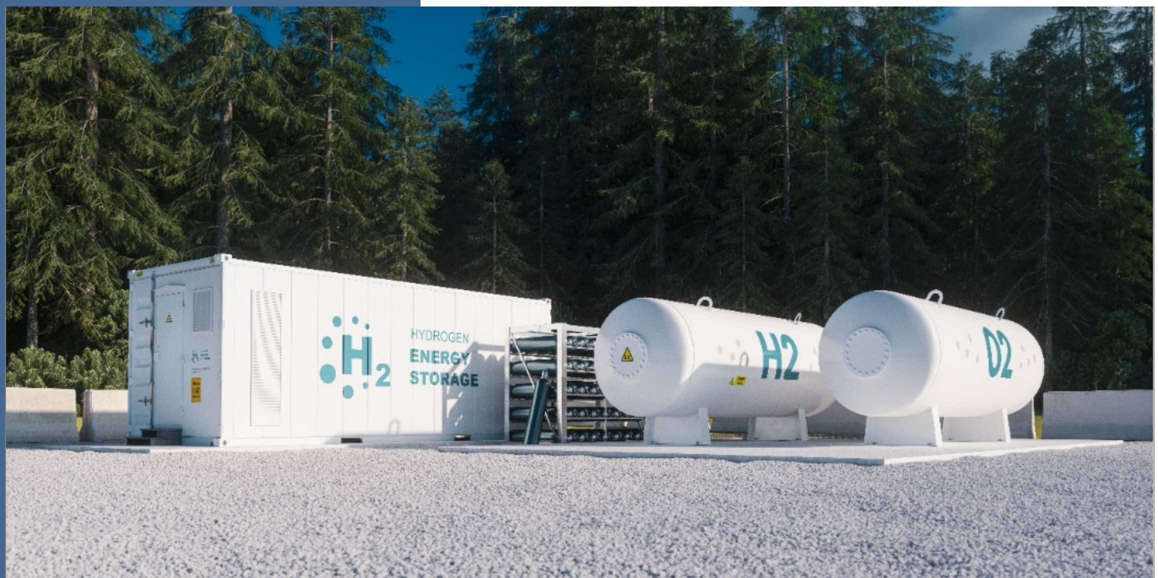

Appendix D: Earth Resources Technical Appendix

For Programmatic Environmental Impact Statement on Green Hydrogen Energy Facilities in Washington State

By

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For the

Shorelands and Environmental Assistance Program

Washington State Department of Ecology

Olympia, Washington

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Acronyms and Abbreviations List

ASL	above sea level
BESS	battery energy storage system
BMP	best management practice
CSZ	Cascadia Subduction Zone
CWA	Clean Water Act
DNR	Washington State Department of Natural Resources
Ecology	Washington State Department of Ecology
FEMA	Federal Emergency Management Agency
NPDES	National Pollutant Discharge Elimination System
PEIS	Programmatic Environmental Impact Statement
RCRA	Resource Conservation and Recovery Act
RCW	Revised Code of Washington
RSLR	relative sea level rise
SEPA	State Environmental Policy Act
SFZ	Seattle Fault Zone
SLR	sea level rise
USGS	U.S. Geological Survey
WAC	Washington Administrative Code

Summary

This technical appendix describes earth resources in the study area. It also describes the regulatory context, potential impacts, and measures that could avoid or reduce impacts.

This technical appendix analyzes the following key features of earth resources for each of the green hydrogen facility types evaluated in the Programmatic Environmental Impact Statement (PEIS):

- Geomorphology and geology
- Topography
- Soil resources (erosion and accretion)
- Geologic hazards

Findings for earth impacts described in this technical appendix are summarized as follows:

- Through compliance with laws and permits, and with implementation of measures that could avoid and reduce impacts, construction, decommissioning and operation activities would likely result in **less than significant impacts** to soil resources and from geologic hazards.

1 Introduction

This technical appendix describes earth resources within the study area and assesses probable impacts associated with the types of green hydrogen facilities, and a No Action Alternative, which are described in Chapter 2 of the State Environmental Policy Act (SEPA) Programmatic Environmental Impact Statement (PEIS).

This section provides an overview of earth resources and lists relevant regulations that contribute to the evaluation of potential impacts.

1.1 Resource description

Earth resources relate to the region's geography, geology, hydrology, and hydrogeology, including geologic resources as well as geologic hazards, both natural and anthropogenic in origin. Any type of development would result in impacts on soil and rock resources, including those directly associated with on-site construction activities such as grading, as well as the regional utilization of available construction materials such as aggregate for access roads. Sub-elements within earth resources include geology, soils, topography, unique physical attributes, topographic or geologic features, and geologic and seismic hazards, as well as natural system processes and geomorphic conditions such as fluvial or aeolian systems.

The scope of geologic hazards includes both local and regional hazards that are avoidable or may be mitigated, such as liquefaction, and hazards that are unavoidable or may not be mitigated, such as ashfall from a volcanic eruption. Some geologic hazards, such as deep liquefaction susceptibility or large-scale landslides, may preclude development at a particular site due to the severity and lack of avoidance or mitigation options, or excessive mitigation costs, for a potential hazard, whereas other geologic hazards may require varying levels of design consideration and/or mitigation but may be manageable.

In the study area, the following resources could have impacts that overlap with impacts to earth resources. Impacts on these resources are reported in their respective technical appendices:

- **Water resources:** Aspects related to surface water, groundwater, wetlands, floodplains, and water availability are covered in the *Water Resources Technical Appendix*. The earth discipline focuses specifically on water impacts related to erosion, deposition, and subsidence.
- **Environmental health and safety:** Consideration of wildfire risk areas related to slope instability or debris flow risks are addressed in this technical appendix. The *Environmental Health and Safety Technical Appendix* more broadly addresses hazardous materials and wildfire sub-elements.
- **Noise and vibration:** Noise- and vibration-generating activities are considered in the *Noise and Vibration Technical Appendix*.

- **Historic and cultural resources:** Excavation, grading, and other ground disturbances to existing or native ground surfaces that may disturb existing cultural or historic artifacts are addressed in the *Earth Resources Technical Appendix*. Considerations for cultural or historic areas or artifacts are considered in the *Historic and Cultural Resources Technical Appendix*.

1.2 Regulatory context

Table 1 provides an inventory of applicable laws, plans, and policies that contribute to the evaluation of earth resources. Local regulations and plans would be dependent on the location of a facility. The developer would consult with the appropriate county or other local officials to determine local regulatory guidance that would be applied to project-level SEPA reviews.

Table 1. Applicable laws, plans, and policies

Regulations	Description
Federal	
33 USC 1251 et seq., Clean Water Act (CWA)	The Federal Water Pollution Control Act of 1948 was the first major U.S. federal law to address water pollution. The law was amended in 1972 and became commonly known as the Clean Water Act. The CWA establishes the basic structure for regulating pollutant discharges into waters of the United States and makes it unlawful to discharge any pollutant from a point source into those waters without a permit.
Resource Conservation and Recovery Act (RCRA)	Gives the U.S. Environmental Protection Agency the authority to control hazardous waste from cradle to grave. This includes the generation, transportation, treatment, storage, and disposal of hazardous waste. RCRA also establishes a framework for the management of non-hazardous solid wastes.
Toxic Substances Control Act	Regulates the manufacture, distribution, use, and disposal of chemical substances in the United States. Its primary objective is to ensure that chemicals are safely managed to protect human health and the environment from unreasonable risks of injury.
State	
Chapter 78.44 Revised Code of Washington (RCW), Chapter 332-18 Washington Administrative Code (WAC), Surface Mining Act	Regulatory framework for surface mining activities to minimize their impacts on the environment and communities in Washington. It establishes procedures for permitting, compliance enforcement, and public participation in the regulatory process.
Chapter 36.70A RCW, Washington State Growth Management Act	Requires local governments to manage growth by identifying and protecting critical areas and natural resource lands, among other measures.

Regulations	Description
Chapter 365-190 WAC, Critical Areas	Establishes guidelines for the protection and management of sensitive environmental areas in Washington. Critical areas include wetlands, fish and wildlife habitat conservations areas, frequently flooded areas, geologically hazardous areas, and critical aquifer recharge areas. The regulations aim to ensure responsible land use planning while safeguarding ecologically sensitive zones.
Chapter 365-190 WAC, Critical Areas - Section 120, Geologically Hazardous Areas	Pertains to regulations in Washington addressing geological hazards such as landslides, erosion, and seismic activity. It outlines requirements for identifying, mapping, and managing areas prone to geological hazards to ensure public safety and environmental protection during land use and development activities.
Chapter 90.58 RCW, Washington State Shoreline Management Act	Establishes a state-local partnership for managing, accessing, and protecting Washington's shorelines. The law requires local governments to prepare locally tailored policies and regulations for managing shoreline use in their jurisdictions called shoreline master programs (SMPs). Local governments review shoreline development proposals for compliance with SMP standards. Applies to shorelines of the state, including marine waters, streams, and rivers with greater than 20 cubic feet per second mean annual flow, lakes 20 acres or larger, upland areas extending 200 feet landward from the edge of these waters, biological wetlands and river deltas connected to these water bodies, and some or all of the 100-year floodplain, including all wetlands.
Title 86 RCW, Flood Control Management Act	Establishes regulations for floodplain management to ensure local government compliance with the National Flood Insurance Program (NFIP).
Chapter 90.48 RCW, Water Pollution Control Act	The Water Pollution Control Act sets standards to ensure the purity of all waters of the state and to work cooperatively with the federal government where interest overlaps in a joint effort to extinguish the sources of water quality degradation. Grants Ecology the jurisdiction to control and prevent the pollution of streams, lakes, rivers, ponds, inland waters, salt waters, water courses, and other surface and groundwater in the state, including wetlands. Tool Ecology uses to regulate certain activities in wetlands and waters that are non-jurisdictional under Section 404 of the CWA through authorization to work in waters of the state.
Title 51 WAC, Department of Enterprise Services (Building Code Council)	Adopts and implements state building code and guidelines that establish requirements for building design within zones of certain geologic hazard, including seismic.
Chapter 173-158 WAC, Flood Plain Management	Directs floodplain management and compliance with minimum requirements of the NFIP.

Regulations	Description
Local	
Critical areas ordinances	As required under Washington's Growth Management Act, cities and counties have development regulations to protect critical areas including wetlands and their buffers, waterbodies and their buffers (fish and wildlife habitat conservation areas), critical aquifer recharge areas, and frequently flooded areas.
Shoreline codes	Local codes regulate development within shorelines of the state in accordance with Shoreline Master Programs and state Shoreline Management Act requirements.

2 Methodology

This section provides an overview of the process for evaluating potential impacts and the criteria for determining the occurrence and degree of impact.

2.1 Study area

The study area for earth resources includes the PEIS geographic scope of study for green hydrogen facilities (Figure 1) and the surrounding areas with relevant geologic features.

The study area for the evaluation of earth resources associated with the construction and operation of green hydrogen facilities would be determined by the presence (or absence) of earth resources during project-specific reviews. Parameters could include aboveground features (topography, soils, rock and other biomass, water resources) and belowground features (geologic units, seismic and landslide hazards).

Figure 1, which shows the PEIS geographic scope of study, does not include federal lands, national parks, wilderness areas, wildlife refuges, state parks, or Tribal reservation lands, but information related to these areas is provided as context for the affected environment.

