**ASSOCIATION OF ENVIRONMENTAL &
ENGINEERING GEOLOGISTS**

**Field Course #3
September 19 2023
Scoggins Dam**

**Annual Meeting in Portland
September 18 to September 23
2023**

Field Course #3: Scoggins Dam Engineering Geology in the Cascadia Subduction Zone / Networking Opportunity

DATE:
Tuesday, 9/19/23

TIME:
Departs at 8:00am and returns at 3:00pm. Departs from the hotel lobby.

COURSE LEADER: Bryan Simpson and Ray Wells

COST (per person): $125 per person, $175 after 8/1/23

ATTENDEES:
Minimum 24 ; Maximum 46

ACTIVITY LEVEL - Easy, however, the reservoir shoreline can be slippery when wet so we recommend wearing grippy shoes.

Scoggins Dam is a zoned earthen embankment dam located on Scoggins Creek, west of Portland. It is owned and operated by the Bureau of Reclamation. This trip will focus on the site geology with a discussion of the recent geologic/geotechnical field exploration program by Bryan Simpson PG, PE of Reclamation in support of seismic risk-based design modifications. This trip will also feature a presentation by Dr. Ray Wells, USGS Research Geologist, an expert on Cascadia's active tectonics. He will discuss how the Cascadia Subduction Zone and active upper plate faults impact seismic risk assessments for infrastructure in the region. There will be various stops, discussing the Scoggins Dam Facility and a box lunch served onsite. A Networking Event will be held at the McMenamins Cornelius Pass Roadhouse Brewbpub in Hillsboro, on the way back to Portland.

Schedule

Leave Hotel Lobby on Buses (2) at 8:00 am.

Stop 1: Dam Site Overview

Stop 2: Right Abutment Overview

Stop 3. Lunch/Upstream Left Abutment Geology

Stop 4. McMenamins Cornelius Pass Roadhouse Brewpub in Hillsboro, on the way back to Portland. Networking Opportunity.

Stop 5. Return to hotel, approximately 3:00 p.m.

Introduction

Scoggins Dam is a 151-foot-high zoned earthfill structure that is 2,700 feet long at the crest and contains 4 million cubic yards of material. The upstream side of the dam is faced with rock riprap for protection against wave action; the downstream side is faced with topsoil and planted with grass. Total capacity of Henry Hagg Lake is 59,910 acre-feet (active 53,600 acre-feet). The dam was complete in 1975. Scoggins Dam is fed by a drainage basin of 40.6 square miles. Several streams feed Henry Hagg Lake behind Scoggins Dam, including Scoggins Creek, Sain Creek, Turner Creek, and Wall Creek.

Figure 1. Henry Hagg Reservoir, impounded by Scoggins Dam. 2021.

The dam is a zoned earthfill embankment with a maximum structural height of 151 feet at a crest elevation of 313.0 feet, a maximum hydraulic height of 111 feet, a crest length of 2,700 feet, and a crest width of 30 feet. The upstream face of the dam has a 2.5H:1V slope with a 3-foot-thick layer of riprap from the crest.

to elevation 235. Below elevation 235 is an upstream berm sloped at 20H:1V to the upstream toe. The downstream face of the dam has a slope of 2.5H:1V from the dam crest to elevation 250. Below elevation 250 is a slope of 5H:1V to the toe of the dam. The downstream face has grass cover which provides a measure of slope protection. The spillway is located on the left abutment and includes an approach channel protected by riprap, a concrete intake structure with two radial gates, a reinforced concrete chute, a stilling basin, and a riprapped discharge channel. A 33-footwide bridge provides crossing over the crest structure for a county road. At reservoir water surface elevation of 305.8, the maximum release from both spillway radial gates is 14,100 ft3 /s.

The outlet works was largely constructed through rock within the left abutment. It includes a vertical, trash-racked intake structure at elevation 229, a segment of 6-foot-diameter, reinforced concrete pressure pipe, a gate chamber, a bypass pipe, and a segment of 64-inch-diameter steel pipe. The steel pipe bifurcates to provide water to two branches: the Scoggins Creek Branch and the Municipal and Industrial Branch. The Scoggins Creek Branch includes an additional bifurcation to provide water to the fish handling structure, which is no longer operated. At the end of the Scoggins Creek Branch is the control house, which includes highpressure regulating gates, and a 14-inch manually-operated jet flow gate for making releases into Scoggins Creek. At reservoir water surface elevation 305.8, the maximum outlet works releases are 366 ft3 /s from both regulating gates and 34.5 ft3 /s from the 14-inch jet-flow gate.

