PanGEO INCORPORATED
Geotechnical & Earthquake Engineering Consultants

December 9, 2020
File No. 20-122

Ms. Carol L. Creasey, County Hydrogeologist
Reservoir Project Manager, Clallam County
Department of Public Works
223 East 4th Street, Suite 6
Port Angeles, Washington 98362-3000

Re: **Geotechnical Engineering Feasibility Report Review**
Dungeness Off-Line Storage Facility
River Road, Clallam County, Washington

Dear Carol,

As requested, PanGEO, Inc. (PanGEO) prepared this revised report for your use, regarding our review of the siting report by Anchor QEA for the proposed Dungeness Off-Stream Reservoir for potential geologic hazards related to earthquake faulting.

The proposed reservoir will be constructed near Sequim, Washington, west of the intersection of River Road with Happy Valley Road. Recent studies by the United States Geological Survey (USGS) have used Lidar images to infer the potential presence of earthquake faults just east of and possibly into the proposed reservoir. This revision of the report includes an on-site review of field conditions by Mr. Brian Sherrod and Mr. Steve Angster of the USGS for potential evidence of faulting in the vicinity of the reservoir site. This review was conducted on October 15, 2020.

SCOPE AND AUTHORIZATION

The project was authorized in a Personnel Services contract dated April 5, 2020, where our scope of work included reviewing the Executive Summary and Project Proposal from Anchor QEA, dated January 2016, to identify potential hazards mainly related to the seismic stability of the site and the risk of failure from earthquake faulting. We were also tasked with reviewing available geological and geotechnical material as related to potential landslide hazards that may affect the site. We also conducted a site reconnaissance on May 13, 2020, to confirm existing conditions and the potential presence of features that might

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suggest ground instability or past movement from faulting. The scope also includes on-going consultation as needed, and the preparation of this technical report detailing our observations and outlining additional studies that may be needed during the design phase of the project.

PROJECT DESCRIPTION

The project site is located along the Dungeness River, southwest of Sequim, Washington. The Dungeness River is a major water source for agriculture irrigation in Clallam County, and is also a major fish bearing stream.

The County has identified water storage as a critical issue for the Dungeness River, and we understand that this concept has been under consideration for as much as 30 years. The current project was conceived in 2014 as a 1,500 acre-foot water storage facility that could be filled during winter and released in the summer to maintain river flows for fish habitat and crop irrigation. Other potential benefits include flood control, groundwater recharge, and potential recreational use.

The planned project includes the development of a 319-acre proposed reservoir site and a second 77-acre parcel locate east of River Road (see Figure 1). Both parcels are currently owned by the Washington State Department of Natural Resources. The main parcel is currently called the Dungeness Trails, and is used for trail walking and mountain biking. The project includes the excavation of upslope material for subsequent use in the downslope dikes of the reservoir.

DOCUMENTS REVIEWED

The following documents were reviewed as the basis of our evaluation:

The Dungeness Off-Stream Reservoir Project – Executive Summary and Project Proposal, by Anchor QEA, January 2016.

Dungeness River Flow Enhancement Project, Designs and Supporting Analyses, Technical Memorandum Attachment D-2, River Road Storage Project, Preliminary Geotechnical Memorandum, by Anchor QEA, May 23, 2014.

Dungeness River Flow Enhancement Project, Designs and Supporting Analyses, Technical Memorandum Attachment D-3, River Road Storage Project, Preliminary Drawings, by Anchor QEA, May 22, 2013.

Proposed "River Road Transfer" property transaction – geologic review summary, DNR Olympic Region, Clallam County, Washington, by Ana Shafer, Geologist, Washington State Department of Natural Resources Forest Resources and Product Sales & Leasing Divisions, June 29, 2019.

In addition to the materials provided by Clallum County, we also reviewed the following publications:

Nelson, A.R.; Personius, S.F.; Buck, J.; Bradley, L.; Wells, R.E.; and Schermer, E.R., 2007, Field and Laboratory Data from an Earthquake History Study of Scarps of the Lake Creek–Boundary Creek Fault between the Elwha River and Siebert Creek, Clallam County, Washington, U.S.G.S. Scientific Investigations Map 2961.

