map “Site Features and Geologic Constraints (A-3)” attached to the December 19, 2019 GNN memo *Review of Revised Expansion Plans*.

Talus is defined as (Neuendorf and others, 2005):

Rock fragments of any size or shape (usually coarse and angular) derived from and lying at the base of a cliff or very steep, rocky slope. Also the outward sloping and accumulated heap or mass of such loose broken rock, considered as a unit, and formed chiefly by gravitational falling, rolling, or sliding.

Gilluly and others (1968, p. 193) note that:

A talus pile maintains a nearly uniform slope as it grows. The slope angle, commonly about 30°, though varying with the mean size and shape of the rock fragments, is called the angle of repose because it is the steepest slope on which the talus material will rest without rolling farther.

Insofar as these block fields are talus, they would be indicative of rockfall hazard that receives only the most cursory attention in the DEIS. However, most of these block fields are not talus: they are not beneath cliffs or very steep, rocky slopes and they are not steep enough.

Such block fields are common above tree line, where shattering and heaving of the underlying bedrock by frost out-compete soil forming processes such as rock weathering, accumulation of lichen and plant debris, and deposition of wind-borne dust. Block fields below timberline beg for another explanation. I suspect they reflect on-going disturbance of bouldery debris by landsliding.

The origin of the low-angle, undulating block fields that are abundant on L1 and cover much of L2 should be investigated before any development is permitted.

(7) HOW THE MAGNITUDE AND FREQUENCY OF LANDSLIDE HAZARD MIGHT BE EVALUATED

Several investigations might be undertaken to better understand the magnitude and frequency of landslide hazard in the proposed development. Each would be difficult, none is guaranteed to provide actionable information, and for many the likely outcome is confirmation that development of these slopes would be extremely challenging. Here’s a brief list:

- Map geomorphology of the area using existing lidar or new, more detailed lidar collected prior to development. Develop a relative chronology of landslide movement and incision of Squilchuck Creek.

- Use surface morphology to estimate depths to base of landslide masses. Confirm these estimates by drilling.
- Map forest stand history, large trees, and tilted trees. Core selected trees for ages and to build a reference tree-ring chronology.
- Trench sag ponds in landslides in search of Holocene volcanic ash stratigraphy that could, if undisrupted, demonstrate local stability since ash deposition.
- Examine road, stream, and landslide-scarp cuts for buried logs that could be dated (^{14}C , dendrochronology) to obtain limiting ages of landslides.
- Use lichenometry to assess the recency of movement of block fields.
- Map surface roughness of landslides and develop calibration points to enable roughness dating of slides (e.g., LaHusen and others, 2016).
- Estimate the effect of plausible near-future climate change on hillslope water content.
- Calculate the effects of development (local impermeable surfaces, landscaping, landscape maintenance, and wastewater disposal by OSS/LOSS) on hillslope water content. Calculate current margins of safety across L1 and L2, and how margins of safety are decreased by increases in hillslope water content.

(8) GEOLOGY BENEATH THE PROPOSED PUBLIC ACCESS ROAD

Previous mapping (Tabor and others, 1982) and my field observations (Fig. 2) suggest much of the proposed public access road route (Fig. 1) is underlain by Eocene fanglomerate and sandstone. Lidar topography shows ribs on the slope above that I interpret as outcrops of resistant beds of sedimentary rock. Orientations of the ribs are consistent with the NNW strike and steep NE dip of bedding I measured in outcrop along the pioneer road. Seismic surveys and exploratory borings by GNN confirm that these are reasonably competent rocks. However, unlike granitic intrusive rocks (which is what GNN identified them as), fanglomerate and sandstone are likely to be interbedded with layers of less competent mudstone and siltstone.

From the DEIS I cannot determine the length of proposed public access road that is to be built on L1, but it appears to be about a quarter mile. GNN reports no results from test pits, seismic refraction surveys, or exploratory borings in this stretch. This lack of information, observed recent deformation within L1, the circa 250 ft long crossing of L2 near the SW end of the proposed public access road, and the likelihood of less competent interbeds in the intervening half mile of steep hillside together indicate that construction and maintenance of the proposed public access road may be considerably more expensive than one might surmise from the DEIS, particularly from the 5 reports by GNN included in Appendix B. Below I step through some relevant details from these reports.