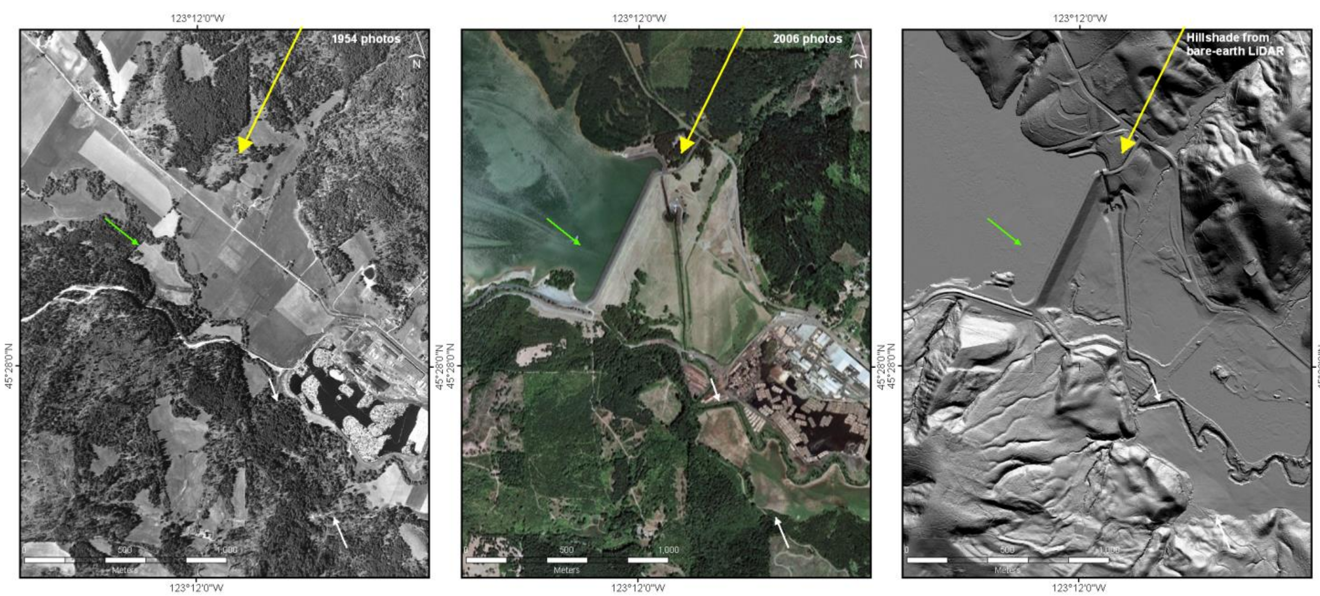


Figure 2. Site Pre-Construction 1954, Historic photo 2006, Lidar 2022.

Regional Geology

Scoggins Dam and Reservoir are situated in the foothill on the eastern slope of the north-trending coast ranges of northwestern Oregon. This portion of the eastern flank of the coast ranges is a northeast-dipping monocline consisting of marine volcanic and sedimentary formations of Tertiary age. Near the eastern limit of the foothills (east of the damsite), these units are unconformably overlain by the Columbia River Basalt of Miocene age. The basalt is in turn unconformably overlain by various nonmarine sedimentary units of Pliocene and Pleistocene age (Schlicker and Deacon, 1967; fig. EG-1). This region is broken by a series of northwest trending faults having displacements of several hundred to more than a thousand feet (Schlicker and Deacon, 1967). All major valleys, including Scoggins Creek on which the dam is situated, are underlain by unconsolidated stream alluvium of recent (Holocene) age.

General:

Scoggins Creek meanders southeasterly through the damsite area in a 1,700-foot-wide, flat-bottomed valley. The creek channel is about 30 to 40 feet wide and has been cut 10 to 15 feet into the valley fill near the right center of the valley floor. The abutments are on topographic spurs on the lower slopes of dissected ridges that parallel both sides of Scoggins Creek Valley. The slope above the left abutment rises on an average grade of about 12 percent, some 780 feet in elevation above the valley floor, to the crest of a ridge. The slope above the right abutment rises on an average grade of about 18 percent, some 540 feet in elevation above the valley floor, to the crest of a ridge.

Site Geology:

There are several large ancient landslides on the right side of the valley both upstream and downstream from the damsite and a few smaller landslides on the left side of the valley upstream from the damsite.

Bedrock units at the damsite and within the reservoir area, in order of decreasing age, are the middle Eocene sedimentary and volcanic undifferentiated unit in the upper reservoir area; siltstone and shale of the upper Eocene Yamhill Formation in the middle and lower reservoir area; and sandstone of the upper Eocene Spencer Formation at the damsite. All of these units are overlain by thin to thick accumulations of residual soil and slope wash, consisting of clayey soil on the valley sides, and alluvium in the valley bottom consisting of predominantly clay deposits with a few silt, sand, and gravel layers.

Bedding planes and contacts in the bedrock units strike north to northwest and dip relatively uniformly to the east and southeast between 10 and 20% Locally, bedding attitudes may vary from the regional trend due to landsliding and surficial creep. (7) Young alluvium - Young alluvium is present in the flood plains, channels of all of the main streams, and most of the smaller tributaries in the region. The composition of the young alluvium is mainly silty clay, clayey silt, and fine sand, with local areas of peat and organic clay. The nature of the deposits is dependent upon the rock types in the drainage source area and upon local groundwater conditions. This unit is recent (Holocene) in age.

Dam Site Stratigraphy

The regional geologic units are described in detail below in order of decreasing age:

(1) Eocene volcanics and sediments undifferentiated - This unit is a sequence of structurally complex basalt flows, pillow lava, tuff, agglomerate, and breccia with well-indurated marine siltstone and sandstone interbeds. The sequence dips east and northeast and is several thousand feet thick in the Scoggins Creek area, thickening westward in the coast ranges. Only the extreme northwest portion of the reservoir is underlain by this unit. It is overlain, presumably conformably, by the Yamhill Formation.

(3) Spencer Formation - The Spencer Formation is exposed in a nearly continuous, 17-mile belt that commences just east of Carlton and trends northwesterly nearly to Gales Peak, a few miles north of Scoggins Creek. The formation is more than a mile wide east of Carlton and narrows to about a quarter of a mile where it crosses the Tualatin River and Scoggins Creek. The formation consists of thick-bedded to massive, well-sorted, friable, fine- to medium grained feldspathic sandstone with occasional thin carbonaceous siltstone and claystone interbeds. In the top and bottom portions of the formation, thin-bedded siltstone and claystone predominate. The sandstone is typically composed of about 40 percent quartz, 55 percent plagioclase feldspar, and 5 percent muscovite, biotite, and chlorite. In the northwest, two-thirds of its outcrop belt, where it averages 200 feet in thickness, the formation is composed almost entirely of friable, fine sandstone. This unit is less susceptible to landsliding than the other Tertiary marine units in the area. The Spencer Formation is upper Eocene in age and is overlain by Oligocene marine sediments.

