Appendix B: Earth Resource Report

For Programmatic Environmental Impact Statement on Utility-Scale Onshore Wind Energy Facilities in Washington State

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For the

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Acronyms and Abbreviations List

BESS	battery energy storage system
BLM	Bureau of Land Management
BMP	best management practice
CSZ	Cascadia Subduction Zone
DNR	Washington Department of Natural Resources
FEMA	Federal Emergency Management Agency
gen-tie line	generation-tie transmission line
GMA	Washington State Growth Management Act
LiDAR	Light Detection and Ranging
PEIS	Programmatic Environmental Impact Statement
RCRA	Resource Conservation and Recovery Act
RCW	Revised Code of Washington
SFZ	Seattle Fault Zone
USC	*United States Code*
USEPA	U.S. Environmental Protection Agency
USGS	United States Geological Survey
WAC	Washington Administrative Code

Executive Summary

This resource report describes the conditions of earth resources in the study area. It also describes the regulatory context, outlines methods for assessing potential impacts, and assesses the potential impacts and actions that could avoid or reduce impacts.

This resource report analyzes the following key features of earth resources in the discussions of the affected environment, potential impacts, and actions to avoid and reduce impacts:

- Geology
- Soils
- Topography
- Unique physical features
- Erosion or accretion
- Geologic and seismic hazards (including tsunamis)

Findings for earth impacts described in this resource report are summarized as follows:

- Construction, operation, and decommissioning for all facilities would have **less than significant impacts** related to soil resources and geologic hazards.
- For all types of facilities considered, through compliance with laws and implementation of measures to avoid and reduce impacts, there would be **no significant and unavoidable adverse impacts** related to earth from construction, operation, or decommissioning of onshore wind energy facilities.

Crosswalk with Earth Resource Report for Utility-Scale Solar Energy

Two Programmatic Environmental Impact Statements (PEISs) are being released at the same time, one for utility-scale solar energy facilities and one for utility-scale onshore wind energy facilities. This crosswalk identifies the areas with substantial differences between the earth resource reports for each PEIS.

Utility-Scale Solar Energy PEIS	Utility-Scale Onshore Wind Energy PEIS (this document)
• Some differences in actions to avoid and reduce impacts	• Larger study area includes consideration of different affected environment areas (e.g. overlap with tsunami inundation zones and additional faults) • Differences in landslide and erosion risks from potential for facilities to be on steeper slopes • Some differences in actions to avoid and reduce impacts

1 Introduction

This resource report describes earth resources within the wind study area and assesses probable impacts associated with the types of facilities (alternatives) including a No Action Alternative. Chapter 2 of the State Environmental Policy Act Programmatic Environmental Impact Statement (PEIS) provides a description of the types of facilities evaluated (alternatives).

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 or energy generation 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 roadways. 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.

1.2 Regulatory context

Table 1 identifies key legal frameworks, regulatory measures, and policies that may impose requirements for environmental protections during all phases of wind energy facility construction, operation, and decommissioning. Not all laws and regulations discussed here may be relevant to every wind energy facility. Each facility would need to be evaluated based on its specific activities, location, regulatory jurisdictions, and contextual factors.

Table 1. Applicable laws, plans, and policies

Regulation, Statute, Guideline	Description
Federal	
Federal Land Policy and Management Act (43 *United States Code* [USC] 1701)	Establishes management guidelines on public lands managed by the Bureau of Land Management (BLM) to protect, develop, and enhance public lands.
Resource Conservation and Recovery Act (RCRA)	This act gives the U.S. Environmental Protection Agency (USEPA) 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.
Clean Water Act (33 USC 1251 et seq.)	The Clean Water Act 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.
Safe Drinking Water Act	Protects public health by regulating the nation's public drinking water supply.
Energy Act	Addresses various aspects of energy production, distribution, and use in the United States. One of its key provisions is the establishment of renewable energy incentives and requirements. It also promotes the development of alternative energy sources, such as wind, solar, biomass, and geothermal energy, through tax credits, loan guarantees, and research funding.
BLM 2016 Wind and Solar Rule	Governs the leasing and development of wind and solar energy projects on public lands managed by the BLM. It encourages development in areas with the highest generation potential and fewest resource conflicts through financial incentives. The rule establishes procedures and requirements for obtaining right-of-way grants for wind and solar energy development, including site-specific environmental assessments and mitigation measures.
National Scenic Areas	These are designated areas of significant natural beauty or cultural importance protected under federal law. This designation imposes certain regulations and management practices aimed at preserving the unique characteristics of the landscape while allowing for compatible land uses such as recreation and tourism.
State	
Chapter 90.03 Revised Code of Washington (RCW), Washington State Water Code	Governs the management, allocation, and protection of water resources within the State of Washington. The framework ensures equitable access to water resources while also protecting the environment and public health.
Chapter 78.44 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.