Schasse, Henry W.; Logan, Robert L., 1998, Geologic map of the Sequim 7.5-minute quadrangle, Clallam County, Washington: Washington Division of Geology and Earth Resources Open File Report 98-7, scale 1:24,000.

Schasse, H.W.; Wegmann, K.W., 2000, Geologic map of the Carlsborg 7.5-minute quadrangle, Clallam County, Washington: Washington Division of Geology and Earth Resources Open File Report 2000-7, scale 1:24,000.

Other materials were also used in this review.

SITE RECONNAISSANCE

On May 13, 2020, we conducted a site reconnaissance visit to the property to observe current site conditions. Observations from our reconnaissance are discussed below.

SITE LOCATION AND DESCRIPTION

The site is located west of the intersection of River Road and Happy Valley Road (see Figure 1). The site slopes generally to the north at roughly a 2 percent grade. The site is currently vegetated with young trees and other brushy growth. As shown by the topographic map, the site is constrained on the west by a 25 to 30-foot, 40 percent bluff

that descends to the present flood plain of the Dungeness River. Our site reconnaissance shows that many areas of the top of the bluff are near vertical. East of River Road and south of Happy Valley Road another bluff rises roughly 50 feet at a maximum gradient of about 45 percent, then continues to rise at a lesser slope into the ridges of the Olympic Mountains.

Anchor's preliminary geotechnical memorandum (Anchor, 2014) describes the main

Plate 1. View of the main property, 2015

Plate 2. View of the main property, 2019.

property as vegetated with grasses, shrubs and evergreen trees ranging from saplings to mature trees, which is consistent with the aerial image in Plate 1. Since then, the previously unlogged portion of the site, mainly in the north, northern portion of the site was logged (see Plate 2) and saplings have grown to heights of 10 to 20 feet in the southern portion of the site.

The 77-acre parcel is heavily timbered and consists of moderately rising ground.

SUBSURFACE CONDITIONS

REGIONAL GEOLOGY

The site is located within the Carlsborg Quadrangle which was mapped by Schasse and Wegmann in 2000. According to the mapping, the site is located on an older floodplain

terrace of the Dungeness River. They describe the deposits underlying the older terrace as consisting of "crudely stratified, cobbly, pebbly and bouldery gravel in a matrix of sand, silt and clay". The bluff to the east of River Road and south of Happy Valley Road, the location of the 77-acre parcel, is mapped as bedrock with a mantle of glacial till.

Water well logs in the area describe soils consisting of gravel and boulders, which is consistent with course grained alluvium.

SITE SUBSURFACE CONDITIONS

Anchor QEA, performed a preliminary site geotechnical investigation consisting of seven test pits, mainly in the southern portion of the site that was then open (see Technical Memorandum Attachment D-2, referenced above, for pit locations). The preliminary investigation outlined four soil units; a topsoil unit from 0.5 to 1.0 feet, a silty sand unit ranging from 1.0 to 2.0 feet thick, and dense coarse alluvium at depth, except in TP-7, which encountered a silty sand bed below the coarse alluvium. The alluvium is described as consisting mainly of cobbles and boulders, with a matrix consisting of silt, sand and gravel. Finer grained sand and gravel "pockets" or lenses were described in four of the test pits. This is consistent with a bedded alluvial deposit, which can be expected to demonstrate variable gradations across the site (see Plate 3).

No groundwater was encountered in the test pits and is not anticipated for this site. No seeps were observed along the bluff above the current floodplain of the Dungeness River during our site reconnaissance. However, a small borrow pit along the powerline road in the south portion of the property did have a small pool of standing water. This is most likely due to silting in of the pool bottom over time.

Outcrop or excavations were lacking on the 77-area parcel. We anticipate that most of the parcel will be underlain by till, as mapped.

Plate 3. Outcrop of older alluvium, on the bluff above the present river level, May 13, 2020.

LANDSLIDE HAZARD ASSESSMENT

Schasse and Wegmann (2000) mapped one small landslide in the area of the proposed project. This landslide was located above Happy Valley Road as it ascended the bluff to the east of the River Road (see Figure 2). To assess the potential for landslide hazard on this site, we reviewed the Lidar imagery for the area (see Figure 3). The area was most recently flown in 2019 (Olympics South Opsw). In the DNR geological review (Shafer. 2019), the Lidar data from 2002, 2008 and 2016 was also reviewed.