(2) Yamhill Formation - The Yamhill Formation consists primarily of well-indurated, thin-bedded shale and siltstone with occasional interbeds of green basaltic sandstone and poorly sorted tuffaceous sandstone (photo EG-1). Locally, basalt and gabbro dikes and sills have invaded the formation. The Yamhill Formation underlies most of the Yamhill River Valley and trends northerly in a thinning outcrop belt to within a short distance north of Scoggins Creek. It is also present in isolated exposures in the bed of Gales Creek. Its thickness ranges from probably less than 1,000 feet in the Scoggins Creek area to more than 2,000 feet in the Yamhill River Valley. Its primary structure is monoclinal eastward with local irregularities. This unit weathers deeply and, because of its fine-grained nature, is very susceptible to landsliding on relatively shallow slopes (Tengesdal, 1968). The Yamhill Formation is lower upper Eocene in age and is unconformably overlain by the Spencer Formation.

(4) Oligocene marine sediments undifferentiated - The uppermost rocks of the Oligocene sequence are composed of tuffaceous sandstone and siltstone. Beneath this sequence, in most areas, is a section of moderately indurated quartzitic sandstone' The lower part of the Oligocene section generally consists of siltstone, basaltic sandstone, and local conglomerate. In the Scoggins Creek Quarry, basaltic sandstone and conglomerate occur below a well-indurated, limey sandstone which contains abundant megafossils in several 1-foot layers. The total maximum thickness of the undifferentiated Oligocene sequence is estimated to be about 3,000 feet, although its thickness varies considerably in the map area. On the basis of faunal data, the lower Oligocene section is estimated to be about 1,000 feet and the upper Oligocene about 2,000 feet thick. The Oligocene sequence generally dips to the east and northeast at low to moderate angles. Locally, fault beds dip 40 to 500. In a few areas, dips are reversed to the south and southwest to form local anticlines. This sequence is overlain unconformably by the Columbia River Basalt.

(5) Columbia River Basalt - The Columbia River Basalt is widespread, is the bedrock of many of the hills, and underlies most of the valleys east of the damsite. The formation is composed of a series of weathered and unweathered lava flows with scattered interflow zones of breccia, ash, and baked soil horizons. This formation is Miocene in age and does not exist in the dam or reservoir area. (6) Willamette Silt - The Willamette Silt underlies nearly all of the lowlands east of the damsite. It generally extends onto the surrounding uplands to an approximate average elevation of 250 feet, where it occurs on sloping terraces. The Willamette Silt lies on the erosional surfaces of all the older bedrock units. The unit is composed of unconsolidated beds and lenses of fine sand, silt, and clay. Stratification is commonly on the order of 4- to 6-inch beds; 3- to 4-foot beds are

locally present; and in many areas, the silt is massive with indistinct stratification. Lenses of pebbly, fine to medium sand with scattered cobbles of granite and quartzite occur in some of the outcrops. The silt is usually light brown to buff in color and occasionally light gray where granular soils predominate. This unit is upper Pleistocene in age and does not exist in the dam or reservoir area. Structure - The region surrounding the dam and reservoir site is structurally simple. All pre-Quaternary units are part of a large homoclinal structure on the northeast flank of the coast ranges and have relatively gentle east to northeast dips. Locally, the area is cut by several northwest trending faults that appear to displace only Tertiary-age units (fig. EG-1). Little is known of the nature of these faults, although Schlicker and Deacon (1967) indicate vertical displacement on them. A fault zone is mentioned in the Geologic Report for Final Design (1969) that may correspond to the fault in Scoggins Creek. This fault dips 450 to the northeast, but sense of displacement was not determined.

Landslides:

There of a number of existing imbricated landslide located around the reservoir rim, mostly associated with the Yamhill Formation which is which is generally comprised of near flat lying interbedded siltstone and shale.

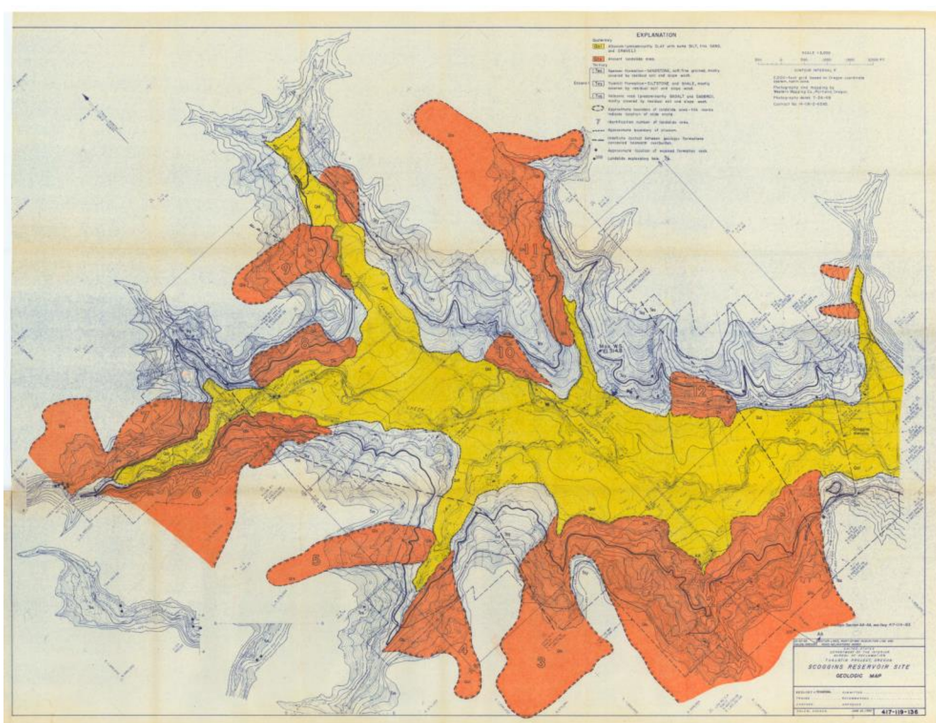


Figure 3. Existing landslides (orange) around reservoir rim.