Regulation, Statute, Guideline	Description
Chapter 36.70A RCW, Washington State Growth Management Act (GMA)	Land use planning framework aimed at guiding growth and development while preserving natural resource lands, protecting the environment, and enhancing quality of life in WA. It requires cities and counties in Washington to develop and implement comprehensive plans that align with the GMA's goals.
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.
Shoreline Management Act	The Shoreline Management Act (Chapter 90.58 RCW and Chapter 173-18 WAC) requires all counties and most cities and towns within the State of Washington to develop a shoreline master program to regulate the use of stream, rivers, and marine shorelines.
Local	
Local critical areas ordinances	Municipal or county-level regulations designated to protect environmentally sensitive areas, such as wetlands, floodplains, steep slopes, and wildlife habitats, within a jurisdiction. Establish standards and guidelines for development in these areas, including setback requirements, vegetation preservation, and mitigation measures to minimize environmental impacts.

2 Methodology

2.1 Study area

The study area for earth resources includes the overall wind geographic study area (Figure 1). Factors relating to earth resources encompass both aboveground, surficial features (topography, soil types, water resources) and belowground features (geologic units, seismic and landslide hazards). Aboveground, buffer zones may be applied to certain hazard types, such as fault lines or landslide-prone areas, to capture potential impacts to adjacent areas related to these types of hazards. Belowground, the study area extends to the depth of the construction work activity types for facilities.