Shafer (2019) concluded that there was no evidence for the landslide as mapped by Schasse and Wegmann (2000) and shown on Figures 2 and 3. However, she suggests a deep-seated landslide in the south portion of the property and postulated that the slide was in the area of the fault mapped by Schasse and Wegmann (2000). The feature we believe she identified is marked on Figure 3.

Our site reconnaissance observed one area of sliding, opposite the entry to the main entry to the parking area for the Dungeness Trails, as marked by a warning road sign on River Road. The site has recently experienced a shallow slide (see Plate 4). This small slide consisted of the slumping of surficial colluvium. A smaller slide, that did not extend to the road level, is present off the frame to the left. The entire active zone is roughly 300 feet

Plate 4. Shallow landslide above River Road, opposite the parking area for the Dungeness Trails park.

wide, prompting the irrigation district's use of approximately 300 feet of corrugated plastic pipe to cross areas of prior ground movement.

While we observed this small, shallow slide south of the proposed reservoir, we believe that the slide zone will not pose a hazard to the facility. Essentially, active slides in the area are shallow and we did not observe any clear evidence of deep-seated slides. Furthermore, there are no features visible on the Lidar DEM suggestive of any significant instability in the reservoir area.

SEISMIC CONSIDERATIONS – OVERVIEW

GPS monitoring has established that western Washington, including the Olympic Peninsula, is rotating north, colliding with British Columbia, creating a generally compressional tectonic regime. This has resulted in the prominent east-west strike and northward dip of the bedrock strata along the northern Olympic Peninsula, and several mapped thrust faults (Washington State Geologic Portal).

In 2007, Nelson, et al, conducted a trench investigation of the Lake Creek – Boundary Creek Fault system in the valleys of Little River and Indian Creek, starting roughly 7.5 miles west of the current project site and extending past the Elwha River to Lake Crescent.

The report of the conclusions was presented in an article publish in the Bulletin of the Seismological Society of America (2017) where they conclude that the fault has been active in the Holocene, with several ruptures post 13,000 year BCE, and mainly right lateral strike-slip motion with a vertical component. They postulate a return interval of about 3,500 years, and a maximum potential magnitude of M 7.1 to 7.5. Figure 2 of the 2007 study shows an eastward projection of the fault trend into the Sequim area, that they label as the Sequim Fault (see Plate 5, and Figures 2 and 3). However, they make no explanation of the basis of this projection, nor is the Sequim Fault described elsewhere in the 2007 or the 2017 papers. To the best of our knowledge, this is the only source for the existence of the Sequim Fault. From discussions with Brian Sherrod of the U.S.G.S., we understand that if evidence was strong for this lineament, the Nelson team would likely have conducted a trench investigation of it.