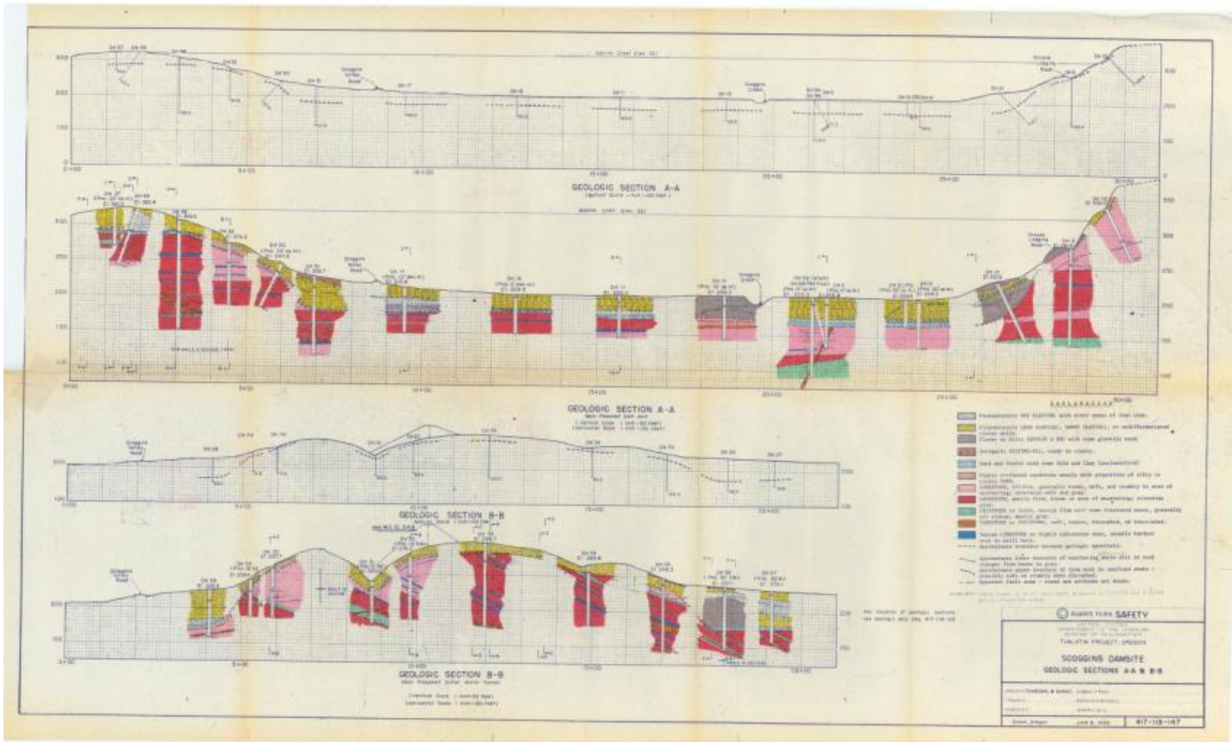


Figure 4. Example of historic geologic cross sections for landslide characterization around reservoir rim.

Ongoing Field Exploration for Seismic Risk Design

Starting in 2022, a field exploration program was initiated and is still in progress today. The purposed of the Field Exploration Request (FER) is to detail exploration requirements for a Safety of Dams (SOD) program to gather Final Design data for modifications proposed for Scoggins Dam.

The purpose of this FER is to provide additional subsurface characterization of soils and bedrock beneath proposed dam elements and within the main dam area directly or indirectly impacted by the proposed modifications. Additional holes are planned to evaluate hydrogeologic conditions to support foundation dewatering design efforts. Field fitting of the proposed boring locations may occur to accommodate better site access and avoid any environmentally sensitive areas related to permitting.

The program consist of surface geophysics, drill hole advancement using flight auger dry coring/sonic coring utilizing standard penetration and acrylic liner sampling. Advancement into the underlying bedrock using wireline HQ3 coring drilling methods allows for additional subsurface characterization of the foundation bedrock using downhole optical/acoustical televiewing, in addition to dilatometer testing for insitu strengths to compare with laboratory testing results.

This field program is to support a current foundation modification design to further reduce risk related to seismic potential failure modes.