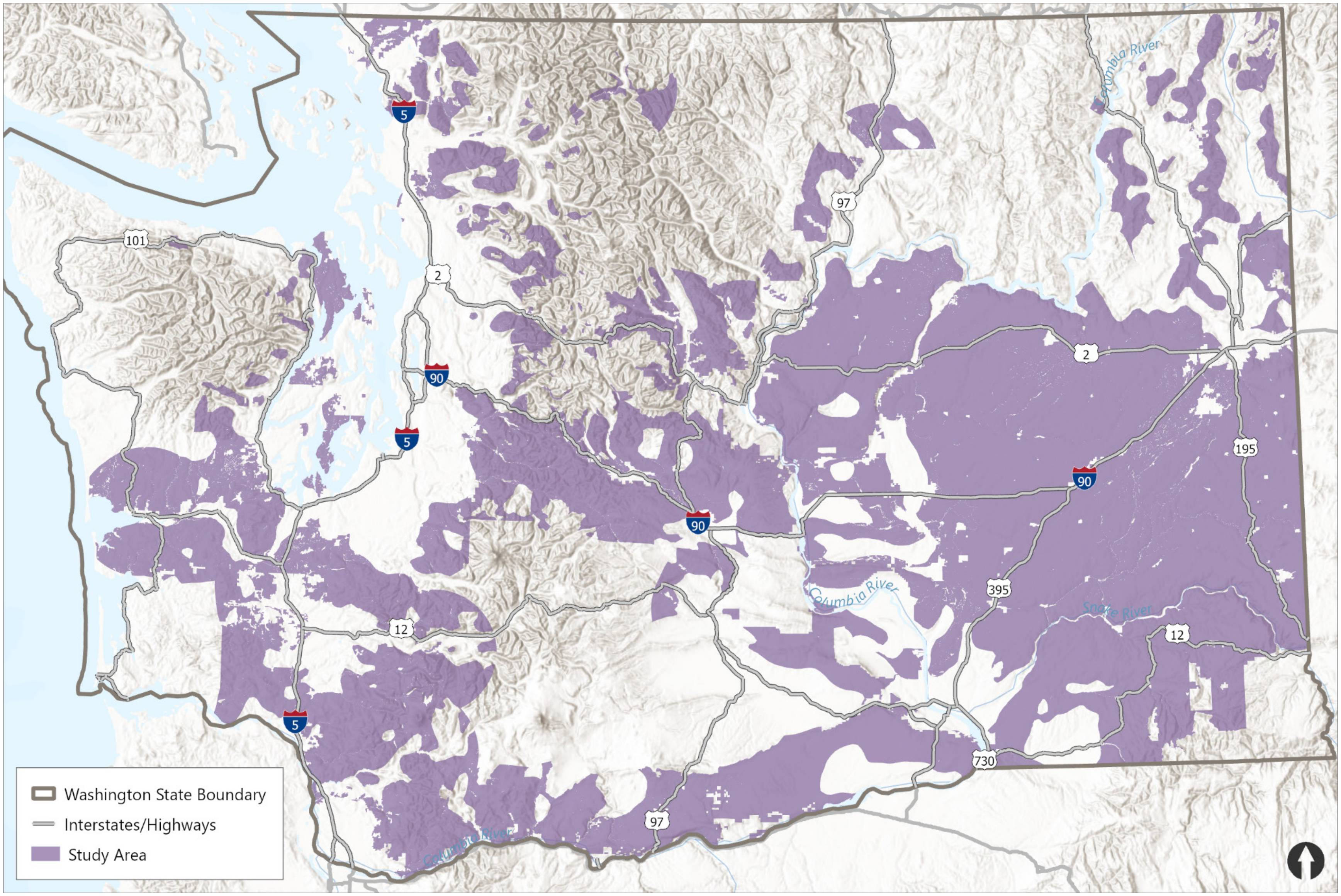

Figure 1. Onshore Wind Energy Facilities PEIS – geographic scope of study

2.2 Technical approach

The technical approach used to determine the environmental impacts of onshore wind energy generation included research, analysis, and large-scale qualitative evaluation of documented conditions and features—such as geographic or geologic hazard areas, topography, soil types, surface waters conditions, groundwater conditions, and land use types—utilizing published maps, literature and datasets. These include surface geology, topography and soils, Light Detection and Ranging (LiDAR) hillshade, geological hazards, surface mining sites, wildfire burn areas, land use types, and others. The onshore wind PEIS study area was selectively overlayed with selected datasets and reviewed to identify the severity and prevalence of potential geohazards and potential resource impacts.

Impacts on earth resources were determined by considering the typical activities required to construct and operate utility-scale onshore wind energy generation facilities and the mechanisms through which those activities could adversely affect underlying and adjacent earth resources. The potential for construction and operation of such facilities to increase soil erosion and/or the risk of occurrence and damage from identified geologic hazards (e.g., landslides) were also considered. Additionally, where identified geologic hazards may not be of such severity that their associated risk outweighs potential siting benefits for other reasons, likely derivative impacts that would be associated with hazard mitigation (e.g., high seismicity area requiring a relative increase in construction materials and/or ground disturbance due to seismic design requirements) were also qualitatively characterized.

In the context of the PEIS, the technical approach is less site specific and more targeted toward overall facility selection and regional characterization. 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 Department of Natural Resources (DNR) were considered to evaluate features such as faults, steep topography, landslide, tsunami, liquefaction, and other hazard types.

2.3 Impact assessment

The assessment of probable impacts was conducted qualitatively, and impacts were evaluated for activities associated with pre-construction site characterizations, construction, typical operations, and decommissioning of the facility options.

The impact analysis considered the following:

Impacts to soil resources

- The potential for soil erosion from ground-disturbing activities, changes in drainage patterns, or addition of impervious surfaces
- Direct ground disturbance associated with soil and/or rock excavation and grading

- Slope instability from ground-disturbing activities, underground construction, or other activities that could increase local susceptibility to certain geologic hazards
- Subsidence related to tapping, withdrawal, or disturbance of groundwater reserves
- Borrow of construction materials (such as quarried rock, sand, and general fill)

Impacts from geologic hazards:

- Potential for a site to be affected by a naturally occurring geologic or seismic hazards
- Potential for a site to be affected by anthropogenically influenced or altered geologic hazards

The scope of this nonproject PEIS excludes site-specific analysis or a granular approach to evaluating all potential impacts; however, the framework established herein provides a practical methodology for preliminarily assessing and planning potential wind energy facilities. Broadly mapped areas may be identified as more or less susceptible to erosion, landslides, or seismic impacts based on local soil or geology, climate, elevation, adjacent land use types, proximity to wildfire burn areas, or other factors; however, site-specific investigations would be completed to determine specific conditions for individual, future facilities.

3 Technical Analysis and Results

3.1 Overview

This section describes the potential adverse impacts on earth resources that might occur for a utility-scale onshore wind facility analyzed in the PEIS. This section also evaluates actions that could avoid, minimize, or reduce the identified impacts, and potential unavoidable significant adverse impacts.

3.2 Affected environment

3.2.1 Geography and topography

The geography of Washington is diverse and includes several regional environments ranging from coastal lowlands to dense mountain ranges to arid shrubsteppe biomes (DNR 2023a). These regional environments all contain unique geologic and environmental conditions that contribute to their geography.