Expanding on GNN's memo of September 2017, GNN's memo of November 2017 reports (p. 11-12):

Although not shown on published geologic maps of the area, several notable outcrops of granitic intrusive dikes were observed in the project vicinity (see Figure 2). Two separate outcrops of this granitic rock were observed on the northwest facing slope near the proposed access roadway alignment. The noted outcrops of this resistant rock are generally present as pinnacles and cliff faces. A correlating outcrop of this intrusive rock was also observed on the southeast facing slope above Mission Ridge Road, less than ¼ mile from the base area of Mission Ridge Ski Resort.

The lower photo in Plate 2 and both photos in Plate 3 of the November 2017 memo, all captioned "Intrusive igneous (granitic) dike noted at the site", show lumpy surfaces typical of what Tabor and others (1982) mapped as unit Tcf, "monolithologic fanglomerate" of "quartz diorite to granodiorite material" in this locale. The outcrop above the Mission Ridge Road (see top photo, Plate 6, captioned "Correlating intrusive igneous dikes along Mission Ridge Road") is readily identifiable as a coarse sedimentary breccia interbedded in the surrounding sandstone, not an intrusive dike. Tabor and others (1982, their Table 1, no. 9) sampled a "granodiorite boulder in fanglomerate in Leavenworth fault" at or near this outcrop. See <https://www.youtube.com/watch?v=xgQwRk6WiVQ> for video of an August 2020 visit to these outcrops by Mike Eddy, Erin Donaghy, and Nick Zentner.

GNN's memo of November 2018 reports results of 8 exploratory test pits in the vicinity of the proposed public access road. On page 2 it is stated:

However, site-specific field observations reveal that the primary underlying geologic unit along the majority of proposed access roadway alignment consist primarily of granitic plutonic bedrock. The noted granitic rock exhibited varying degrees of weathering, ranging from completely weathered/residual soil to fresh hard rock including very competent exposed outcrops that present as steep cliffs and pinnacles. Site observations provide no apparent indications of recent slope instability along the alignment of the access roadway.

I note that none of the test pits were in L2 at the SW end of the proposed public access road, or in L1 at its NE end. Material descriptions in the test pit logs and photographs of the test pits are consistent with weathered sandstone and fanglomerate.

GNN's memo of September 2019 reports on 7 short seismic refraction lines along the pioneer trail for the proposed public access roadway. The memo makes no interpretation of subsurface rock type. Reported seismic velocities are 3,000–7,000 ft/s, corresponding to the spectrum of highly weathered rock to competent rock. A quick Google search (e.g., https://pburnley.faculty.unlv.edu/GEOL452_652/seismology/notes/SeismicNotes10RVel.html) suggests that P-wave velocities of sandstone are commonly in the range 4,600–14,100 ft/s. Granite velocities are higher, 18,000–19,400 ft/s. Near-vertical velocity contours in many of the

seismic profiles suggest steeply dipping bedding consistent with sedimentary, not intrusive, rock.

GNN's memo of February 2020 states (p. 6):

An existing approximately 8 to 10 foot wide trail ... has been pioneered across the general vicinity of the proposed roadway alignment.

...

Observations of the exposed backcut along the existing trail revealed a variety of soil/rock conditions ranging from relatively soft/wet clayey soils in the vicinity of the creek crossing, to cobbly/bouldery mass-wasting debris, to granitic bedrock that varied from completely weathered to fresh/competent pinnacles across a majority of the alignment.

Several boreholes were drilled to 50 ft, or in one case to refusal at 35 ft. No boreholes were in L1. Boreholes B-1 through B-7 (Appendix II of the 2020 report) in the vicinity of the proposed access road are reported to bottom in "weathered granitic bedrock". Images of core from these boreholes are consistent with my observation that this is granitic-clast fanglomerate.

Boreholes B-9 and B-10 are in the toe of L2 and encountered sandy lean clay and clayey sand. On page 8 it is stated that:

Furthermore, based on the subsurface soil conditions and the geomorphology of this area, we suspect that Zone A [the toe of L2] likely represents an earthflow (slope creep) that may potentially be active.

On page 15 it states:

Based on the subsurface soil conditions encountered and the noted surficial expression (geomorphology) of the area, we believe this portion of the project alignment [the toe of L2] may be characterized as a potentially active earthflow (slope creep).