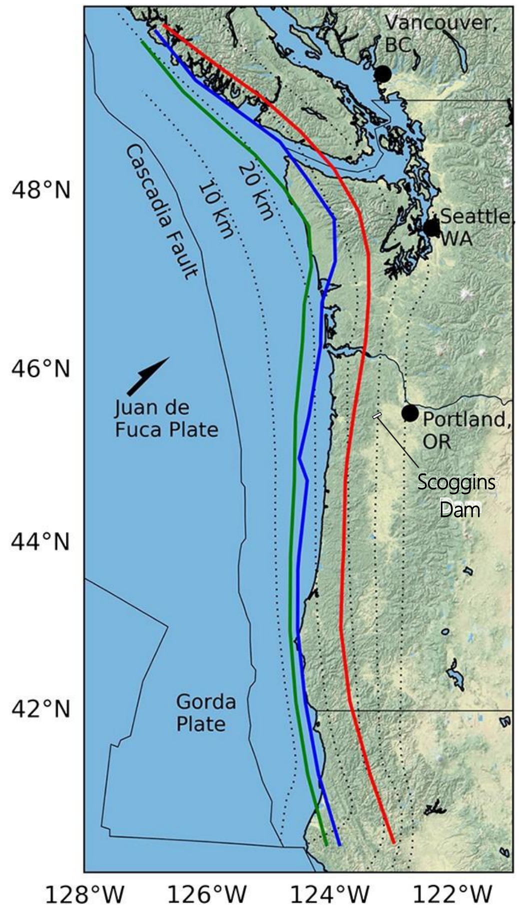
Tectonic Setting of Scoggins Dam

Scoggins Dam lies about 40 km above the Cascadia subduction zone, where the oceanic Juan de Fuca plate dives beneath North America (Fig. 5). The Cascadia plate boundary fault, also known as the Cascadia megathrust, dips gently beneath the forearc and has been the source of M 9 subduction earthquakes, most recently in 1700 AD (Atwater et al., 2005).

The subduction zone also produces deeper earthquakes in the downgoing slab between 30 and 90 km depth and earthquakes on crustal faults in the deforming upper plate (Fig. 6).

A repeat of the 1700 event will not likely rupture beneath the dam, but the down dip limit is likely to reach the coast, about 70 km from the dam. The dam site would be be subject to strong ground shaking of several minutes' duration, potentially producing liquefaction and or landsliding in the vicinity (see Figure 3).

Scoggins Dam also lies within the Gales Creek Fault Zone (Wells et al., 2020a, b), a large upper plate fault recently documented to be the source of multiple Holocene surface-rupturing earthquakes (Fig. 7). We have recently completed a detailed study of the local geology of the dam and have confirmed a likely active splay beneath the dam and several smaller fault splays near both abutments (Wells et al in press). We will discuss the hazards to the dam and inspect some of these structures during the field trip.



Wirth et al., 2018

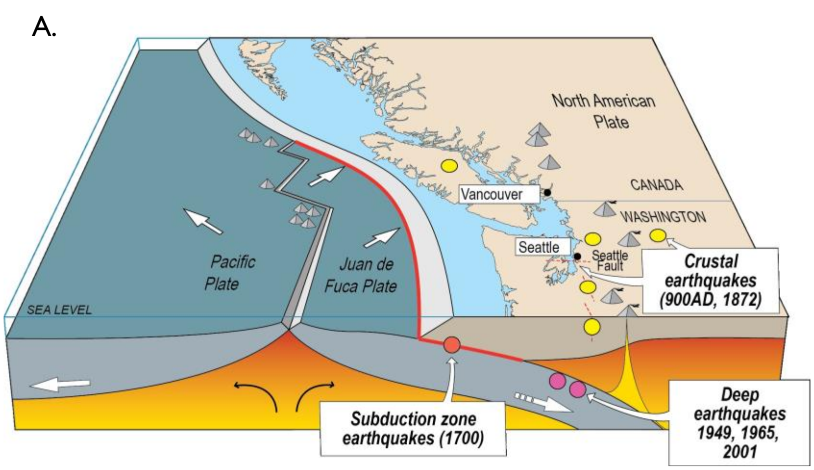
Figure 5.

Map illustrating the tectonic setting of the Pacific Northwest and locations of major population centers. Solid black lines denote plate boundaries, and dotted lines are contours of the subducting slab spaced every 10 km. Arrow indicates the convergence direction of the subducting Juan de Fuca plate. This study considered three possible down-dip rupture extents for an M 9 Cascadia earthquake, shown by the thick solid lines: the up-dip limit of the nonvolcanic tremor zone (red), the 1 cm/yr locking contour (blue), and the midpoint of the 1 cm/yr locking contour and the fully locked zone (green).

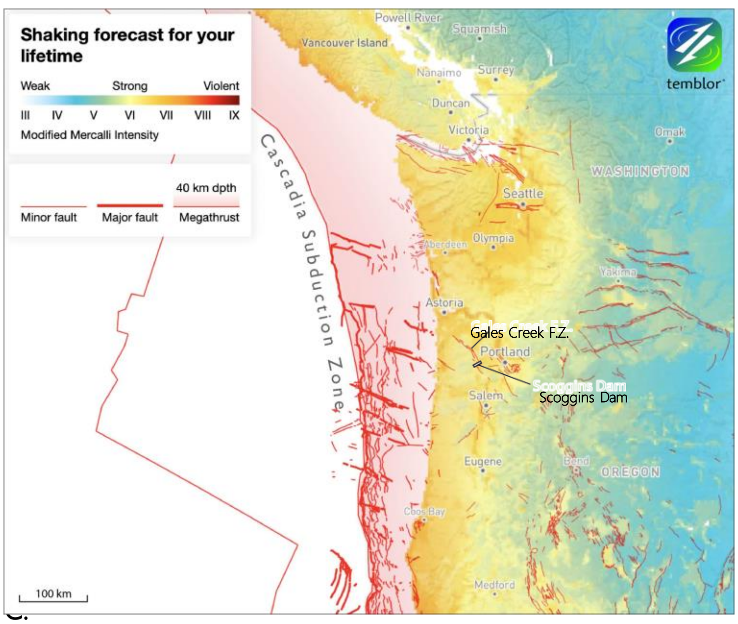
Description of the field course, background information, general geologic setting and reference to maps and figures illustrating the introductory information. Maps showing stops, regional geology, other general information, and route maps (if required) to pinpoint stop locations and pertinent geographic information. References for the introductory material.