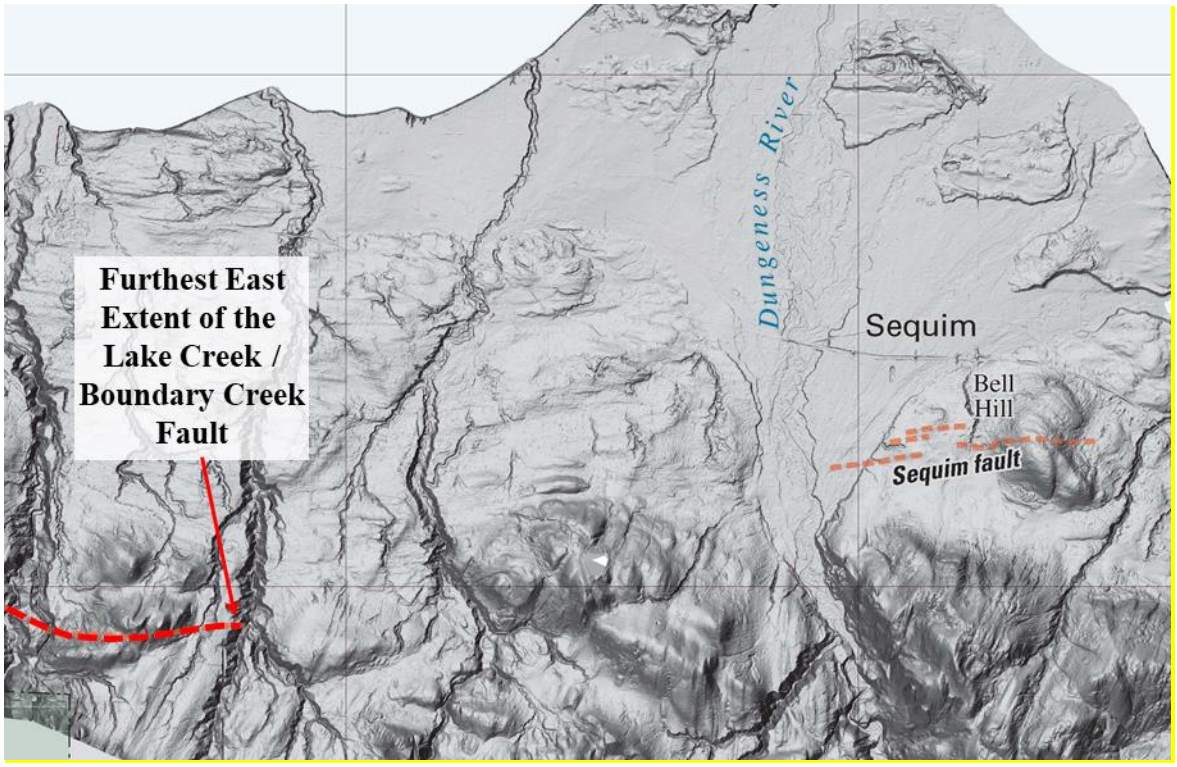


Plate 5. Section of Figure 2, Nelson, et al, 2007, showing the postulated Sequim Fault in the east. The easternmost extension of the known Lake Creek – Boundary Creek Fault is shown as the dashed red line on the left. The inference is that, if extant, the Sequim Fault would be an extension of the other fault.

Schasse and Wegmann (2000) mapped a fault running south of the project area, which they infer as a high angle normal fault, dipping and down to the north. This fault motion would

be unusual under the general compressional tectonic regime, and we question the existence of such a fault.

SEISMIC CONSIDERATIONS – USGS REVIEW

We asked Brian Sherrod to review the Lidar data for the area. In his review, he identified possible, subtle lineaments, but nothing striking. He also commented that the potential lineament was only visible in the older exposed surfaces, and that he could not trace it across younger, post glacial surfaces such as the project site. To determine if there was any evidence of the presence of faulting in the project area, we visited the site again on October 15, 2020, with Brian Sherrod and Steve Angster, also of the U.S.G.S., who are both experienced in identifying seismic features in the field. Joe Donisi of the County also attended. We traversed surface trails and a trail that runs just beneath the rim of the bluff in the west side of the project area. This enabled us to look for surface expressions and visible evidence in profile. None was observed in the project area.

Following the traverse of the project area, Brian, Steve and Joe walked the alignment of the irrigation ditch above the project area. Brian and Steve then scouted the Bell Hill area where Nelson et al. (2017), had identified possible traces of the Sequim Fault. They found no certain evidence of past faulting, and no suggestion of Holocene movements.

CONCLUSIONS AND RECOMMENDATIONS

Generally, we find no fatal flaws in the proposed location of the facility. We concur that, with the apparent permeability of the alluvial soils, the reservoir will need to be fully lined to control water loss. The recommended slope angles for the berm are reasonable, as are the other design recommendations.

Also, from our office and field reviews, there is no identifiable evidence of faulting in the project area. Nonetheless, as the project excavation proceeds, attention should be paid to any soil anomalies that might have origins in a seismic feature. We recommend that PanGEO and/or the U.S.G.S. review the excavation periodically as excavation progresses to look for any such indications.

As we have described, there is a landslide at the southeastern corner of the planned reservoir area. The current activity consists of a shallow colluvial slide and is not a hazard to the project. However, a slide that closed River Road could pose an inconvenience to the

operation of the facility. In our opinion only an Oso-like, long runout landslide would pose a significant risk to the facility, and such a slide is very unlikely in till soils with shallow bedrock. Even a deep-seated, rotational landslide would not greatly affect the site. If this remains a concern, a slope inclinometer could be installed to confirm the stability of the slope.