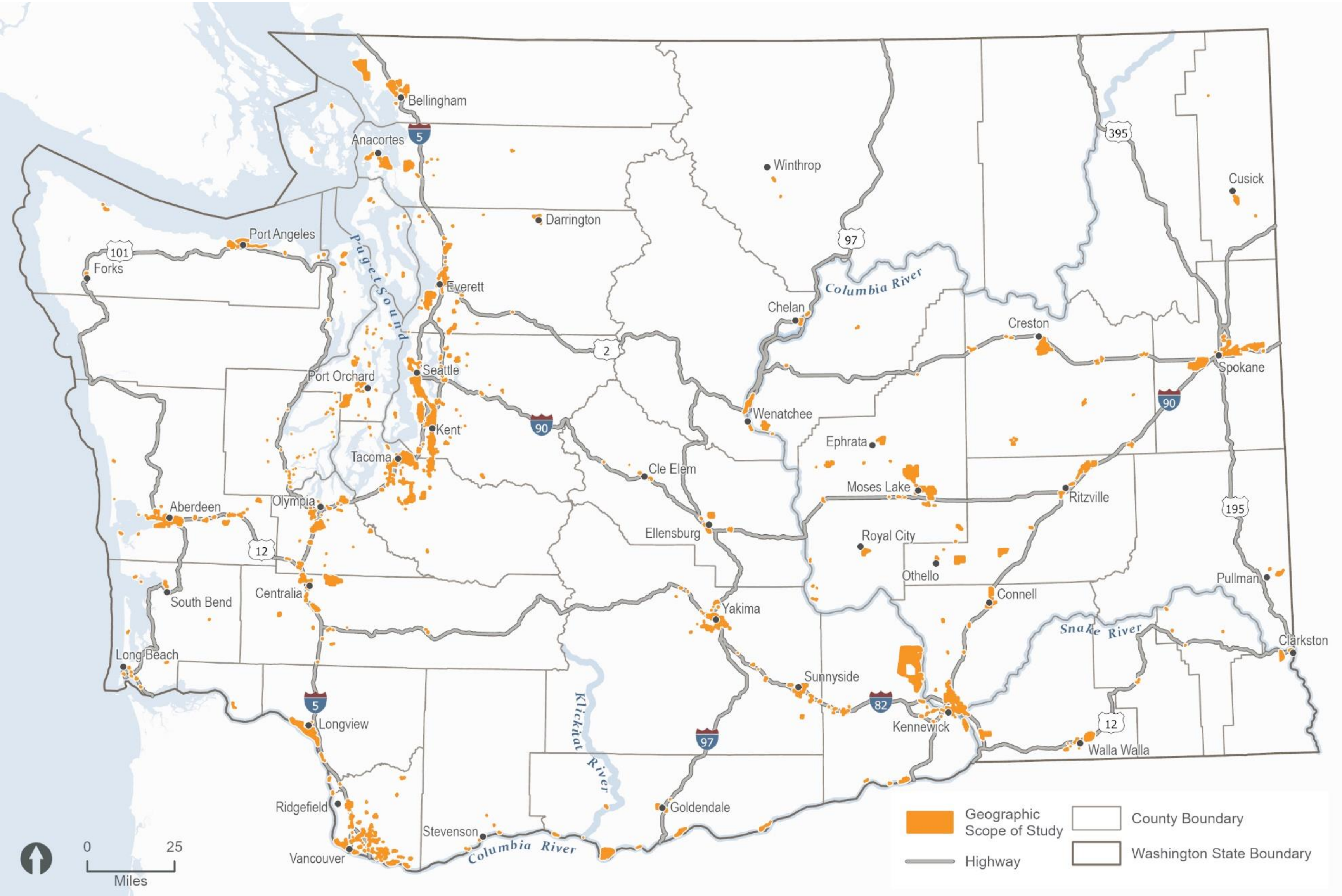

Figure 1. Green Hydrogen Energy Facilities PEIS geographic scope of study

2.2 Technical approach

The technical approach for analyzing earth resources included using publicly available data sources and reviewing mapping data from federal, state, and local sources, agency guidance and reports, and scientific literature. Data sources utilized to perform the analysis included technical resources such as published geologic, topographic, and soil maps. Additionally, map resources and data layers published by the U.S. Geological Survey (USGS) and the Washington State Department of Natural Resources (DNR) were considered to evaluate features such as faults, steep topography, landslide, tsunami, liquefaction, and other hazard types.

Impacts on earth resources were considered relative to the requirements to construct and operate green hydrogen facilities and the mechanisms through which those activities could adversely affect underlying and adjacent earth resources. The potential for construction and operation of facilities to increase soil erosion and the risk of occurrence and damage from identified geologic hazards (e.g., landslides) were also considered. Geologic hazards are typically not generated by construction or development activities (except for landslides and subsidence). However, identification of these potential hazards is necessary to understand the potential impact of a hazard on a proposed facility.

The PEIS analyzes a timeframe of up to 25 years of potential facility construction and up to 50 years of potential facility operations (totaling up to 75 years into the future).

The approach used in this analysis is not site-specific and focuses on facility site selection and regional characterization. No new data gathering efforts, research, field studies, or modeling was performed as part of the analysis.

2.3 Impact assessment approach

The assessment of probable impacts was conducted qualitatively, and impacts were evaluated for activities associated with pre-construction site characterization, construction, typical operation, and decommissioning of the facility options. The impact analysis considered the following:

- Impacts to soil resources:
    - The potential for soil erosion and accretion from direct ground disturbance associated with soil and/or rock excavation, grading, and filling
    - Slope instability from ground-disturbing activities, underground construction, or other activities that could increase local susceptibility to certain geologic hazards
    - Subsidence related to groundwater withdrawal or disturbance of groundwater reserves
    - Borrow of construction materials (such as quarried rock, sand, and general fill)
- Impacts from geological hazards:
    - Potential for a site to be impacted by a naturally occurring geologic or seismic hazard

- Potential for a site to be impacted by anthropogenically influenced or altered geologic hazards

Evaluation was based on information and assumptions from the PEIS alternatives and descriptions of the types of facilities. Assumptions define the types and sizes of facilities and the ranges of activities that are expected during the construction, operation, and decommissioning of a green hydrogen facility. Impacts were described relative to applicable laws and regulations.

For the purposes of this assessment, a **potentially significant impact** would occur if a facility resulted in the following:

- Broad areal extent of grading and high volume of soil and/or rock excavation and fill associated with construction and decommissioning activities
- Widespread and frequent ongoing earthwork associated with operation and maintenance activities
- Widespread increase in the potential for landslides and slope instability
- Widespread subsidence related to tapping and withdrawal of groundwater reserves as a result of construction and decommissioning activities
- Widespread increase in the potential tapping and withdrawal of groundwater reserves as a result of ongoing operation and maintenance activities
- Widespread local utilization of borrow material as a result of construction and decommissioning activities, backfill, and road construction
- Widespread utilization of borrow material as a result of ongoing activity for road and facility maintenance

3 Technical Analysis and Results

3.1 Overview

This section describes the affected environment, anticipated permit requirements, and potential impacts on earth resources for green hydrogen facilities analyzed in the PEIS. This section also evaluates measures that could avoid, minimize, or reduce potential significant adverse impacts.

3.2 Affected environment

The affected environment represents existing conditions at the time this study was prepared. Figure 1, which shows the PEIS geographic scope of study, does not include federal lands, national parks, wilderness areas, wildlife refuges, state parks, or Tribal reservation lands, but information related to these areas is provided as context for the affected environment.

3.2.1 Geography and topography

The geography of Washington is diverse and includes nine major geologic provinces, each with distinct and unique geologic and environmental conditions (Figure 2) (DNR 2024a). The study area is in eight of the provinces, listed below. The study area is not in the Blue Mountains.

The eight provinces have distinct processes that are influenced by their topography, geology, and climate and are characterized as follows:

- **Olympic Mountains** – Located in the northwest corner of Washington. Elevation ranges from sea level to nearly 8,000 feet above sea level (ASL). The Olympic Mountains are bounded on three sides by water (Pacific Ocean, Strait of Juan de Fuca, and the Puget Sound). Glaciers are present on the high peaks. The province is dominated by a large section of oceanic crust that that accreted onto the continent. This is bordered by Lower Tertiary basalts and Quaternary sediments and glacial deposits.
- **North Cascades** – Located east of the Puget Lowland in northcentral Washington, the mountains average 7,000 feet ASL and are geologically complex due to their long and dynamic history.
- **Okanogan** – Located in the northeast corner of the state, the Okanogan Highlands, an extension of the Rocky Mountains, are bounded on the north by Canada and on the east by Idaho. Elevations within the province extend to 8,000 feet ASL. The geologic history of the province extends into the Precambrian, and it contains the oldest sedimentary and metamorphic rocks in the state (DNR 2012). Extensive gold mining and other ore extraction has occurred in the area. Uranium was produced on the Spokane Indian Reservation during the Cold War (Baulne 2024).
- **Willapa Hills** – The Willapa Hills, south of the Olympic Peninsula in western Washington, are characterized by weathered coastal mountains and hills comprised mostly of sedimentary and volcanic rocks that rise and extend slightly over 3,000 feet ASL. The

province includes broad river valleys that drain to the Pacific Ocean. Barrier beaches are located along the coastline from Long Beach and north to Ocean Shores. Basalt is common in the Willapa Hills, and sand, gravel, and rock are all mined within the province.

- **Puget Lowland** – The Puget Lowland is a wide low-lying area between the Cascade Mountain range to the east and the Olympic Mountain Range to the west. Extensive glacial deposits from the advance and retreat of icesheets characterize the province (Booth and Goldstein 1994). Coal has been mined along the eastern margins of the province, and sand and gravel aggregate are currently mined within the Puget Lowland.
- **Columbia Basin** – The Columbia Basin province includes the southcentral portion of the state. It is characterized by basalt canyons, plateaus, and ridges with areas of productive loess. The province was sculpted by cataclysmic glacial floods throughout the Pleistocene Epoch.
- **Portland Basin** – The Portland Basin province is characterized by a broad valley through which the Columbia River flows between Camas and Longview, Washington. Coastal hills bound the valley on the eastern and western flanks. Basalt flows from the Columbia River Basalt Group flooded the province beginning about 17 million years ago. These flows are exposed along the northern and southern boundaries of the basin but have otherwise been buried by sediment to depths of 1,000 feet or more.
- **South Cascades** – The South Cascades province extends from the Columbia River to Interstate 90 along the northern margin in southcentral and central Washington. The area is geologically complex due to its long and dynamic history. Three major stratovolcanoes are in the South Cascades: Mt. Rainier, Mt. Adams, and Mt. St. Helens.

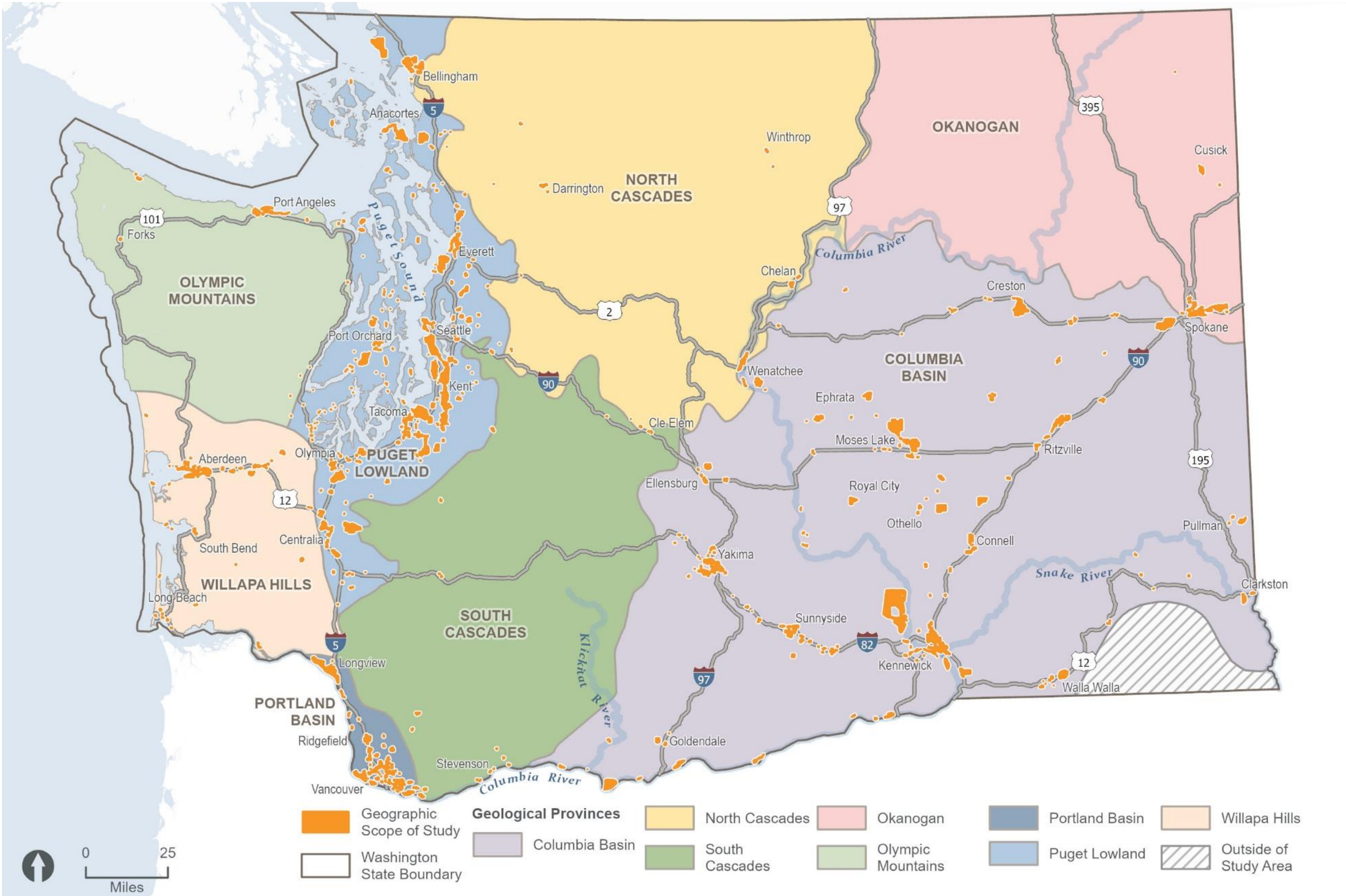

Figure 2. Geologic provinces in the study area

3.2.2 Surface soils

The formation of soil is a long and complex interaction between climate, topography, ecology, and attributes such as provenance or geologic parent materials (EFSEC 2023). The physical properties of soils such as grain size and minerology contribute substantially to their interactions with the greater environment. Impacts such as erosion may be exacerbated by the surface soil characteristics and would differ based on other environmental and anthropogenic factors such as climate, elevation, temperatures, precipitation, and land use type.