Cascadia earthquake sources

A.



B.



C.

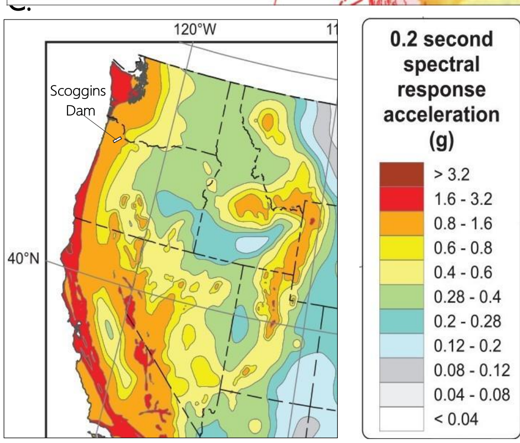


Figure 6

The Cascadia convergent margin has three earthquake sources:

1. Cascadia megathrust
M 9 potential; ~500 yr recurrence

2. in-slab EQ
M 7 potential; 30-50 yr recurrence

3. Crustal Earthquakes
M 7+ potential; 1000's of yr recurrence (M 7)?

https://www.usgs.gov/publica- tions/2018-update-us-nation-
al-seismic-hazard-model-overview-mo del-and-implications

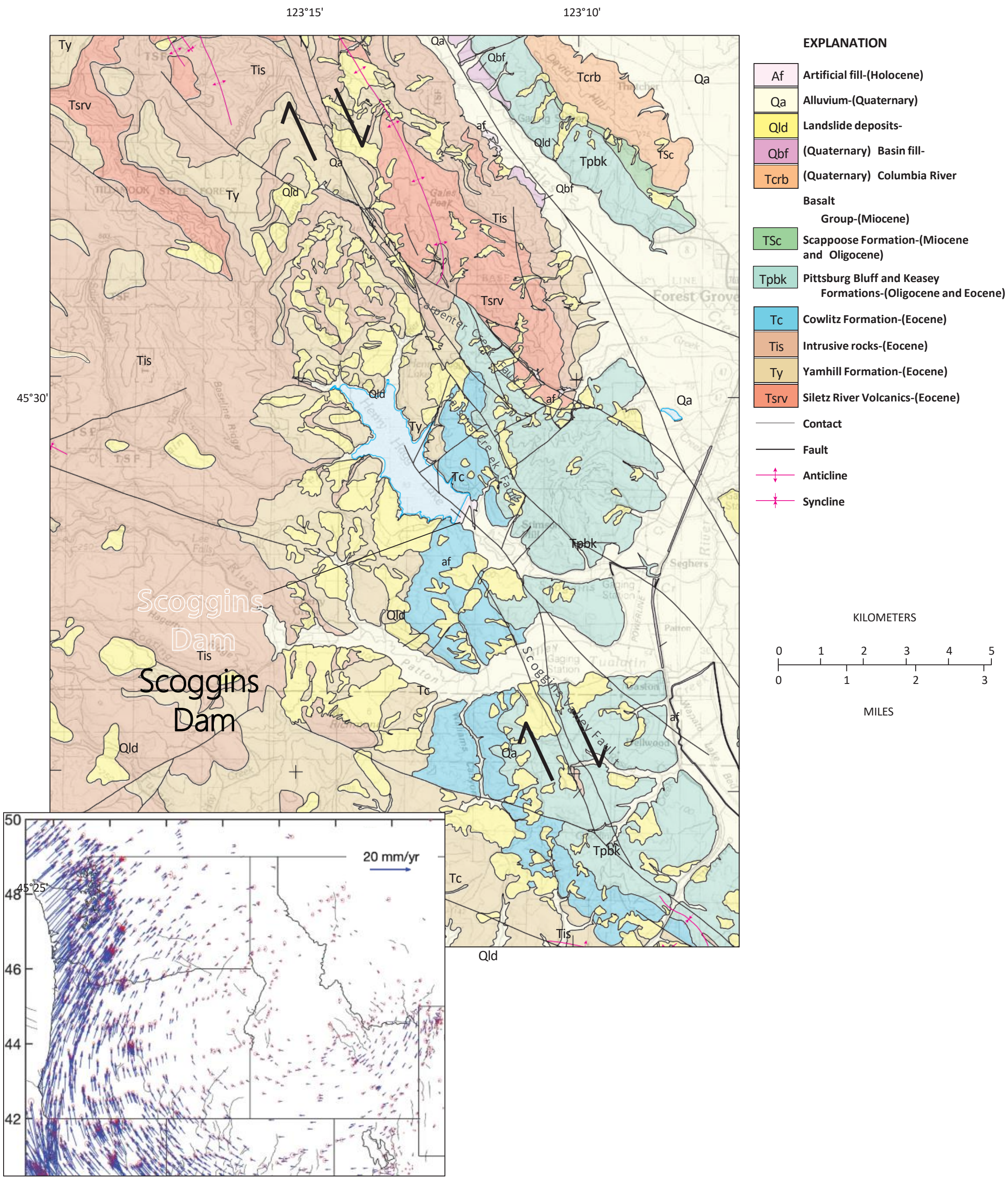
The Cascadia Megathrust

Figure B from temblor.net shows that Scoggins Dam lies within the active Gales Creek Fault Zone, about 70 km from the downdip edge of the expected M 9 Cascadia megathrust rupture offshore (Wirth and Frankel, 2019).