Based on our review of site conditions, we believe that there may be an excess of cobbles and boulders at the site that may not be suitable for use in the embankment fill. Specifically, Attachment D – 2, Preliminary Geotechnical (Anchor, 2014) report indicated that the cobble and boulder content of the alluvium ranged from 40 to 80 percent. The Attachment D – 3, Preliminary Drawings (Anchor, 2013) indicate that on the order of 711,000 cu yards of material will be excavated from the reservoir site. However, the drawing also suggests that nearly 770,000 cu yards will be needed for the berms, suggesting that there may be insufficient material on site for the berms.

The geotechnical report recommends the removal of all material over 4 inches in diameter, to protect the lining. It is unclear if the drawings calculations took this into account in making their volume estimates of available material that could be suitably placed and compacted in the embankment. If they didn't, then there may be a significant deficiency of material for the berms. Removal and disposal of the over-size material, if done, may be an added expense that may also not have been considered in the Anchor QEA proposal. We recommend that further studies be undertaken to verify the availability of material to construct the proposed berms, and to identify remedial actions as necessary. Such remedial measures that may be available to mitigate the issue may include, 1) deepening the excavation and lowering the berms, 2) using all available material and covering the over-size material with a layer of 4-inch minus soil as a filter, and 3) borrowing additional material from outside the reservoir footprint, such as from the secondary parcel or the area of the main parcel south of River Road.

While in our opinion the potential hazard of landslides from above is negligible, we recommend further review of the stability of slope below and to the west of the proposed reservoir. The conceptual design calls for a setback of roughly 200 feet from the top of the slope down to the current floodplain on the Dungeness River. In our opinion, this set back is adequate to provide protection for the facility. Nonetheless, we recommend further review of the dynamics of the river to verify that the potential for undercutting the bank on the west is low.

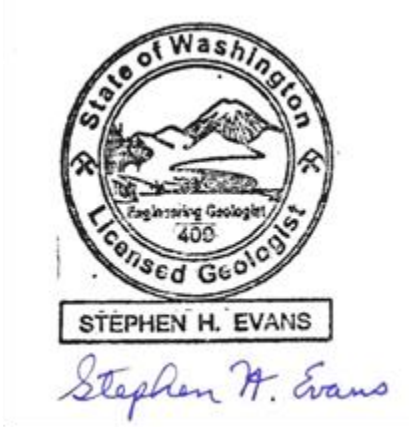
LIMITATIONS AND UNIFORMITY OF CONDITIONS

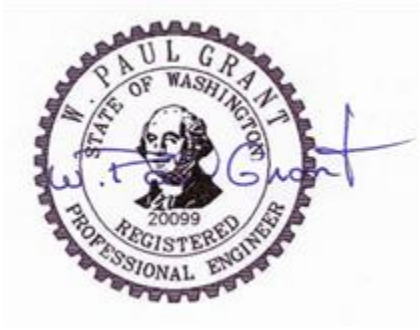
This report was prepared for the use of Clallam County. Recommendations contained in this report are based on a review of the preliminary design documents provided, a review of other pertinent geological and geotechnical information, and our understanding of the proposed project. The study was performed using a mutually agreed-upon scope of work in accordance with the generally accepted standards of local practice at the time this report was written. No warranty, express or implied, is made.

CLOSURE

We appreciate this opportunity to be of service. Contact us if you have any questions.

Regards,





Stephen H. Evans, L.E.
Senior Engineering Geologist

W. Paul Grant, P.E.
Principal Geotechnical Engineer

Encl.

Fig. 1 – Vicinity Map
Fig. 2 – Mapped and Inferred Faults
Fig. 3 – Lidar Map

References:

Anchor QEA, May 22, 2013, Dungeness River Flow Enhancement Project, Designs and Supporting Analyses, Technical Memorandum Attachment D-3, River Road Storage Project, Preliminary Drawings.

Anchor QEA, May 23, 2014, Dungeness River Flow Enhancement Project, Designs and Supporting Analyses, Technical Memorandum Attachment D-2, River Road Storage Project, Preliminary Geotechnical Memorandum.

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Shafer, Ana, Geologist, Forest Resources and Product Sales & Leasing Division, June 29, 2019, Proposed "River Road Transfer" Property Transaction – Geologic Review Summary, DNR Olympic Region, Clallam County, Washington.