Surface soils often form in common groupings or horizons, as a relative function of the environs in which they are present. Compaction, grain size distribution, soil layer thicknesses, and soil structures (such as low- and high-permeability layers) generally form according to the environmental conditions relative to the physical properties of the soil and based on climate, precipitation, provenance, and vegetation cover. Exposed soils in central and eastern Washington, where it is characteristically dry and windy, lead to loss of soil and impacts to air quality, including from large dust storms that occur generally from spring through fall.

Other soil structures such as biological soil crusts or desert pavements may also be sensitive to disturbance and play an important role in local ecology; both are unique biological and physiological conditions that are specific to the environment in which they form and may take long periods to recover. Biological soil crusts, which contain living organisms, are found throughout the world and may also include lichens, mosses, microfungi, bacteria, and green algae. Within Washington, biological soil crusts are found most in the arid and semi-arid ecosystems and may be dominated by cyanobacteria. Biological soil crusts serve an important role in controlling erosion by slowing and retaining precipitation (Belnap 2001).

The study area includes several regions in Washington that may contain these sensitive soil structures (NRCS 2019). Identification of these areas is not feasible on the same scale as other elements; however, these types of features are common within the study area and would require identification during site-specific investigations. Studies to identify soil types on a site are expected to be done in researching project sites and during site characterization.

The industrially zoned areas or areas zoned to support industrial uses in the study area are not expected to have designated agricultural soils and forest land types.

3.2.3 Geologic hazards

Geologic hazards have the potential to affect environmental quality and change topography, habitat, vegetation, drainage patterns, and other attributes. Understanding geologic hazards such as earthquakes, surface fault ruptures, tsunamis and seiches, liquefaction, volcanic hazards, sea-level rise, landslides, and subsidence is important because risks of these hazards can impact the safety and feasibility of facility construction, operation, and decommissioning.

3.2.3.1 Earthquake Hazards

Washington has dozens of active faults and fault zones capable of producing earthquakes or vibrational motions produced mostly by the rupture of rock along the faults. Earthquake hazards are present throughout the study area. Faults are found throughout the state and coastal waters; some cross major cities, like the Seattle Fault Zone (SFZ), the Whidbey Island Fault Zone, and the Tacoma Fault Zone; and others are in more rural areas (DNR 2024b). The Pacific Northwest is home to the Cascadia Subduction Zone (CSZ), a major tectonic boundary between the Juan de Fuca and Gorda oceanic plates and the North American continental plate (USGS 2024a). Subduction zones such as the CSZ produce the largest earthquakes, reaching magnitude M9+. Scientists have determined that the last major earthquake along the CSZ occurred around 1700.

Ground shaking

Earthquake ground shaking is generated from the elastic rebound of crustal rock on both sides of the rupture plane following fault rupture. Ground motions occur as seismic waves, emanating from the focus of fault rupture, and travel through the subsurface materials. The intensity and effects of seismic waves traveling outward from the epicenter can be amplified by unconsolidated materials such as alluvium or basin fill. Earthquake-induced shaking may cause other impacts on the ground surface including hazard types such as landslides, fault rupture, and liquefaction (USGS 2024b).

Given the presence of seismic features in the state, the study area is within regions that are at risk of seismic activity. The seismic design maps for Washington (Cakir and Walsh 2007) generally identify the range of seismic structure design categories required for implementation across the state and may be used as a general tool to identify potential areas of concern. The seismic design maps consider events from random crustal sources as well as mapped major fault systems (CSZ, SFZ, and Tacoma Fault Zone) and lesser faults and fault systems (Cherry Creek Fault, Oak Flat Fault, and Saddle Mountain Fault), and derive seismic design category values that would be required for a facility sited within each seismic zone.

Liquefaction

Liquefaction is a process through which loose, saturated, non-plastic to low-plasticity soils such as sands and some silts temporarily lose shear strength during and immediately after a seismic event. Liquefaction occurs as shear stresses propagate through these soils and cause particles to dislodge and contract or collapse, increasing pore pressures if the water cannot drain quickly enough. This increase in pore pressure causes a decrease in frictional resistance at particle interfaces, resulting in an effective loss of shear strength and potential ground deformations, such as post-seismic reconsolidation settlement and lateral spreading.

Cyclic softening is differentiated from liquefaction in that it refers to effects of the progressive increase in shear strain on fine-grained soils, such as silts and some clays, when subject to seismic loading. Unlike liquefaction, cyclic softening typically does not result in a sudden decrease in shear stiffness or ground deformations associated with post-seismic reconsolidation settlement; however, the accumulation of large shear strains can result in strength loss that may be of concern for slopes and structures.

Following the 2001 Nisqually earthquake, DNR was awarded a grant by the Federal Emergency Management Agency (FEMA) to generate earthquake hazard maps on a county-by county basis for the entire state (USGS 2024b). These maps included seismic site class maps, consistent with the National Earthquake Hazards Reduction Program, and liquefaction susceptibility maps. These maps are available in GIS format on DNR's Geologic Information Portal (DNR 2022) and can be used to preliminarily identify areas of likely liquefaction sensitivity and delineate geologically hazardous areas. Due to the scope and scale of these mapping efforts, however, areas that may be susceptible to cycle softening are not specifically mapped, and some areas that fall outside of the mapped boundaries may be susceptible to liquefaction (see Figure 3 and Figure 4).

Figure 3. Geographic scope of study liquefaction susceptibility in western Washington State

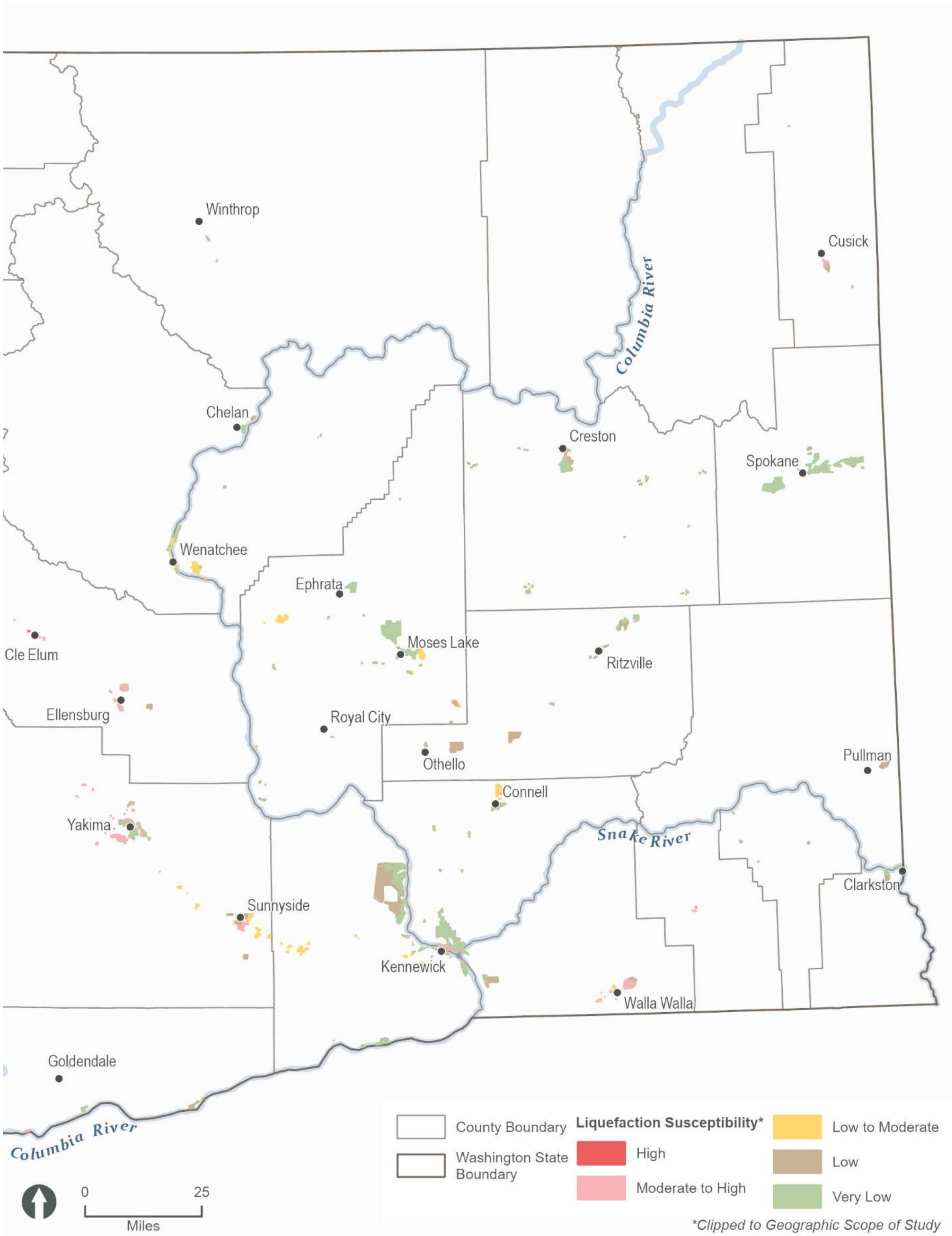

Figure 4. Geographic scope of study liquefaction susceptibility in eastern Washington State

Surface fault rupture

Surface fault rupture occurs when relative displacements on either side of a fault rupture plane are expressed at the ground surface as abrupt horizontal and/or vertical offsets or fissures. Surface fault rupture may bisect infrastructure, roads, buildings, pipelines, energy transmission lines, or other structures, potentially causing substantial damage. The expression of surface fault rupture varies depending on the fault type; for instance, faults like the SFZ may exhibit both horizontal and vertical displacement. In contrast, normal and reverse faulting typically results in vertical offset predominance. Surface ruptures may also be a function of ground subsidence, which may be the result of tectonic or seismic displacement, settling, or compaction or consolidation of soil. Detailed geotechnical and hydrogeological site characterizations would identify this hazard type in advance of facility design and should be considered necessary to avoid or design with specific consideration to the hazards.

3.2.3.2 Tsunamis and seiches

Tsunami and seiches are types of waves generated by the rapid displacement of water. Tsunamis are often caused by vertical movement of the sea floor during an undersea earthquake, by landslides, or by volcanic eruptions. Meteotsunamis may occur because of meteorological conditions. However, they are often much smaller (NOAA 2024). A 1949 tsunami caused by landslides that were triggered by the Olympia earthquake resulted in 6- to 8-foot waves in the Tacoma Narrows (City of Seattle 2024). An earthquake along the CSZ may create waves nearly 100 feet high, while a tsunami induced by an earthquake on the Seattle Fault could travel 1 mile inland and be up to 16.4 feet high. A 2009 landslide above Lake Roosevelt triggered an inland tsunami with an estimated height of 30 feet (Burnett 2009). Landslide-induced tsunamis may occur within the study area where there are large bodies of water near physical features capable of sudden mass wasting (the movement of soil and rock downhill due to gravity). The potential for tsunami occurrence throughout the study area is widespread near waterbodies (Figure 5).