Western Washington includes the Olympic Peninsula, the Puget Sound lowlands and mountains to the north, and the Willapa Hills and Coast Range Mountains to the south. These areas receive heavy annual precipitation and frequent cloud cover. This region is near the Pacific Ocean and has generally moderate temperatures and weather, except the Olympic Mountain Range, which rises in elevation up to almost 8,000 feet and receives significant, frequent snowfall in the fall through spring months.

Central Washington comprises the Cascade Mountain Range, a range that spans over 500 miles south to north from Northern California to British Columbia and includes sharp peaks, deep glacial values, and a chain of strata cone volcanoes. The western slopes and middle of the range are characterized by heavy annual precipitation and dense vegetation below timberline, while the eastern slopes are characterized by progressively decreasing annual precipitation and vegetation density (moving from west to east).

Eastern Washington, the Columbia basin and plateau, the northeast Blue Mountains, and the Okanogan region of the upper northeast corner of the state are generally higher in elevation and more arid. Lower shrubsteppe plains, river valleys, and rolling hills and mountains are more characteristic of this region. Vegetation in eastern Washington is generally less dense, except in the low mountainous regions northeast of Spokane and in the northeast Blue Mountains. Geography in much of the northern half of Washington has also been heavily influenced by glaciation.

3.2.2 Geology and seismicity

The geologic history of Washington is deeply connected with the themes of continental tectonic forces, volcanism, uplift, and glaciation. In central and eastern Washington, the Missoula floods caused massive flooding events that created geologic features in the Columbia River drainage basin, such as scablands. The Palouse region is also notable for its undulating landscape made of windblown silt (loess), which is rich in nutrients and important for agriculture in the region. Geology and the effects of seismicity differ greatly across the state and are strongly influenced by the effects of the Cascadia Subduction Zone (CSZ), the offshore plate boundary in which the Juan de Fuca Plate is being subducted beneath the North American Plate. This tectonic action has been occurring steadily throughout the last several million years and is ongoing. Sedimentary, metamorphic, and igneous rock deposits and emplacements found across the state are chiefly derived from this tectonic activity. Sedimentary and metamorphic rocks and structures are common throughout western Washington, and igneous volcanic and plutonic rock are commonly associated with the mountain ranges and Columbia plateau. Glacial deposits are common in northern Washington, where the Cordilleran Ice Sheet once extended, whereas much of southeastern Washington generally includes finer-grained loess soil in varying thicknesses perched above massive layers of Columbia River basalts (DNR 2024a). Soil and geology in the mountainous regions of the Cascades, Olympics, northeast Blue Mountains, and North Cascades also vary widely dependent on their location. Surficial geology and soils in the state are shown in Figure 2.

Dense fault complexes are present throughout several areas in the state and offshore. The CSZ is a megathrust fault system capable of producing very large-magnitude earthquakes (viz., Mw 9.0+) and associated tsunamis (DNR 2024b). The coastal regions of the study area include smaller faults such as Langley Hill and Saddle Hill Faults, but the primary seismic impacts would stem from nearby offshore seismicity in the CSZ. Other inland fault systems in western Washington, such as the Seattle Fault Zone (SFZ), Tacoma Fault Zone, Darrington-Devils Mountain Fault, and Whidbey Island Fault Zone, are also active fault systems that are capable of generation of large-magnitude earthquakes. Much of central, southern, and southeastern Washington along the Columbia River Gorge region is also seismically active. Faults and fault systems from Ellensburg to Yakima, Goldendale, the Tri-Cities, and Walla Walla are widely distributed across the study area. The locations of all mapped active faults in the state and seismic design categories are included in Figure 3.