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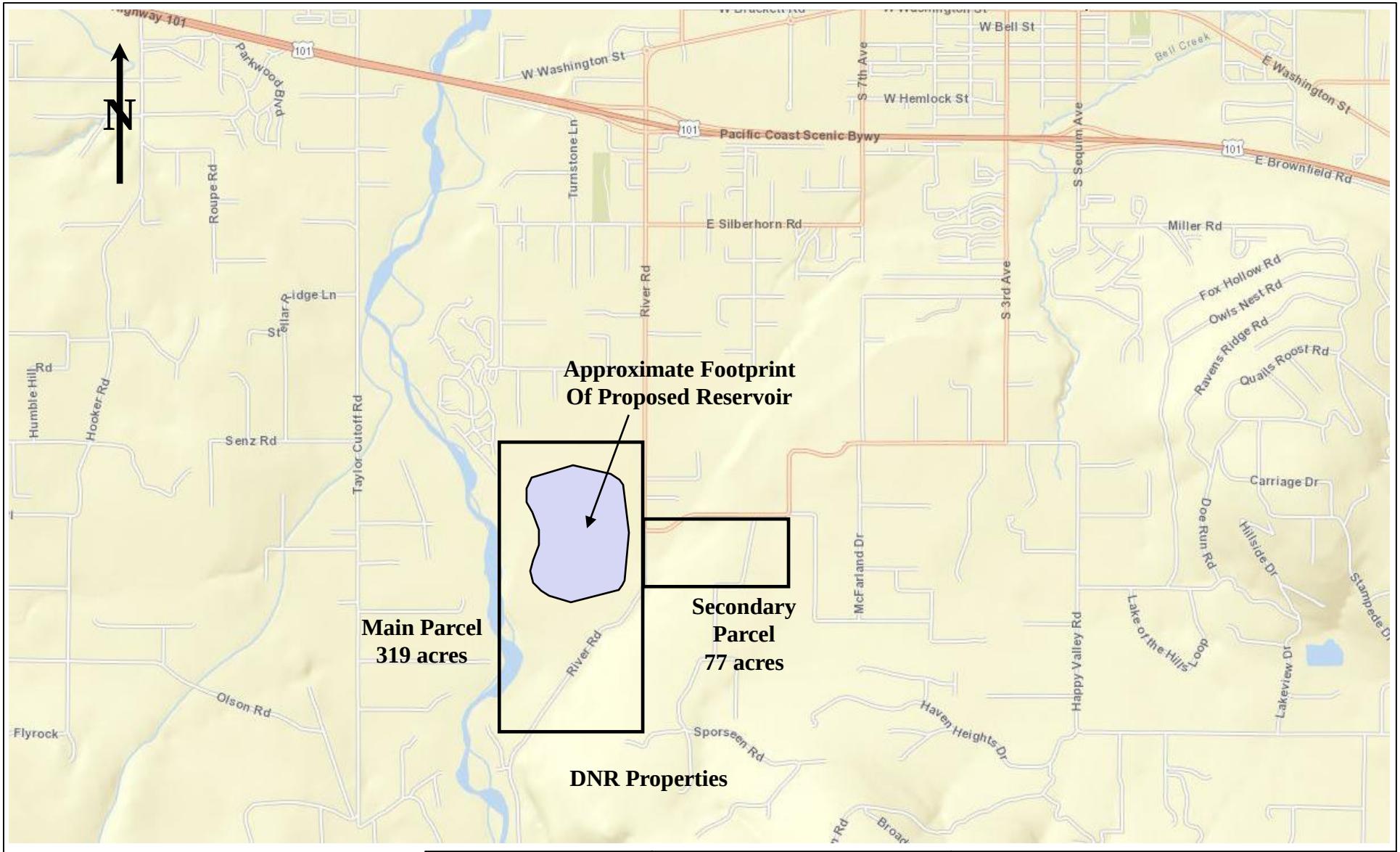
Schasse, H.W., and Logan, R.L., 1998, Geologic Map of the Sequim 7.5-minute Quadrangle, Clallam County, Washington, scale 1:24,000, Washington Division of Geology and Earth Resources Open File Report 98-7.