Seiches are standing waves in waterbodies that are often caused by seismic waves or atmospheric pressure. Seiches can occur thousands of miles away from an earthquake epicenter (City of Seattle 2024). For example, seiches were observed in Devils Hole in Death Valley National Park in 2022 due to an earthquake 1,500 miles away (National Park Service 2022). Inland lakes such as Lake Union in King County are particularly vulnerable to seiches. The most damaging seiches would likely be caused by an earthquake on the CSZ.

Detailed analysis should be conducted for potential facility locations adjacent to waterbodies to assess potential inundation risks related to tsunamis and seiches.

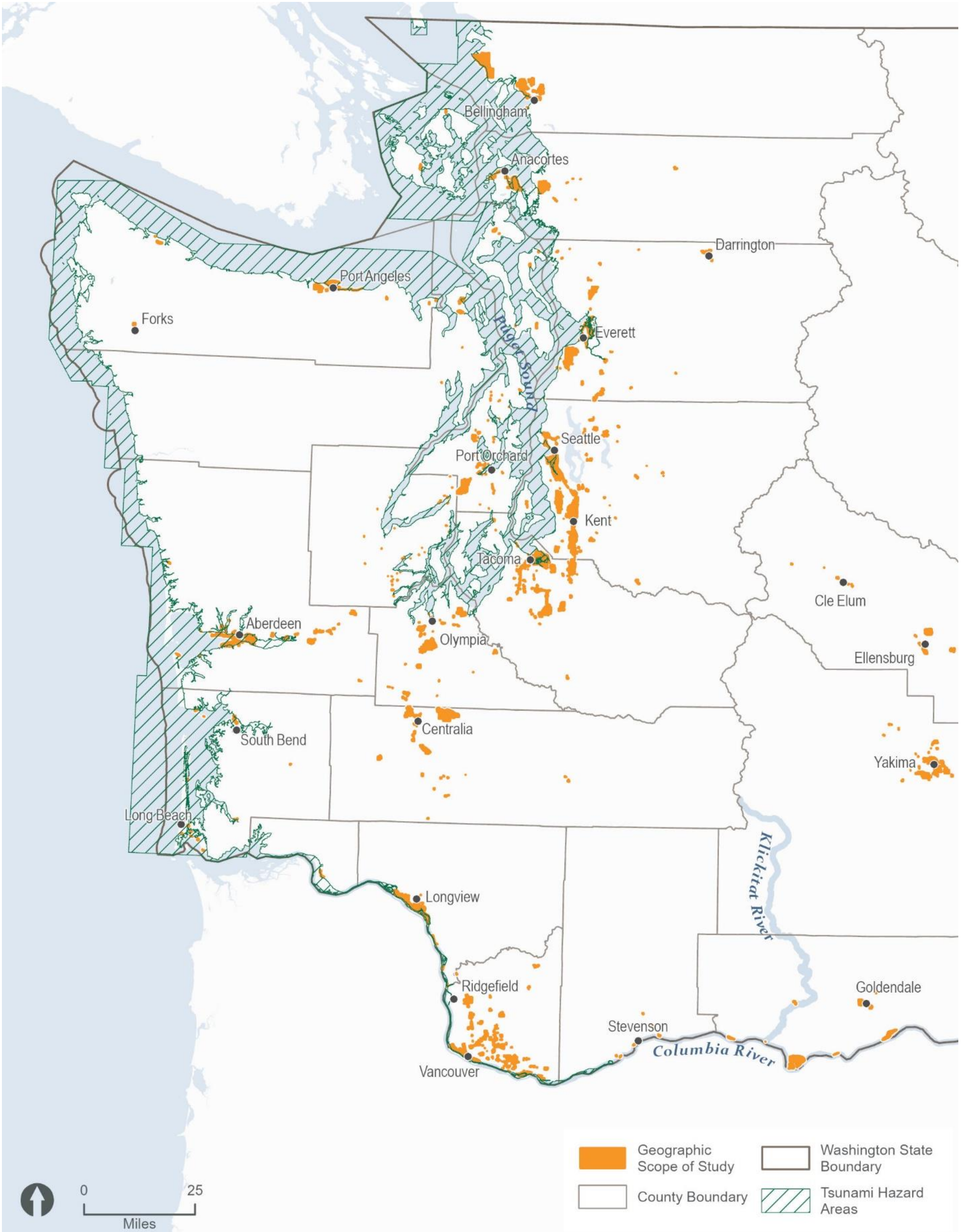

Figure 5. Tsunami hazard areas in Washington State

3.2.3.3 Volcanic hazards

The USGS recognizes active or potentially active volcanoes in and around Washington at Mt. Saint Helens, Glacier Peak, Mt. Rainier, Mt. Adams, Mt. Baker, and Mt. Hood (USGS 2024c). The effects of a volcanic eruption could be far reaching and cause damage to facilities anywhere in the state. In consideration of the severity of eruption impacts and relative activity levels, the USGS considers the threat level of the identified volcanoes to be High (Mt. Adams) to Very High (all others listed) (Ewart et al. 2018). Unlike seismic hazard aggregation used to define seismic design maps, an aggregated probability of eruption in a defined time period (e.g., 100 years) considering all Pacific Northwest volcanoes is not available; however, the USGS notes that "during the past 4,000 years eruptions have occurred at an average rate of about 2 per century" for Cascade Range volcanoes (Myers and Driedger 2008).

Ashfall

All explosive volcanic eruptions generate small particles of rock and naturally formed glass that can be projected upwards and carried downwind of the eruption for thousands of miles. The scope of impacts from ashfall are driven by wind, weather, and the size and orientation of the eruption. Ashfall from past eruptions is found throughout the study area, except in far western Washington. The fallout from falling ash is dependent on several factors, including the scale of the volcanic event, ejection direction, and wind or weather conditions at the time of the eruption. Large quantities of falling ash may be heavy enough to threaten building or vehicular damage. Ashfall can have enormous impacts on economies and modern industrial processes. Much of the economic damage from the 1980 eruption of Mt. St. Helens was caused by ashfall (Kenedi et al. 2004).

Flows and slides

Various types of flows and slides pose substantial risks, particularly in regions with active Cascade Range volcanoes. USGS and DNR maps identify several volcanic flow or slide hazard areas on Mt. Baker, Glacier Peak, Mt. Rainier, Mt. St. Helens, and Mt. Adams.

Volcanic landslides and debris flows

Volcanic landslides and debris flows occur when the flank of a mountain or volcano collapses and travels downslope. These landslides do not need an eruption to occur and are influenced by weak bonding between layers of ash and rock and the circulation of hydrothermal fluids on a volcano (DNR 2024c). The landslides incorporate water, snow, vegetation, and buildings during the slide out. Debris flows can become lahars (large, more violent flows) with sufficient water input (USGS n.d.). The steep slopes of Cascade Range volcanoes are susceptible to debris flows, especially during heavy rainfall or volcanic activity. Debris flows can mobilize large volumes of rock, soil, and other materials, endangering communities located downhill from these volcanoes through direct and indirect impacts (such as blocking or diverting existing surface waters).

Lahar

Lahars are most commonly generated during volcanic eruption but can occur at almost any time. Lahars occur when sufficient water, volcanic ash, and rock mix and flow downhill. They can be initiated by heat from a volcano, pyroclastic flows, and surface water events (snow or ice melt, or flood events). In Washington, lahars can travel 120 miles per hour and reach the Pacific Ocean (DNR 2024c). The Osceola Mudflow (lahar) occurred following a small eruption on Mount Rainer nearly 5,600 years ago. The lahar traveled 70 miles and covered 212 square miles. DNR has developed generalized lahar hazard maps for each of the five active volcanoes in Washington.

Lava flows

Lava flows, products of volcanic eruptions, are masses of molten rock that pour onto the earth during an effusive eruption. Lava flows are variable and depend on the type of lava, discharge during eruption, and the characteristics of the volcanic vent and surrounding topography (USGS 2024d). Volcanoes in the Cascade Range can produce different types of lavas and therefore different types of lava flow (DNR 2024c). While lava flows from Cascade Range volcanoes typically move slowly, they can still pose risks to vegetation, infrastructure, and communities in their paths. Past eruptions of volcanoes like Mt. Rainier and Mt. Hood have produced lava flows that affected surrounding areas.

Pyroclastic flows

Pyroclastic flows are a mixture of particles broken during explosive volcanic eruptions capable of rapid travel from a volcano. These flows can travel long distances, engulfing anything in their path with intense heat and volcanic ash. Although pyroclastic flows are less common from Cascade Range volcanoes compared to other volcanic hazards, they remain a threat to nearby communities during explosive eruptions. Pyroclastic flows during the 1980 eruption of Mt. St. Helens covered nearly 230 square miles (DNR 2024c).

Seismicity due to volcanoes

Volcanoes are responsible for two types of earthquakes: volcanic-tectonic earthquakes and volcanically caused, long-period earthquakes. Volcanically triggered earthquakes are typically smaller than non-volcanic earthquakes. However, they still have the potential to produce earthquakes of sufficient magnitude to damage structures. Volcanic-tectonic earthquakes occur due to slip on a nearby fault. These types of earthquakes are more likely to occur in response to crustal strain and weakness associated with the presence of a volcano. Volcanically caused, long-period earthquakes are caused by movement of magma or other fluids within a volcano; increased pressure causes rock failure, resulting in small earthquakes (PNSN 2024). Earthquake data around the Cascade Range volcanoes is monitored by USGS and the Cascade Volcano Observatory. Seismicity due to volcanos can also potentially trigger landslides and debris flows.

3.2.3.4 Landslides

Landslides can pose catastrophic threats to buildings, structures, and people, and may occur in varying levels of severity ranging from fast-moving debris flows to slow soil creep. The origination of landslides may be connected to a variety of drivers that may be natural or anthropogenic in origin; however, they generally occur when driving forces outweigh the resisting forces in a rock or soil mass and the two forces fall out of equilibrium. Topography, soil and rock material types, moisture conditions, precipitation, and vegetation are all factors in the slope equilibrium conditions that increase or decrease landslide susceptibility in a given area. In general, slope instability risks are closely related to areas with topography and slopes steeper than about 20%; however, soil, geology, and other local conditions in an area greatly impact this geologic hazard type.

Washington state is one of the states most susceptible to landslides (Figure 6 through Figure 10). Often associated with flooding and intense rainfall or snowmelt events, landslides may occur when rock or sediment forms an impermeable layer. Pressure and friction are reduced when water accumulates, and sliding is facilitated (Miller and Cowan 2017). Landslides are more common on steep slopes that experience heavy rainfall. Due to the prevailing climate in Washington, landslides are more commonly associated with areas west of the Cascades and locally on the windward sides of mountains. Landslide potential may be increased following wildfire as well as through anthropogenic activities. As discussed above, landslides can be triggered by earthquakes and volcanic processes.

The Washington Geological Survey maintains the best available data for landslide hazards in Washington. A compilation of previous landslides within Washington prepared in 2018 was used by the *Washington State Enhanced Hazard Mitigation Plan* to prepare a hotspot map demonstrating overall landslide activity within a region (FEMA 2023). A more focused approach to identification and management of landslide hazards, including field reconnaissance and geotechnical investigations, would occur during site characterization and design. There are county-level landslide mapping efforts underway that could be reviewed during site characterization and design.