... The borings completed at this location (B-9 & B-10) did not reveal a competent bearing stratum within a depth of 50 feet BGS.

In summary, at least part of L1 is recently active and conditions within and beneath it are unexplored. L2 is "potentially active" and competent material is at least 50 ft below ground surface. I have examined outcrops along the pioneer road and the "granitic rock" noted by GNN along the NW-facing slope between L1 and L2 is fanglomerate (Fig. 2) that is likely to contain weaker interbeds of siltstone and mudstone.

REFERENCES CITED

Gilluly, J., Waters, A.C., and Woodford, A.O., 1968, Principles of Geology, 3rd edition. W.H. Freeman and Co., San Francisco, 687 p.

Haugerud, R.A., 2014, Preliminary interpretation of pre-2014 landslide deposits in the vicinity of Oso, Washington: U.S. Geological Survey Open-File Report 2014-1065, 4 p., <http://pubs.usgs.gov/of/2014/1065/>.

Haugerud, R.A., and Harding, D.J., 2001, Some algorithms for virtual deforestation of lidar topographic survey data: International Society for Photogrammetry and Remote Sensing, Commission 3, Working Group 3, Annapolis, MD, 7 p., <https://www.isprs.org/proceedings/xxxiv/3-w4/pdf/haugerud.pdf>.

Haugerud, R.A., Harding, D.J., Johnson, S.Y., Harless, J.L., Weaver, C.S., and Sherrod, B.L., 2003, High-resolution lidar topography of the Puget Lowland, Washington—A bonanza for Earth science: GSA Today, v. 13, n. 6, p. 4-10, [https://doi.org/10.1130/1052-5173\(2003\)13%3C0004:HLTOTP%3E2.0.CO;2](https://doi.org/10.1130/1052-5173(2003)13%3C0004:HLTOTP%3E2.0.CO;2)

KOMO NEWS, 2016, Officials: Chelan County neighborhood at risk of ‘massive landslide’: <https://komonews.com/news/local/officials-chelan-county-neighborhood-at-risk-of-massive-landslide>, accessed 13 October 2025.

LaHusen, S.R., Duvall, A.R., Booth, A.M., and Montgomery, D.R., 2016, Surface roughness dating of long-runout landslides near Oso, Washington (USA), reveals persistent postglacial hillslope instability: Geology, g. 44, p. 111-114, <https://doi.org/10.1130/G37267.1>.

NCWLIFE News, 2017, Potential landslide causes concern for Whispering Ridge residents: https://www.ncwlife.com/news/potential-landslide-causes-concern-for-whispering-ridge-residents/article_eac30772-c6d7-5df0-94d0-b209214ff219.html, accessed 13 October 2025.

Neuendorf, K.K.E., Mehl, J.P., Jr., and Jackson, J.A., editors, 2005, Glossary of Geology, 5th edition. American Geological Institute, Alexandria, Virginia, 779 p.

O’Connor, J.E., Baker, V.R., Waitt, R.B., Smith, L.N., Cannon, C.M., George, D.L., and Denlinger, R.P., 2020, The Missoula and Bonneville floods—A review of ice-age megafloods in the Columbia River basin: Earth Science Reviews 208, 103181, <https://doi.org/10.1016/j.earscirev.2020.103181>.

Tabor, R.W., Waitt, R.B., Jr., Frizzell, V.A., Jr., Swanson, D.A., Byerly, G.R., and Bentley, R.D., 1982, Geologic map of the Wenatchee 1:100,000 quadrangle, central Washington: U.S. Geological Survey Miscellaneous Investigations Series Map I-1311, scale 1:100,000, <https://pubs.usgs.gov/imap/i1311/>.

Tabor, R.W., Waitt, R.B., Frizzell, V.A., Jr., Swanson, D.A., Byerly, G.R., and Bentley, R.D., 2005, Geologic map of the Wenatchee 1:100,000 quadrangle, central Washington: a digital database: U.S. Geological Survey Data Series DS-137, scale 1:100,000, <https://pubs.usgs.gov/ds/137/>.