A great megathrust earthquake is likely to last several minutes, producing widespread ground shaking, a coastal tsunami, and liquefaction and other ground failures (Wirth et al, 2018, 2020). This may impact the dam.

The aggregated shaking hazard from all three potential sources is significant in the Cascadia forearc.

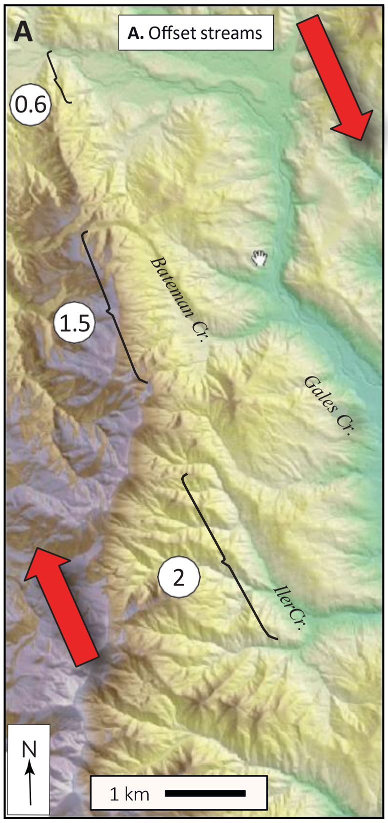
Figure C shows the 2% probability of exceedance in 50 years calculated for the 2018 NSHM at: 0.2-s spectral acceleration, NEHRP site class boundary B/C (VS30 = 760 m/s). https://www.usgs.gov/publications/2018-update-us-nation- al-seismic-hazard-model-overview-model-and-implications



The Gales Creek Fault Zone accommodates right-lateral motion of the Coast Range at a long-term average rate of about 0.6 mm/yr (Wells et al., 2020). Northward motion of the Coast Range is consistent with the GPS velocity field, which indicates about 7.6 mm/yr northward motion of the forearc after correction for locking on the megathrust (McCaffrey et al., 2013).

Figure 7

Evidence for recent activity on the Gales Creek Fault



Lidar imagery show that most streams crossing the Gales Creek Fault Zone are offset in a right-lateral sense, up to 2 km (white circles in A, left, Wells et al 2020; Horst et al., 2021).

B. Paleoseismic results from the Clear Creek trench site (below) reveal that the GCF has produced at least three surface-rupturing earthquakes in the Holocene. E1 occurred between 1168 and 853 yr B.P., E2 occurred between 7078 and 1274 yr B.P., and E3 between 8885 and 8398 yr B.P. (2σ uncertainty). (Horst et al, 2021).

Trench location

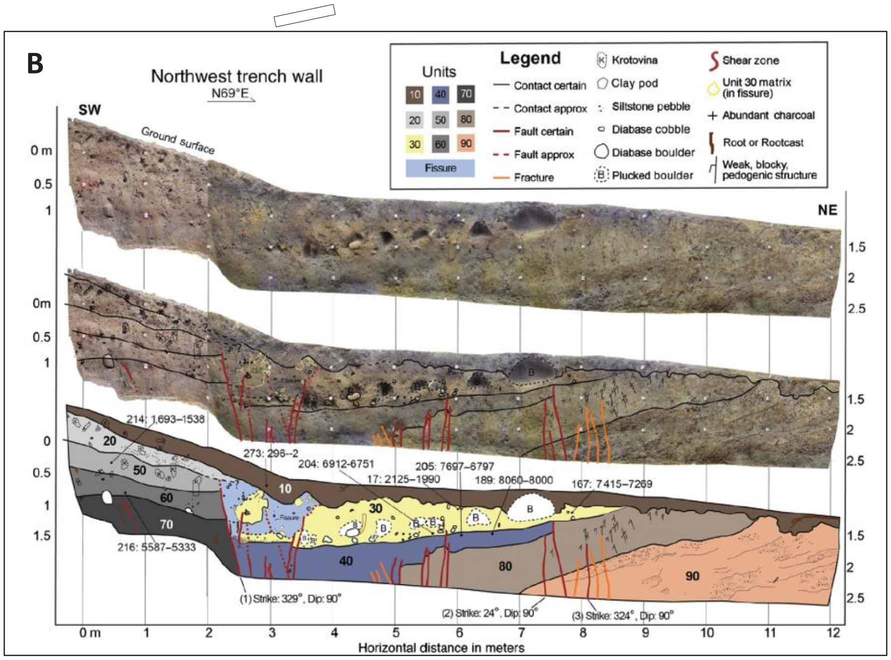
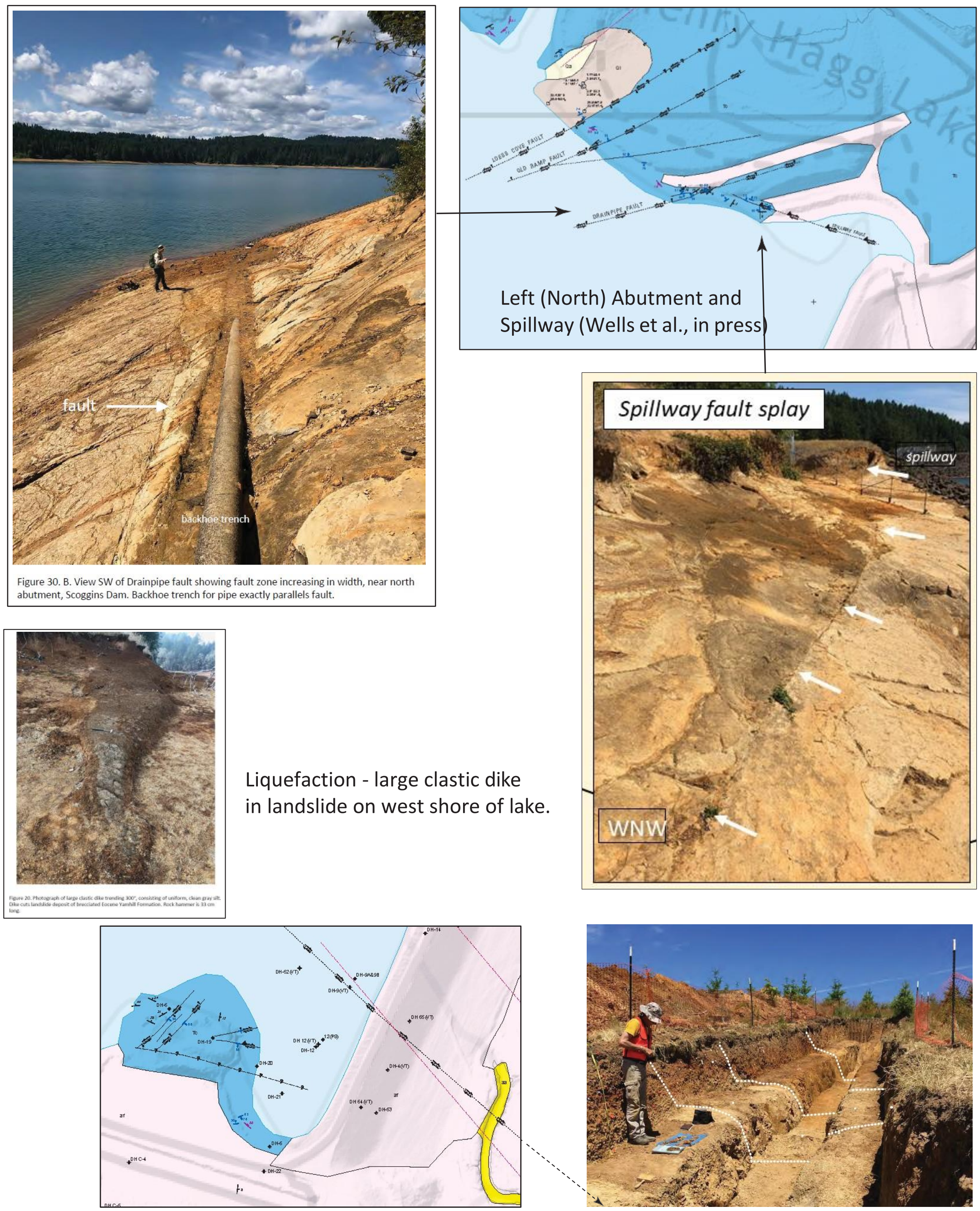