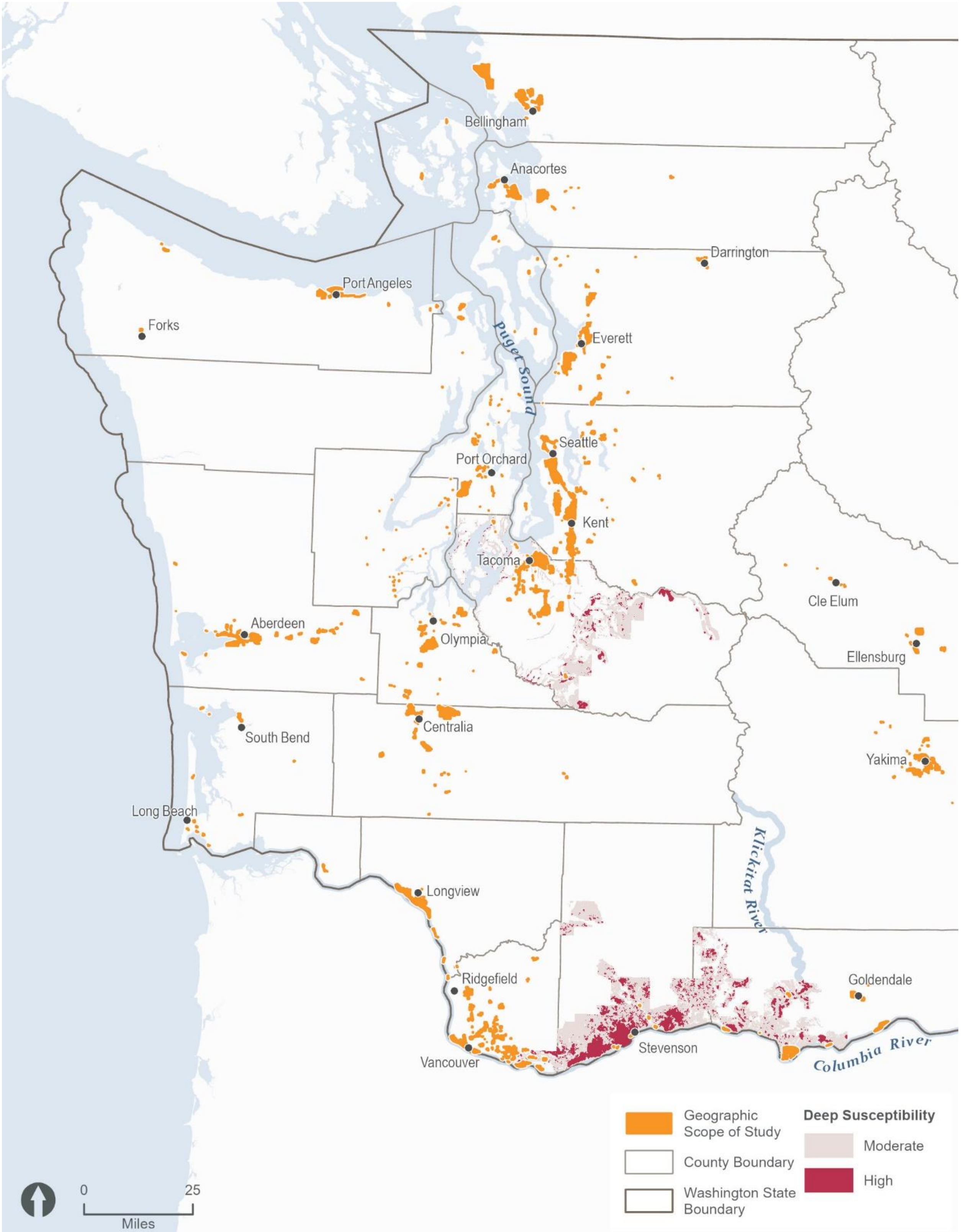

Figure 6. Western Washington State landslides - deep susceptibility

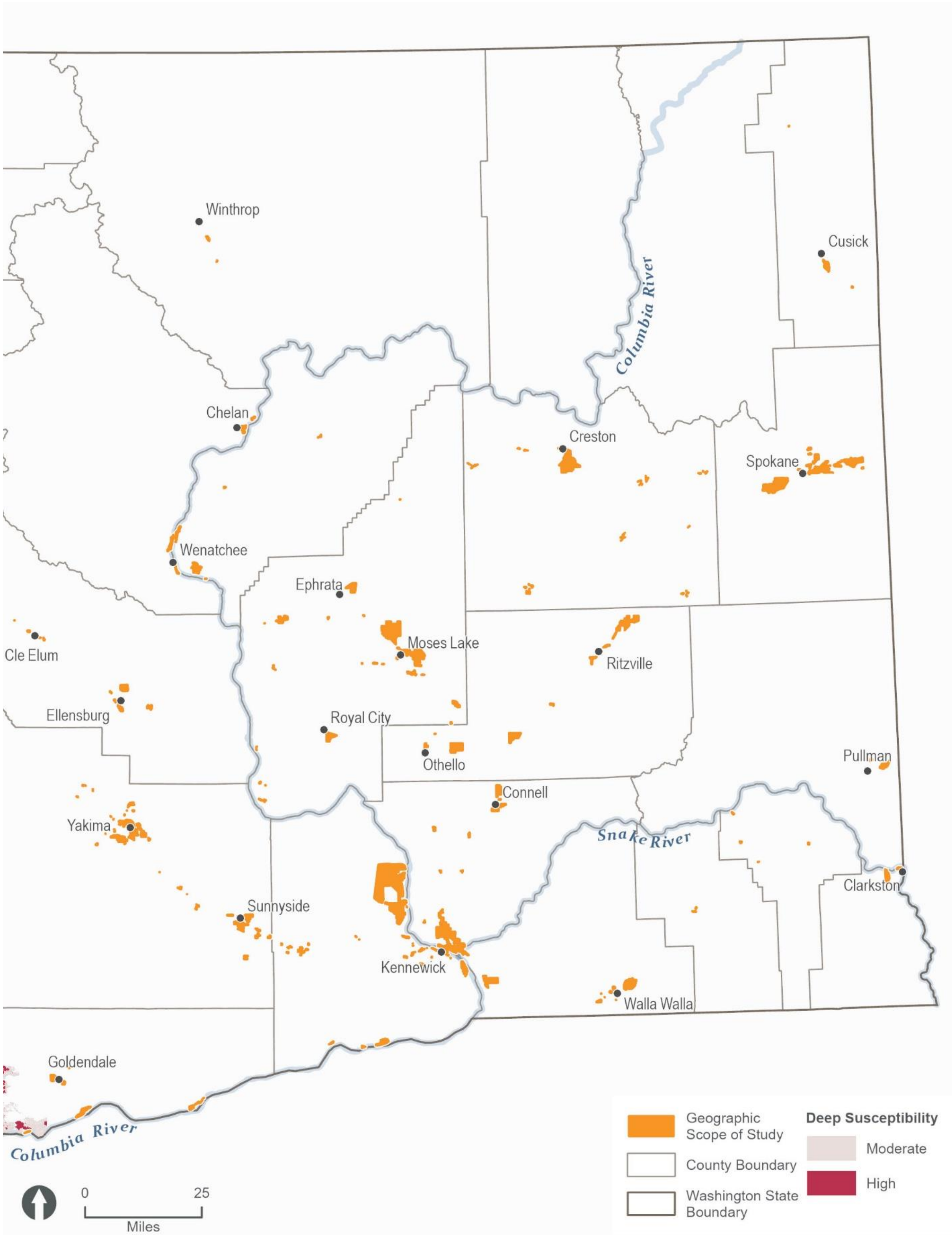

Figure 7. Eastern Washington State landslides - deep susceptibility

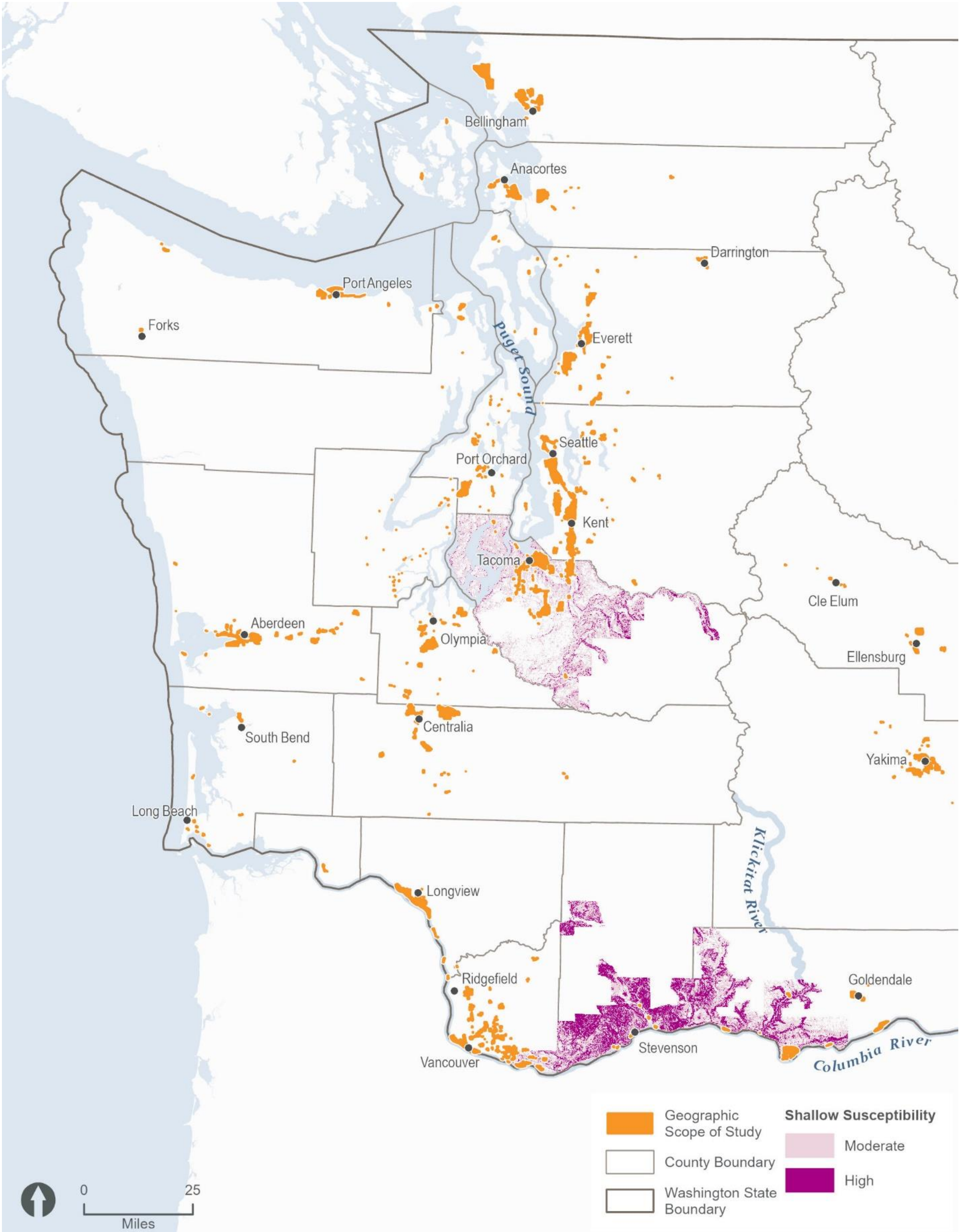

Figure 8. Western Washington State landslides - shallow susceptibility

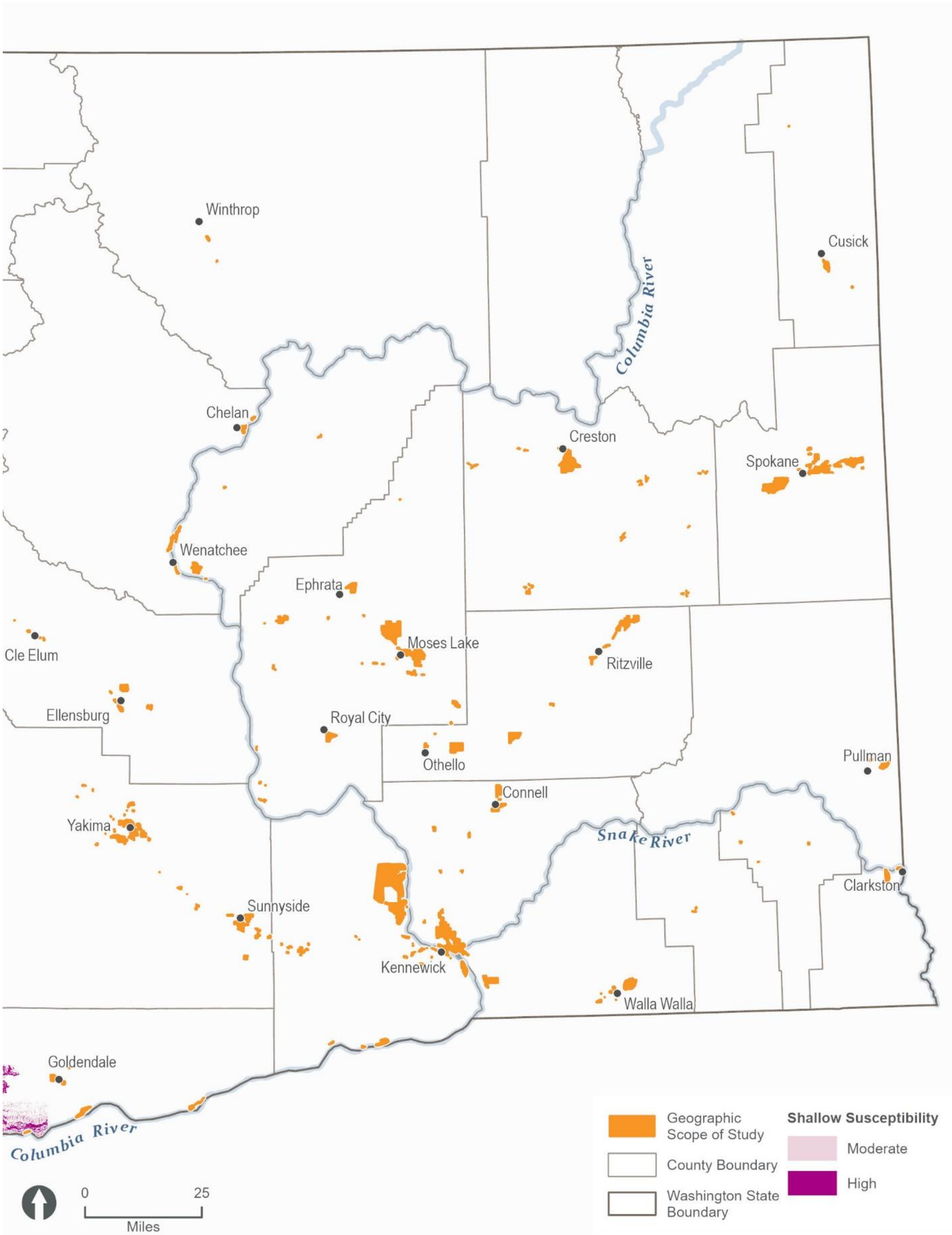

Figure 9. Eastern Washington State landslides - shallow susceptibility

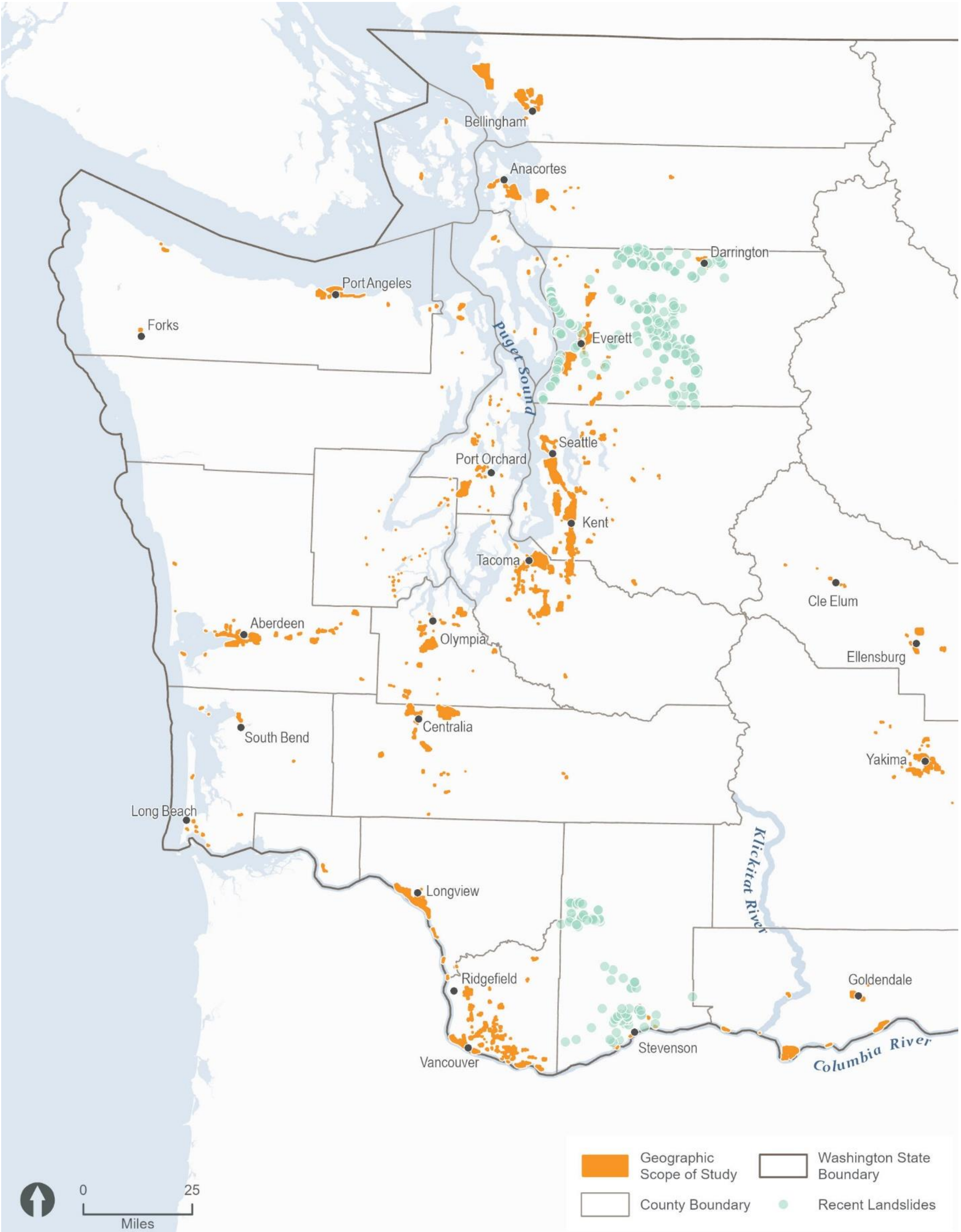

Figure 10. Recent landslides in Washington State

3.2.3.5 Subsidence

The USGS generally defines land subsidence as the gradual settling or sudden sinking of the Earth's surface due to removal or displacement of subsurface earth materials. Principal causes include:

- Mining
- Aquifer-system compaction associated with groundwater withdrawal
- Drainage of soils
- Natural compaction (USGS 2024e)

Subsidence caused by drainage of soils typically occurs when soils rich in organic carbon are drained. This subsidence is typically caused by microbial decomposition, which, under drained conditions, readily converts organic carbon to carbon-dioxide gas and water (USGS 2000). Soils rich in organic carbon soils are mapped throughout the Puget Lowland, along the margins of aquatic resources. Subsidence due to natural compaction (sinkholes and permafrost) are unlikely to occur without failure of nearby infrastructure (e.g., watermain breaks) because of the limited extent of limestone and the lack of permafrost within the study area.

Water for construction, operation, and decommissioning of green hydrogen facilities may come from groundwater sources, including the potential for on-site groundwater wells. Refer to the *Water Resources Technical Appendix* for additional information on water resources. Subsidence due to groundwater withdrawal may be considered active or quick response subsidence (which occurs in coarser-grained sediments), or it may be residual subsidence, which occurs in finer-grained sediments (Galster 1989). The Washington State Department of Ecology (Ecology) administers the Underground Injection Control program (Chapter 173-218 Washington Administrative Code[1] [WAC]; Ecology 2024b), which is authorized by the Safe Drinking Water Act. Subsidence control wells are administered under this program to reduce or eliminate subsidence associated with the removal of groundwater due to construction activities (Ecology 2024b).

Underground coal mine workings are estimated to underly at least 50,000 acres of western and central Washington. The means and methods used in mining generally dictate the type of subsidence that may occur. Mine-related subsidence is typically aerial or cave-in (Galster 1989). The Washington Geological Survey maintains nearly 1,100 maps representing about 230 coal mines in the state. Coal mine maps are grouped by county and can be accessed through their websites (DNR 2024d). Of the mines in Washington, five overlap the study area and one is adjacent (DNR 2023). Sites with the potential to experience subsidence due to underground mines are likely to be eliminated during site characterization.

3.2.3.6 Sea-level rise

Increases in sea level, or sea level rise (SLR), occurs due to two main processes: (1) thermal expansion, in which warm water expands, and (2) melting of land ice. SLR does not occur

[1] https://app.leg.wa.gov/wac/default.aspx?cite=173-218

uniformly and is often described as relative sea level rise (RSLR) or the long-term average sea surface height relative to a specific point on land. RSLR incorporates the effects of SLR, with respect to any subsidence or uplift (e.g., seismic, isostatic rebound) that may be occurring locally (Lavin et al. 2020). SLR may increase coastal erosion and can degrade habitat and ecosystems that can buffer the effects of storms and flood events. The Washington Coastal Resilience Project has developed SLR projects to support coastal impact assessments (Ecology 2024a). RSLR may affect coastal locations throughout the study area.

3.3 Potentially required permits and approvals

Construction, operation, and decommissioning activities for typical green hydrogen facilities would potentially require the following permits related to earth resources:

- **Clean Water Act Section 402 National Pollutant Discharge Elimination System (NPDES) Construction Stormwater Permit (Ecology):** Required for construction that disturbs more than 1 acre of land and has potential to discharge stormwater to state surface waters or construction disturbance of any size that has the potential to be a significant contributor of pollutants or may be expected to cause a violation of any water quality standard (including groundwater standards). Ecology requires that Stormwater Pollution Prevention Plans (SWPPPs) be prepared and implemented to ensure compliance with state and federal water quality standards.