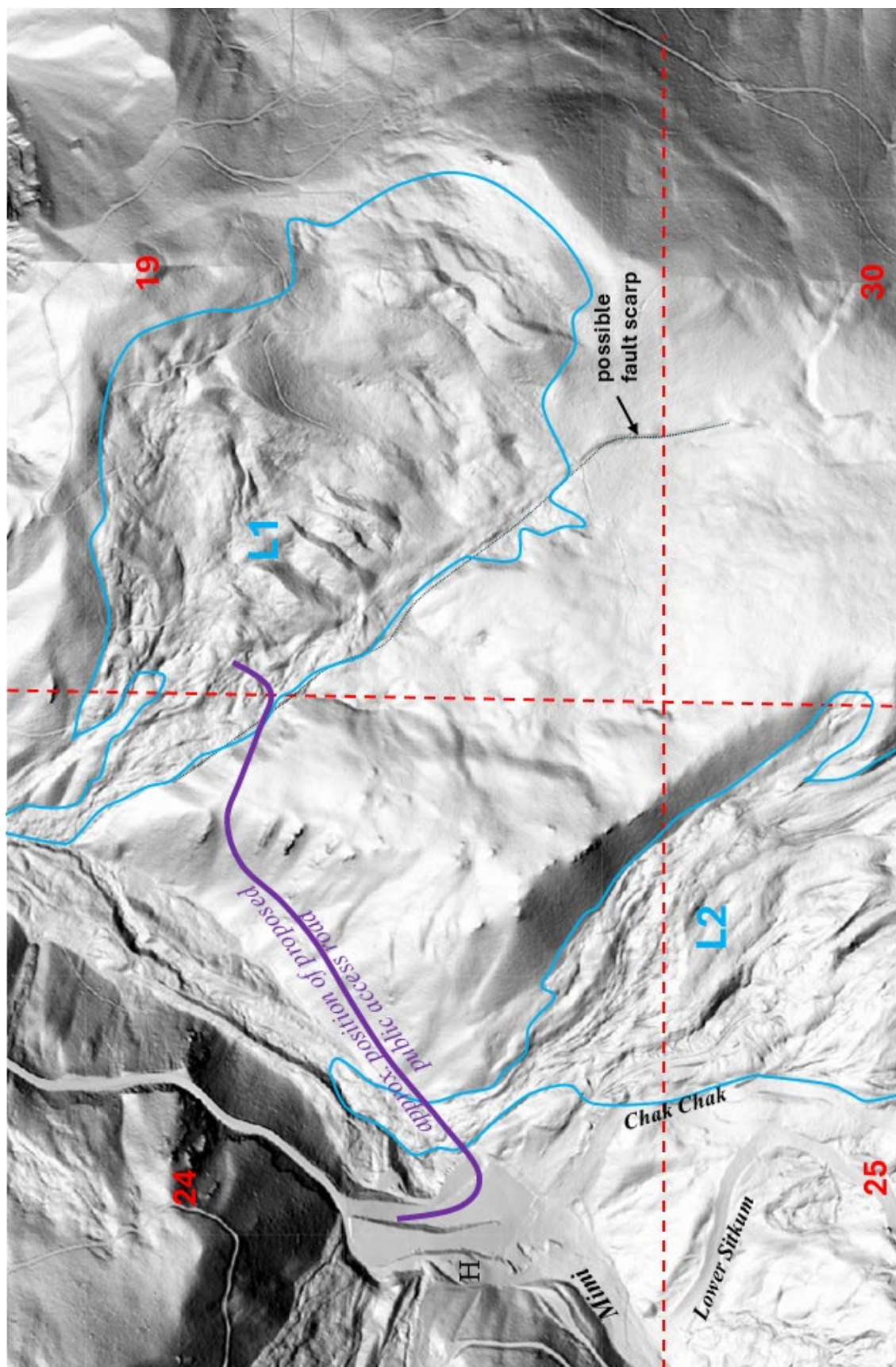


Figure 1. Image-map of Mission Ridge Resort base area and area of proposed expansion. Shows locations of landslides L1 and L2 and approximate location of proposed public access road. H is location of Hampton Lodge. Section lines are approximately located. Width of view is about 1.4 miles. Base image from Washington Lidar Portal, <https://lidarportal.dnr.wa.gov/>.

Figure 2. Outcrop of boulder fanglomerate along pioneer road in vicinity of proposed public access road. Two granitic boulders are separated by matrix of sand- to pebble-sized grüßy debris. View to SE.



Close-up views of left and right boulders. Note differences in texture that demonstrate these are not a single intrusive mass.