Schasse, H.W., and Wegmann, K.W., 2000, Geologic Map of the Carlsborg 7.5-minute Quadrangle, Clallam County, Washington, scale 1:24,000, Washington Division of Geology and Earth Resources Open File Report 2000-7.

Washington Geologic Information Portal, subsurface data well log links, https://geologyportal.dnr.wa.gov/.



Not to Scale
Base Map from
WSDNR Geological
Information Portal

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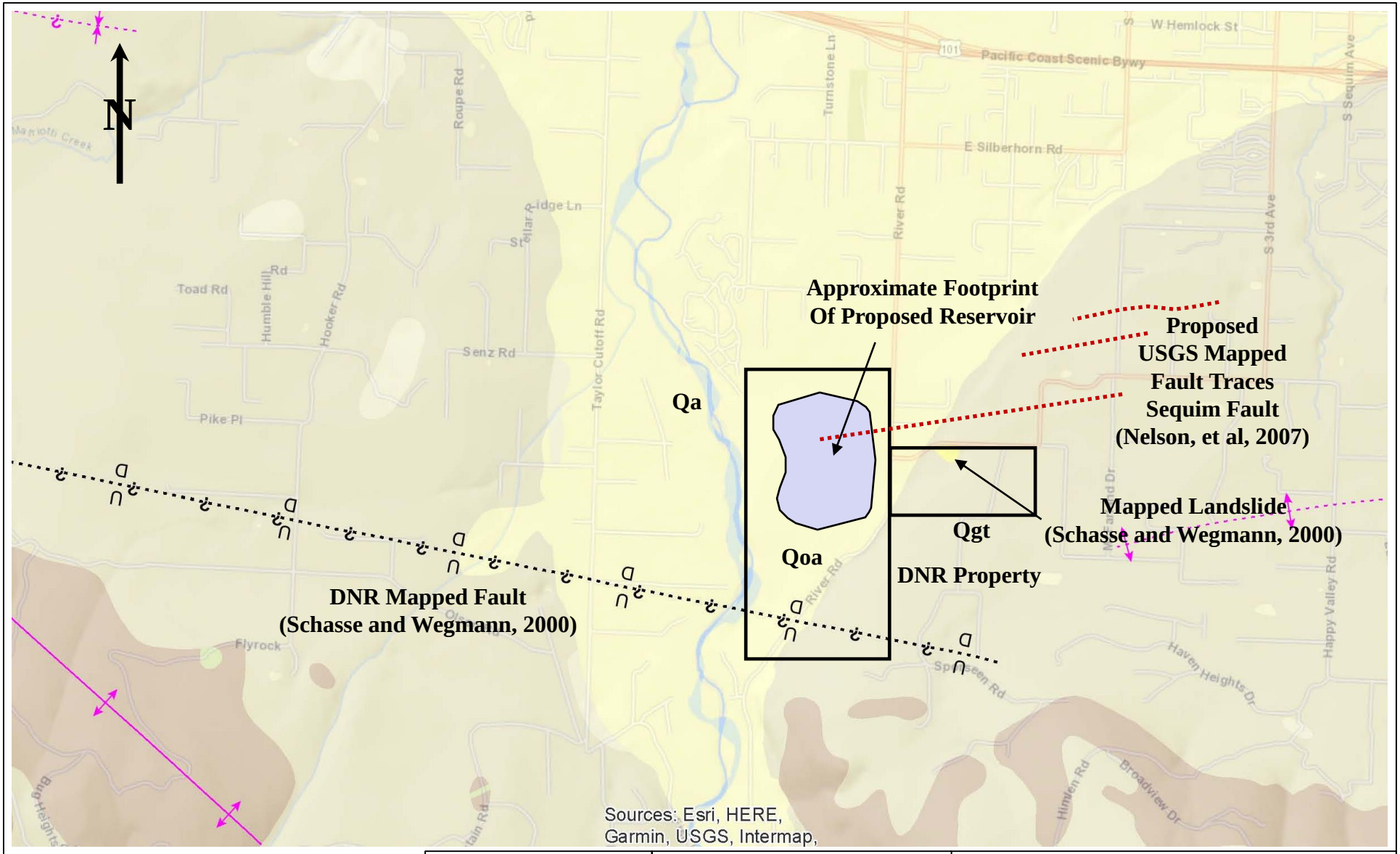
Feasibility Study
Off-Line Reservoir Project
Clallam County, Washington