Figure 8

Faulting and Liquefaction around the shoreline of Henry Hagg Lake from Wells et al. (in press)



Right (South) Abutment

Holocene surface rupture ~ 2km to SE

Figure 9

References:

Horst, A. E., A. R. Streig, R. E. Wells, and J. Bershaw, 2020, Multiple Holocene earthquakes on the Gales Creek Fault, northwest Oregon fore-arc: Bulletin of the Seismological Society of America, v. 111, p. 476–489, https://doi.org/10.1785/0120190291.

McCaffrey, R., King, R.W., Payne, S.J. and Lancaster, M., 2013, Active tectonics of northwestern U.S. inferred from GPS-derived surface velocities: Journal of Geophysical Research——Solid Earth, v. 118, no. 2, pp.709–723.

Redwine, J., Howe, J., Piety, L.A., Cataldo, K., 2019a, Geomorphic study and trenching results from the Option 3/RCC Dam site for the corrective action study of Scoggins Dam, northwest Oregon: Bureau of Reclamation Technical memorandum 85-83000-2019-23, 125 p.

Wells R.E., Blakely R.J., Bemis S., 2020a, Northward migration of the Oregon forearc on the Gales Creek fault: Geosphere, v. 16, no. 2, p. 660–684, https://doi.org/10.1130/GES02177.1

Wells et al, in press, Geologic Map of Scoggins Dam, Henry Hagg Lake and Scoggins Valley, Washington County, Oregon, U.S. Geological Survey Scientific Investigations Map, 4 sheets, various scales, 135 p. pamphlet.

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., 2020b, Geologic map of the greater Portland metropolitan area and surrounding region, Oregon and Washington: U.S. Geological Survey Scientific Investigations Map 3443, 2 oversize sheets, 55 p. pamphlet, scale 1:63,360.

Wirth, Erin A., Arthur D. Frankel, Nasser Marafi, John E. Vidale, and W. J. Stephenson, 2018, Broadband Synthetic Seismograms for Magnitude 9 Earthquakes on the Cascadia Megathrust Based on 3D Simulations and Stochastic Synthetics, Part 2: Rupture Parameters and Variability, Bulletin of the Seismological Society of America, Vol. 108, No. 5A, pp. 2370–2388, doi: 10.1785/0120180029

Wirth, E. A., A. Grant, N. A. Marafi, and A. D. Frankel, 2020, Ensemble ShakeMaps for Magnitude 9 Earthquakes on the Cascadia Subduction Zone, Seismol. Res. Lett. 92, 199–211, doi: 10.1785/0220200240.

Zeng, Yehua, 2022, GPS Velocity Field of the Western United States for the 2023 National Seismic Hazard Model Update, Seismological Research Letters, v. 93 (6), p. 3121–3134, https://doi.org/10.1785/0220220180