- **Clean Water Act Section 402 NPDES Industrial Stormwater Permit (Ecology):** Required to operate sites with certain industrial activities that could discharge stormwater pollutants to surface waters of the state or certain facilities that have the potential to be significant contributors of pollutants or may be expected to cause a violation of any water quality standard (including groundwater standards). Requires a SWPPP.
- **Clean Water Act Section 402 NPDES Individual Permit (Ecology):** Ecology prepares individual NPDES water quality permits for one entity when discharge characteristics are variable and do not fit a general permit category.
- **Construction and Development Permits (e.g., road access, grading, building, mechanical, lights, signage) (local agency):** Various project construction activities and placement of new or modification of existing facilities would be subject to local permits to ensure compliance with land use, grading and drainage, stormwater management, building standards, fire codes, etc.
- **Environmental Permits (e.g., Critical Areas, Shorelines) (local agency):** Must be obtained for construction and development activities within designated critical areas and shorelines regulated by local jurisdictions. Projects would be reviewed under local critical areas ordinances and Shoreline Master Programs.

3.4 Green hydrogen production facility

This section describes potential impacts of green hydrogen production facilities. For the purposes of the PEIS, the estimated footprint of a green hydrogen production facility, based on existing facilities in other areas, ranges from 1 acre to 10 acres, depending on the production method, type of facility, and layout of external pipes and tanks, a parking area, and security fencing. The estimated height of structures is up to 100 feet.

A green hydrogen production facility would typically include a connection to the electricity grid to power all, or a portion of, the facility's equipment needs and buildings. Facilities typically connect to the main transmission line through distribution lines that can be up to 100 feet high and between 1 and 8 miles in length, which would be determined by the project developer based on the distance between a selected site and existing electricity grid infrastructure. This technical appendix includes evaluation of impacts associated with distribution line connections to main transmission lines.

Off-site access roads may be needed to connect a facility to the existing state routes. Most of study area is less than 10 miles from a state route (63% within 1 mile and 99% within 10 miles). If needed, the project developer would determine the length of off-site access road needed, based on the distance between a selected site, existing road infrastructure, and coordination with state and local departments of transportation.

3.4.1 Impacts from construction and decommissioning

3.4.1.1 Soil resources

Site characterization activities completed in advance of construction would include desktop analysis and feasibility and site studies. Likely impacts during site characterization would include ground disturbance from grading for access roads, soil coring, and geotechnical investigation. If existing structures are on site, appropriate demolition considerations would be made during site characterization.

Impacts on soil resources during construction would primarily be a result of excavation, blasting, vegetation removal, and grading for foundations, pilings, and utility and underground service line trenches. Limited excavation and vegetation removal is expected for distribution lines, as they are assumed to be placed in existing road rights-of-way or co-located with existing distribution lines. The stockpiling of site soils, importing of off-site soils, placement and compaction of low-permeability materials, and the use of aggregate resources and structural concrete from local suppliers could occur.

Impacts associated with the above-described activities include the increased potential for soil compaction, mixing of soil horizons, surface erosion and runoff, sedimentation of nearby waterways, and soil contamination. Changing native soil conditions through compaction, grading, and incorporation of stormwater controls could alter surface runoff patterns and volumes, which in turn could lead to greater localized erosion potential and increased sedimentation of nearby waterways. Sand or rock material transported by wind would be minimized through incorporation of best management practices (BMPs) to address potential for erosion. The potential loss of vegetation during clearing would reduce the mechanical ability of root structures to resist the erosive effects of wind and water, also resulting in increased erosion of soil materials. The degree of impact from ground-disturbing activities also depends on site-specific factors, such as surface soil properties, vegetation density and type, slope angle and extent, distance to waterways or water collection infrastructure, and weather. Stormwater permits would require stormwater pollution prevention plans to address erosion and ensure compliance with state and federal water quality standards.