Selected publications by Haugerud on geology of the Pacific Northwest, interpretation of lidar topography, and landslide mapping

Haugerud, R.A., 2009, Preliminary geomorphic map of Kitsap County, Washington: U.S. Geological Survey, Open-file Report 2009-1033, scale 1:36,000, 2 sheets, <http://pubs.usgs.gov/of/2009/1033>.

Haugerud, R.A., 2014, Preliminary interpretation of pre-2014 landslide deposits in the vicinity of Oso, Washington: U.S. Geological Survey Open-File Report 2014-1065, 4 p., <http://pubs.usgs.gov/of/2014/1065/>.

Haugerud, R.A., and Harding, D.J., 2001, Some algorithms for virtual deforestation of lidar topographic survey data: International Society for Photogrammetry and Remote Sensing, Commission 3, Working Group 3, Annapolis, MD, 7 p., <https://www.isprs.org/proceedings/xxxiv/3-w4/pdf/haugerud.pdf>.

Haugerud, R.A., Harding, D.J., Johnson, S.Y., Harless, J.L., Weaver, C.S., and Sherrod, B.L., 2003, High-resolution lidar topography of the Puget Lowland, Washington—A bonanza for Earth science: GSA Today, v. 13, n. 6, p. 4-10, [https://doi.org/10.1130/1052-5173\(2003\)13%3C0004:HLTOTP%3E2.0.CO;2](https://doi.org/10.1130/1052-5173(2003)13%3C0004:HLTOTP%3E2.0.CO;2).

Haugerud, R.A., and Kelsey, H.M., editors, 2017, From the Puget Lowland to East of the Cascade Range: Geologic Excursions in the Pacific Northwest: Geological Society of America Field Guide 49, 254 p., <https://doi.org/10.1130/fld049>.

Haugerud, R.A., and Stanton, K.M., 2022, Geologic history, rocks, and deposits of the Wenatchee area, Washington, in Stanton, K., and McDonald, K., 2022, Geology of Wenatchee, Washington: Tobacco Root Geological Society Northwest Geology 51, 156 p., https://mbmg.mtech.edu/mbmgcat/public/ListCitation.asp?pub_id=32486&#gsc.tab=0.

Haugerud, R.A., and Tabor, R.W., 2009, Geologic map of the North Cascade Range, Washington: U.S. Geological Survey Scientific Investigations Map 2940, scale 1:200,000, 2 sheets, 24 p. non-technical pamphlet, 31 p. technical pamphlet, CD of additional photos, <http://pubs.usgs.gov/sim/2940>.

Haugerud, R.A., and Troost, K.G., 2011, Geologic map of the Suquamish 7.5' quadrangle and part of the Seattle North 7.5' x 15' quadrangle, Kitsap County, Washington: U.S. Geological Survey Scientific Investigations Map 3181, scale 1:24,000, 1 sheet, 9 p., <http://pubs.usgs.gov/sim/3181/>.

Kovanen, D.J., Haugerud, R.A., and Easterbrook, D.J., 2020, Geomorphic map of western Whatcom County, Washington: U.S. Geological Survey Scientific Investigations Map 3406, pamphlet 42 p., scale 1:50,000, <https://doi.org/10.3133/sim3406>.

Tabor, R.W., and Haugerud, R.A., 1999, Geology of the North Cascades: A Mountain Mosaic. The Mountaineers, Seattle, 143 p.

Wells, R.E., Haugerud, R.A., Niem, A.R., Niem, W.A., Ma, L., Evarts, R.C., O'Connor, J.E., Madin, I.P., Sherrod, D.R., Beeson, M.H., Tolan, T.L., Wheeler, K.L., Hanson, W.B., and Sawlan, M.G., 2020, Geologic map of the greater Portland metropolitan area and surrounding region, Oregon and Washington: U.S. Geological Survey Scientific Investigations Map 3443, pamphlet 55 p., 2 sheets, scale 1:63,360, <https://doi.org/10.3133/sim3443>.

Yuh, I.P., Haugerud, R.A., O'Connor, J.E., and O'Daniel, S.J., 2024, Geomorphic map of the Umatilla River corridor, Oregon: U.S. Geological Survey Scientific Investigation Map 3527, scale 1:12,000, 6 sheets, <https://doi.org/10.3133/sim3527>.