VICINITY MAP

Project No.	Figure No.
20-122	1



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Geology Map from WSDNR Geological Information Portal

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Feasibility Study
Off-Line Reservoir Project
Clallam County, Washington

VICINITY MAP

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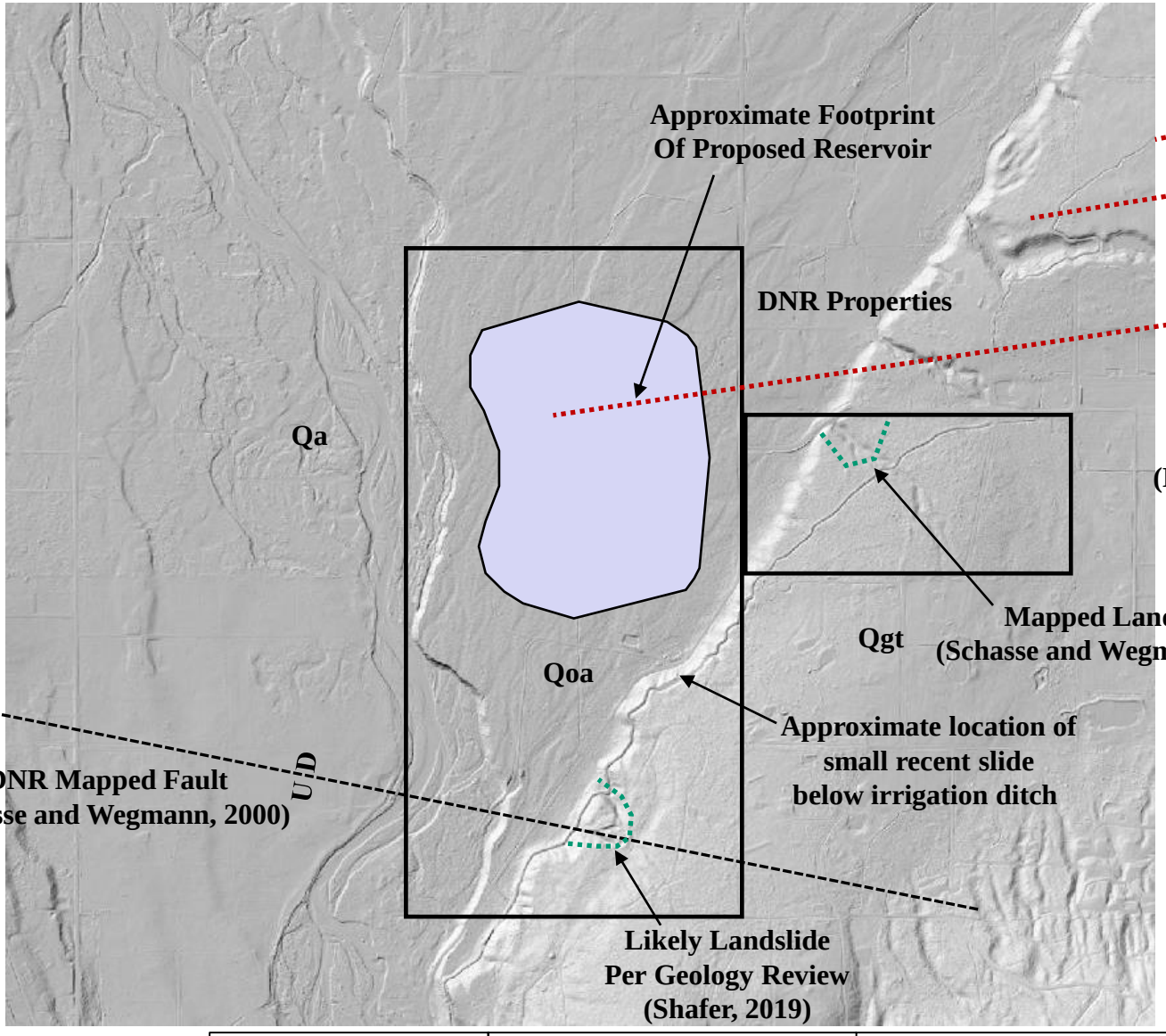

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LIDAR MAP

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