Green hydrogen facilities are expected to be built on relatively flat areas, with slopes less than 15%. Localized slope instability resulting from over-steepened cuts, fills, or grading related to roads increases the potential likelihood of landslide generation. Whereas the inherent risk of landslides is considered in the geological hazard types, it is also important to consider how the effects of hydrogeological alterations, site preparation, grading, cutting, and filling could contribute to unstable conditions as a result of facility development.

Construction of site access, on-site and off-site access roads, foundations, subsurface utility installation and underground service lines may require excavation of soil and rock materials, depending on the site, which are assumed to be reused on site and not be hauled offsite. Additionally, development of a green hydrogen facility site could require importing aggregate (cement and/or gravel) for construction of concrete or hard-pack gravel equipment pads. Impacts on aggregate resources in the vicinity would primarily include a temporary reduction in available supply of those materials for other projects; however, the relative impact on those resources would be dependent on the number of local and regional suppliers as well as the number of other projects to be constructed around the same timeframe.

Construction and decommissioning activities could result in spills, which can lead to contamination of soil, groundwater, and surface water, causing a reduction in soil aeration and water infiltration. Application of herbicides and dust control stabilizers could introduce contaminants into soils. BMPs and other preventive measures, including those found under the NPDES program, would reduce or avoid spills and unintended contamination. Additionally, Washington State's Model Toxics Control Act dictates the handling and cleanup of hazardous materials. Releases would need to be contained, assessed, and remediated, with hazardous waste transported and disposed of according to state and federal regulations. Accidents or failures during construction that could result in the release of hazardous materials are rare and are unlikely to happen at a scale that could result in risk of environmental contamination.

Construction and decommissioning would result in localized ground disturbance, potential changes in local drainage patterns and borrow of construction materials, potential slope stability impacts, and unlikely subsidence. In general, impacts during construction would be greater for facilities that require a large footprint, due to the increased disturbance area and potentially greater number of large vehicles and equipment.

At the end of construction, temporary buildings and materials storage facilities would be removed and disturbed areas revegetated in accordance with applicable erosion and sediment control best management practices.

Decommissioning a green hydrogen production facility may result in temporary impacts associated with site clearing and cleanup, including grading, demolition, and material off haul.

Impacts from these activities may be similar to those generated during construction, as described above; however, they would be of lesser intensity and duration because of the availability of previously developed access routes and staging areas, and site restoration activities would include re-establishing native vegetation. The time to achieve site restoration and native vegetation re-establishment would vary based on facility location, anticipated to be generally slower in drier, more variable temperature zones east of the Cascades.

Through compliance with laws and permits, and with implementation of measures to avoid and reduce impacts, construction and decommissioning activities would result in **less than significant impacts** to soil resources.

3.4.1.2 Geologic hazards

Geologic hazards are not generated by construction or development activities, but rather are intrinsic to the natural environment.

Green hydrogen production facilities are expected to be built on relatively flat areas, with slopes less than 15%. The effects of geologic hazards during construction are generally limited to those associated with increasing slope instability and landslide risks, as described in Section 3.2.3.4. Construction activities that can potentially increase this risk are mainly related to building roads and include grading that results in steepening of slopes, cutting mid-slope or at the base of a slope (e.g., for an access road or building pad), and alteration of drainage patterns and water infiltration rates. The consequences of landslides can extend to surficial waters, impacting them through diversion or sedimentation, as well as affecting surrounding buildings, infrastructure, or people.

The temporary nature of construction for an individual project reduces the likelihood of a significant volcanic event occurring during construction. Channelized volcanic hazards such as pyroclastic flows or lahars could impact the study area. An extensive seismic network has been installed at active volcano sites throughout the region to provide advance warning of a potential volcanic eruption, which would allow for demobilization or safe relocation of select construction equipment as well as relocation of personnel. Volcanic impacts associated with ash fall, though highly dependent on wind conditions at the time, may include ash accumulation on structures and transportation routes and clogging of filters and equipment; dispersal of fine, abrasive particles in air and water; and disruption of vegetation. Following an eruption, it is likely that construction activities would resume when regionally viable and site conditions are safe to do so.

The likelihood of a severe seismic event during the construction period for an individual project is very low, and the damage to construction facilities would be dependent on the stage of construction and the severity of the event. An event midway through construction could result in collapse of temporary construction support systems or toppling of unsecured equipment or materials. Such an event would increase the potential for releases or spills, including any herbicides and dust control stabilizers stored on site. These types of impacts and risk mitigation are further discussed in the *Environmental Health and Safety Technical Appendix.*

A tsunami or seiche event during construction for an individual project is unlikely, and the damage to facilities and impacts to construction associated with an event are dependent on the stage of construction and the severity of the event. A tsunami or seiche could cause flooding, erosion, and debris that could damage construction support systems or topple unsecured equipment or materials.

Use of groundwater for construction could result in localized water table drawdown, which is a potential cause of subsidence. Due to the limited size of the facility footprints (1 to 10 acres), subsidence would be unlikely to be widespread beyond the facility footprint. Subsidence due to past mining activity, drainage of soils, and natural compaction is unlikely to occur within the timeframe of facility construction and could potentially be eliminated during site selection.

Through compliance with laws and permits, and with implementation of measures to avoid and reduce impacts, construction and decommissioning activities would result in **less than significant impacts** from geologic hazards.

3.4.2 Impacts from operation

3.4.2.1 Soil resources

Operational activities would include little to no ground disturbance to maintain access, fencing, buildings, and vegetation. Increased potential for soil erosion could be present along roads, parking areas, buildings, or other on-site improvements where runoff or wind may be channeled around impermeable or unyielding elements. Sand or rock material transported by wind would be minimized through incorporation of BMPs to reduce and eliminate erosion and would subside following completion of facility maintenance and any necessary site stabilization measures (e.g., hydroseeding or revegetation).

Site operations could result in changes in local drainage patterns and limited borrow of construction materials for maintenance but are unlikely to result in localized ground disturbance, slope stability impacts, or subsidence. New or expanded impervious surfaces for buildings and access roads, combined with on-site chemical storage and the presence of maintenance vehicles and equipment on the site, would create potential for pollutants to enter soils and waters through stormwater discharges or inadvertent spills and degrade soil resources. Stormwater permits would require stormwater pollution prevention plans to address erosion and ensure compliance with state and federal water quality standards.

Similar to construction, permits and regulations require safe handling practices that would preclude the use of potentially hazardous chemicals and herbicides; however, the potential for an unintentional spill would remain. Spills to soil would likely be of small quantities and within containment areas or able to be cleaned up. If a spill of hazardous materials were to occur, the liquid would evaporate and disperse, decreasing the likelihood of direct contamination to soil and water resources.

Operation and maintenance of green hydrogen production facilities could involve the use and on-site storage of pollutants associated with operation of typical green hydrogen facilities, including fuel (gasoline and diesel fuel), oil, grease, 6PPD (N-[1,3-dimethylbutyl]-N'-phenyl-p-phenylenediamine), coolant, and hydraulic fluid. For alkaline electrolyzers, potassium hydroxide (or another similar electrolyte) would be stored on site for operation of the electrolyzer. Electrolysis, steam-methane reforming, and bio-gasification would generate wastewater as part of hydrogen production. All wastewater discharge requires a permit, whether it is disposed to surface or groundwater or to a municipal sanitary sewer. The pyrolysis production process would not produce wastewater.

Through compliance with laws and permits, and with implementation of measures to avoid and reduce impacts, operation activities would likely result in **less than significant impacts** to soil resources.

3.4.2.2 Geologic hazards

The impacts of geologic hazards, particularly those associated with seismicity and volcanic activity, are primarily considered during the operational life of a facility. While the various elements of a facility are required to be designed to some level of seismic performance, if earthquake ground-shaking intensity exceeds design standards, damage to facility infrastructure could occur. Depending on the severity of the seismic event, facilities could be temporarily or permanently decommissioned due to structural failure. Additionally, ground shaking may dislodge or topple materials stored on site in support of operations and maintenance activities, which could result in a fluid release or spill. A tsunami or seiche could cause flooding, erosion, and debris that could damage facilities. Saline waters could cause corrosion of materials.

Potential ashfall hazards during operation cannot be avoided via site selection due to the inability to predict actual wind speed and orientation at the time of a potential eruption. The impacts of ashfall on a facility may include general accumulation and potential corrosion of surfaces, damage to ventilation systems, damage to site equipment and electronics, and temporarily reduced or suspended operations.

While it is possible to avoid mapped landslide hazards during siting, the potential exists for sloughing or raveling of near-surface soils on cut-and-fill slopes during sustained or extreme rainfall events. Such instances entail standard operation and maintenance activity to clean up and repair slopes but are not expected to result in damage to the facility or impair general facility operation.

There is a potential for volcanic flows or slides to affect facilities. The potential for a volcanic eruption is often understood months prior to the occurrence of an event. As a result, it would be expected that any facilities that could be affected by an eruption and the resulting ashfall, slides, and flows would reduce operations and relocate and protect equipment as a precaution. Volcanically induced seismicity would not be expected to be of sufficient magnitude to exceed the seismic design standards of a facility in compliance with building codes.

During operation, SLR could cause an increased need for operation and maintenance requirements over the lifetime of the facility. For example, increased flooding would necessitate facility hardening and fortification, which would need to meet state and federal requirements, and increased maintenance of equipment and materials that could degrade prematurely.

Subsidence due to groundwater withdrawal would need to be considered during project-level review. Subsidence due to natural compaction is unlikely unless caused by failure of other infrastructure. Subsidence due to drainage of soils may occur in former wetland areas with soils rich in organic carbon around the Puget Lowland. However, detailed geotechnical site characterizations would likely identify this hazard during site characterization and establish avoidance requirements or specific design considerations to minimize potential impacts.

Through compliance with laws and permits, and with implementation of measures to avoid and reduce impacts, construction and decommissioning activities would likely result in **less than significant impacts** from geologic hazards.

3.4.3 Measures to avoid, reduce, and mitigate impacts

The PEIS identifies a variety of measures to avoid, reduce, and mitigate impacts. These measures are grouped into five categories:

- **General measures:** The general measures apply to all projects using the PEIS.
- **Recommended measures for siting and design:** These measures are recommended for siting and design in the pre-application phase of a project.
- **Required measures:** These measures must be implemented, as applicable, to use the PEIS. These include permits and approvals, plans, and other required measures.
- **Recommended measures for construction, operation, and decommissioning:** These measures are recommended for the construction, operation, and decommissioning phases of a project.
- **Mitigation measures for potential significant impacts:** These measures are provided only in sections for which potential significant impacts have been identified.

Many geologic hazards are mapped (e.g., landslide hazards) and/or have code-based design guidance (e.g., seismic ground shaking), allowing for avoidance and mitigation through careful siting considerations, design, permitting, and BMPs. In a few cases, such as volcanic ash derived from a regional volcanic eruption, the hazard is much harder to map or constrain. While there may not be standard design guidance, and siting to facilitate avoidance for such a hazard would not be practical, the very low likelihood of occurrence typically allows for such hazards to not be considered for design or impact considerations.

Complete avoidance of impacts to soil resources due to ground-disturbing activities is not likely feasible; however, moderate to substantial reduction of impacts could be achieved through careful consideration of impacts, careful design, and limitation of disturbed areas, as well as other measures detailed in this technical appendix.

3.4.3.1 General measures

- **Laws, regulations, and permits:** Obtain required approvals and permits and ensure that a project adheres to relevant federal, state, and local laws and regulations.

  Rationale: Laws, regulations, and permits provide standards and requirements for the protection of resources and the PEIS impact analysis and significance findings assume that developers would comply with all relevant laws and regulations and obtain required approvals.

- **Coordination with agencies, Tribes, and communities:** Coordinate with agencies, Tribes, and communities prior to submitting an application and throughout the life of the project to discuss project siting and design, construction, operations, and decommissioning impacts; and measures to avoid, reduce, and mitigate impacts. Developers should also seek feedback from agencies, Tribes, and communities when developing and implementing the resource protection plans and mitigation plans identified in the PEIS.

  ***Rationale*:** Early coordination provides the opportunity to discuss potential project impacts and measures to avoid, reduce, and mitigate impacts. Continued coordination provides opportunities for adaptive management throughout the life of the project.

- **Land use:** Consider the following when siting and designing a project:
  - Existing land uses
  - Land ownership/land leases (e.g., grazing, farmland, forestry)
  - Local comprehensive plans and zoning
  - Designated flood zones, shorelines, natural resource lands, conservation lands, priority habitats, and other critical areas and lands prioritized for resource protection
  - Military testing, training, and operation areas
  - State-designated harbors
  - Air quality nonattainment areas

  ***Rationale*:** Considering these factors early in the siting and design process avoids and minimizes the potential for land use conflicts. Project-specific analysis is needed to determine land use consistency.

- **Choose a project site and a project layout to avoid and minimize disturbance:** Select the project location and design the facility to avoid potential impacts to resources. Examples include:
  - Minimizing the need for extensive grading and excavation and reducing soil disturbance, potential erosion, compaction, and waterlogging by considering soil characteristics.
  - Minimizing facility footprint and land disturbances, including limiting clearing and alterations to natural topography and landforms and maintaining existing vegetation.

    - Minimizing the number of structures required and co-locate to share pads, fences, access roads, lighting, etc.

  ***Rationale*:** Project sites and layouts may differ substantially in their potential for environmental impacts. Thoughtful selection of a project site and careful design of a facility layout can avoid and reduce environmental impacts.

- **Use existing infrastructure and disturbed lands, and co-locate facilities:** During siting and design, avoid and minimize impacts by:
    - Using existing infrastructure and disturbed lands, including roads, parking areas, staging areas, aggregate resources, and electrical and utility infrastructure.
    - Co-locating facilities within existing rights-of-way or easements.
    - Considering limitations of existing infrastructure, such as water and energy resources.

  ***Rationale*:** Using existing infrastructure and disturbed lands, and co-locating facilities reduces impacts to resources that would otherwise result from new ground disturbance and placement of facilities in previously undisturbed areas.

- **Conduct studies and surveys early:** Conduct studies and surveys early in the process and at the appropriate time of year to gather data to inform siting and design. Examples include:
    - Geotechnical study
    - Habitat and vegetation study
    - Cultural resource survey
    - Wetland delineation

  ***Rationale*:** Conducting studies and surveys early in the process and at the appropriate time of year provides data to inform siting and design choices that avoid and reduce impacts. This can reduce the overall timeline as well by providing information to agencies as part of a complete application for environmental reviews and permits.

- **Restoration and decommissioning:** Implement a Site Restoration Plan for interim reclamation following temporary construction and operations disturbance. Implement a Decommissioning Plan for site reclamation at the end of a project. Coordinate with state and local authorities, such as the Washington Department of Fish and Wildlife, county extension services, weed boards, or land management agencies on soil and revegetation measures, including approved seed mixes. Such plans address:
    - Documentation of pre-construction conditions and as-built construction drawings
    - Measures to salvage topsoil and revegetate disturbed areas with native and pollinator-supporting plants
    - Management of hazardous and solid wastes
    - Timelines for restoration and decommissioning actions
    - Monitoring of restoration actions
    - Adaptive management measures

Rationale: Restoration and decommissioning actions return disturbed areas to pre-construction conditions, promote soil health and revegetation of native plants, remove project infrastructure from the landscape, and ensure that project components are disposed of or recycled in compliance with all applicable laws and regulations.

- **Cumulative impact assessment:** Assess cumulative impacts on resources based on reasonably foreseeable past, present, and future projects. Identify actions to avoid, reduce, and mitigate cumulative impacts. Consider local studies and plans, such as comprehensive plans.

  Rationale: Cumulative impacts can result from incremental, but collectively significant, actions that occur over time. The purpose of the cumulative impacts analysis is to make sure that decision-makers consider the full range of consequences under anticipated future conditions.

3.4.3.2 Recommended measures for siting and design

- Conduct detailed geotechnical engineering, soil, and hydrologic studies to characterize site conditions to identify options for siting and reducing impacts from earthwork.
- Avoid geologic hazard areas such as mapped seismic hazards, landslide hazard areas, surface fault rupture hazard areas, and volcanic flow hazard areas to reduce risk of erosion or damage.
- Identify the level of seismic design, material types, and development strategies needed based on the potential risk of earthquakes. Design facilities to account for current seismic design parameters and building codes.

3.4.3.3 Required measures

This section lists permits and approvals, plans, and other required measures for use of the PEIS, as applicable. See Section 3.3 for more detailed information on potentially required permits and approvals.

- Clean Water Act Section 402 NPDES Construction Stormwater Permit (Washington State Department of Ecology [Ecology])
- Clean Water Act Section 402 NPDES Industrial Stormwater Permit (Ecology)
- Clean Water Act Section 402 NPDES Individual Permit (Ecology)
- Construction and Development Permits (e.g., road access, grading, building, mechanical, lights, signage) (local agency)
- Sand and Gravel Permit General Permit (Ecology)
- Surface Mining Reclamation Permit (DNR)
- Design new roads based on agency requirements and local climate conditions, soil moisture, and erosion potential.
- Develop an Erosion and Sediment Control Plan to prevent transportation of soil materials, particularly into surface waters or wetlands. The plan must be approved by applicable state and local agencies. Plan measures could include:

  - Construct and maintain erosion control in all disturbed areas and along roadways (e.g., silt fences, sediment traps, erosion control surfaces, stabilized road entrances and exit points).
  - Implement vegetative cover or mulching to stabilize exposed soil and reduce erosion risks.
  - Implement regular monitoring and maintenance programs to assess soil erosion, sedimentation, and soil stability throughout the facility life cycle. Promptly implement corrective actions or repairs to address any soil-related issues identified during monitoring activities.
- Develop a Spill Prevention, Control, and Countermeasure Plan if the project has an aggregate storage capacity of oil greater than 1,320 gallons or is located where a discharge could reach a navigable waterbody.

3.4.3.4 Recommended measures for construction, operation, and decommissioning

- Implement grading and excavation techniques that minimize soil disturbance and compaction, such as level grading or cut-and-fill operations with minimal earthmoving.
- Avoid creating potentially unstable slopes during excavation and blasting operations.
- Minimize vegetation removal. Where vegetation or trees are removed, leave root systems intact to minimize soil disturbance and prevent erosion.
- Surface access roads, on-site roads, and parking lots with aggregate with hardness sufficient to prevent vehicles from crushing the aggregate and causing excessive dust or compacted soil conditions.
- Develop an Emergency Response Plan that includes measures to address project-specific geologic hazards, such as landslides or seismic events.
- Utilize weight dispersion mats or weight dispersion equipment in sensitive areas to reduce disturbances to native soil structure and vegetation.

3.4.3.5 Mitigation measures for potentially significant impacts

- No potential significant impacts identified.

3.5 Green hydrogen production facility with co-located battery energy storage system (BESS)

This section describes potential impacts of green hydrogen production facilities with up to two co-located BESS containers. The BESSs would be used to balance loads or to provide up to 15% of power in case of an outage or power quality deviation. One BESS would provide 2.85 megawatts of electricity for 4 hours (a capacity of 11.4 megawatt hours or 11,400 kilowatt hours). Each container would be approximately 60 by 12 feet wide and 10 feet tall.

3.5.1 Impacts from construction, operation, and decommissioning

The types of impacts on soil resources would be the same as those anticipated for projects without a BESS; however, the integration of BESSs introduces specific impacts that differ from green hydrogen production facilities.

Co-locating BESSs would require additional construction-related ground disturbance and increased building footprint relative to facilities with no BESSs. BESS would be installed on gravel or concrete pads designed for secondary containment. A warehouse-type enclosure of a similar scale and size may also be used. A BESS would add another stormwater consideration to a facility and potentially another regulated element to be included in a stormwater pollution prevention plan (SWPPP).

National Fire Protection Association (NFPA) 855 and state regulations require fire and spill containment measures for spills and fire for certain battery types with liquid electrolytes (WAC 51-54A-0322[2] and WAC 51-54A-1207[3]). Additionally, lithium-ion BESSs that are not listed under UL 9540 require a hazard mitigation analysis, which includes an evaluation of potential energy storage system failures and safety-related impacts. Although the likelihood is remote, in the event of a BESS failure, there is a risk of environmental contamination to soil. Emergency response would not typically use water for battery fires, so soil contamination would be limited to the BESS site. However, firefighting water may be used on adjacent facility components to prevent fire spread. State regulations require fire and spill containment measures for spills and fire for lithium-ion batteries (WAC 51-54A-0322 and 51-54A-1207). Spill response measures would be included in the project's Emergency Response Plan and the BESS operations and safety manual as required by NFPA 855. Secondary containment measures would consider the volume of water to be contained, and the methods and materials used for containment and treatment. Stormwater management considerations for BESS are discussed in the *Water Resources Technical Appendix* and hazardous materials are discussed in the *Environmental Health and Safety Technical Appendix.*

Cleanup actions include removal and proper disposal of contaminated soils. Decommissioning of BESS components may necessitate soil testing to determine if failure or contamination has occurred. If contamination is identified, soil remediation efforts would be necessary. Spills would be required to be cleaned up. Other impacts from BESS failure are discussed in more detail in the *Environmental Health and Safety Technical Appendix*.

Geologic hazards described in Section 3.4.2 would apply to facilities with a co-located BESS. The risk of project impacts due to ashfall would increase with the inclusion of a co-located BESS. These include equipment vulnerability due to ash particle infiltration, insulation challenges from ash accumulation, and air intake blockages affecting cooling systems (ACP 2023).

[2] https://app.leg.wa.gov/wac/default.aspx?cite=51-54A-0322
[3] https://app.leg.wa.gov/WAC/default.aspx?cite=51-54A-1207

Through compliance with laws and permits, and with implementation of measures to avoid and reduce impacts, construction, decommissioning and operation activities would likely result in **less than significant impacts** to soil resources and from geologic hazards.

3.5.2 Measures to avoid, reduce, and mitigate impacts

Measures to avoid, reduce, and mitigate impacts would include those identified in Section 3.4.3 and the following measures for BESSs.

3.5.2.1 Recommended measures for construction, operation, and decommissioning

- Implement secondary spill and leak containment measures around BESS components to prevent or minimize the spread of hazardous materials in the event of a failure. Examples include reinforced storage facilities and containment barriers to contain spills and leaks.
- Include spill response measures for BESS failure in the Emergency Response Plan and SWPPP.
- Develop and implement water quality and soil monitoring plans to monitor for contaminants in the event of a BESS failure.

3.6 Green hydrogen storage facility (gas or liquid form)

This section describes potential impacts of green hydrogen storage facilities. A green hydrogen storage facility could store hydrogen in gas or liquid form. Gaseous hydrogen would be stored in stationary, aboveground, cylindrical storage systems, each of which employs different construction materials to achieve maximum working pressure ratings. Liquid hydrogen would be stored in double-walled, vacuum-insulated cryogenic storage tanks. The footprint of storage facilities would depend on the amount of hydrogen to be stored but would be less than 1 acre. This includes the storage tanks, separation space between tanks (if more than one), on-site access roads, and ancillary equipment.

3.6.1 Impacts from construction, operation, and decommissioning

The PEIS assumes that a green hydrogen storage facility could be co-located with a green hydrogen production facility, a standalone facility, at transport terminals, or at an end-use location such as an industrial facility or fueling facility. Hydrogen released from either type of storage would become gaseous and would not impact soil resources.

Through compliance with laws and permits, and with implementation of measures to avoid and reduce impacts, construction, decommissioning and operation activities would likely result in **less than significant impacts** to soil resources and from geologic hazards.

3.6.2 Measures to avoid, reduce, and mitigate impacts

Measures to avoid, reduce, and mitigate impacts described in Section 3.4.3 are applicable to green hydrogen storage facilities.

3.7 No Action Alternative

Under the No Action Alternative, agencies would continue to conduct environmental review and permitting for green hydrogen facilities under existing laws on a project-by-project basis. The potential impacts would be similar to the impacts for the types of facilities described above for construction, operation, and decommissioning, depending on facility size and design, and would likely result in **less than significant impacts**.

3.8 Unavoidable significant adverse impacts

Through compliance with laws and permits, and with the implementation of measures to avoid, reduce, and mitigate impacts, green hydrogen facilities would likely have **no significant and unavoidable adverse impacts** on soil resources and geologic hazards from construction, operation, or decommissioning.

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