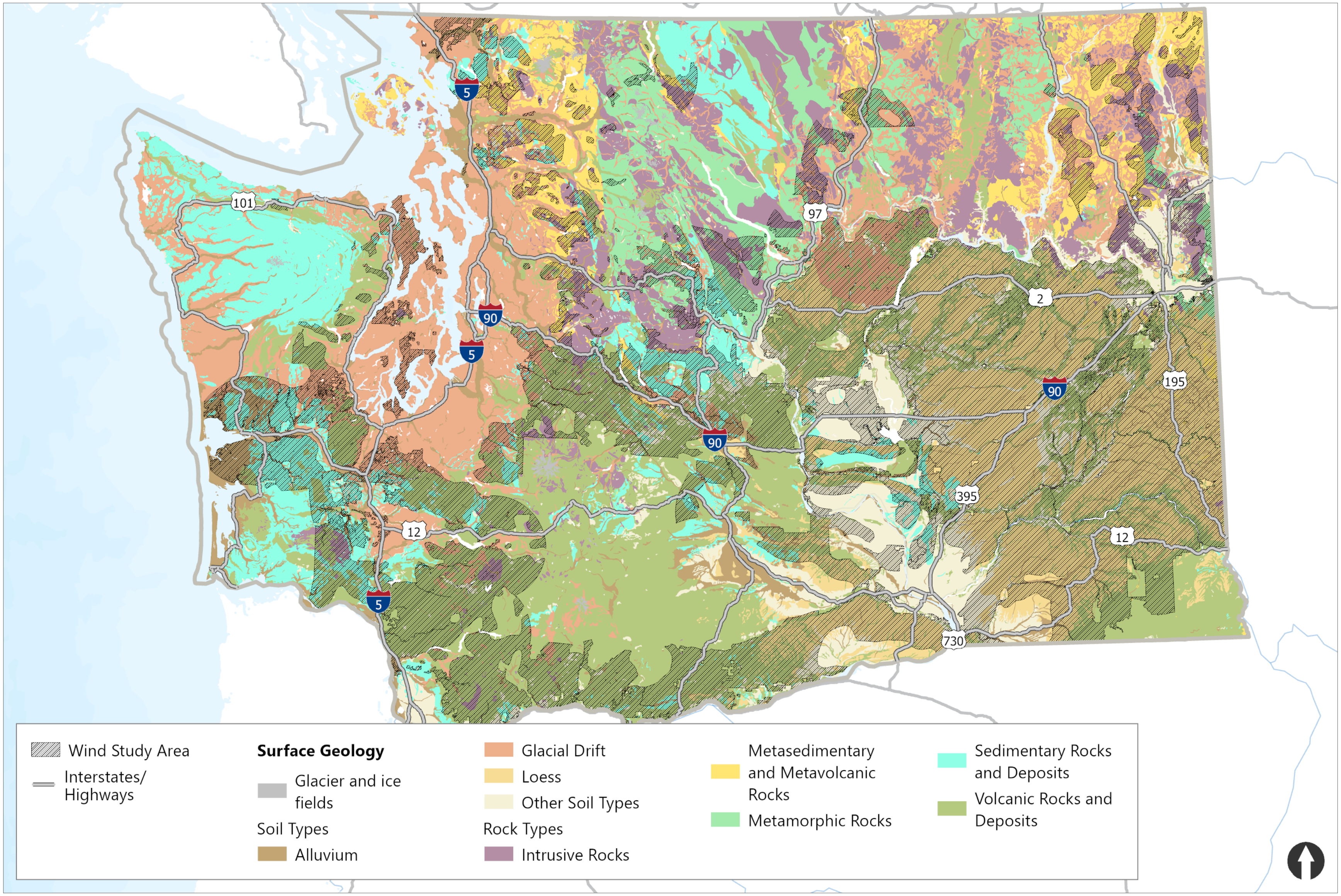

Figure 2. Surficial geology

Data source: DNR 2023b

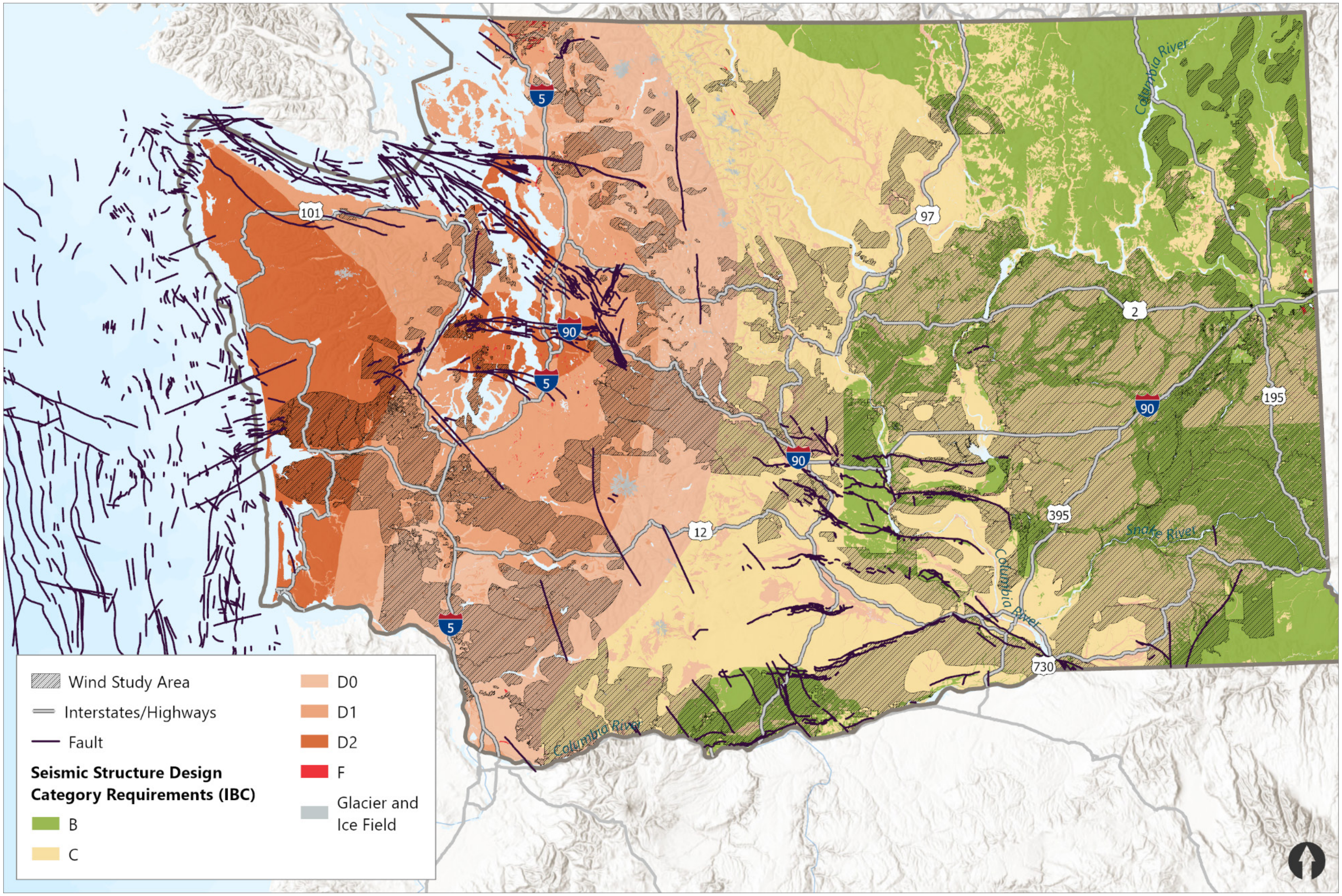

Figure 3. Seismic hazards

Data source: DNR 2023b
Note: Seismic design categories correlate to anticipated seismic ground response conditions. Seismic design category is based on generally anticipated earthquake ground response conditions for the International Building Code (ICC 2024)

3.2.3 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. Other soil structures, such as biological 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 very long periods to recover. 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 potential facility sites and during site characterization.

Soils in agricultural or forested areas may also exhibit unique attributes that may require more detailed characterization. Designated farmlands or forests may have been identified by the Natural Resources Conservation Service based on several conditions that may not be recreated in other regions. The wind study area includes agricultural and designated timber or forest land that is actively farmed, managed, or reserved. Agricultural soil and forest land types may be protected from irreversible conversion by government regulations under the federal Farmland Protection Policy Act and the Forest Legacy Program.

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 generally occur from spring through fall.

3.2.4 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 faults, tsunamis and seiches, liquefaction, volcanic eruptions, and landslides—is important because risks of these hazards can impact the safety and feasibility of facility construction, operation, and decommissioning. They are elaborated upon in the following sections.

3.2.4.1 Earthquake 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, 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. Deep basin effects within the Puget Sound, such as those associated with the Seattle Basin, would further amplify long-period ground motions in the anticipated spectral period range of the tall, slender wind turbines considered under the alternatives (Wirth et al. 2018; Wirth et al. 2019). Earthquake-induced shaking may cause other impacts on the ground surface including hazard types such as landslides, fault rupture, and liquefaction (USGS 2024a).

Given the presence of seismic features in the state, many regions within the study area are at risk of seismic activity, and wind energy generation infrastructure is susceptible to the effects of seismicity (Prowell and Veers 2009). 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 when overlayed onto the wind energy facility study area. The seismic design maps consider random crustal sources, as well as mapped fault systems, such as the CSZ, SFZ, and Tacoma Fault Zone, and derive seismic design category values that would be required for any building or structures at a facility sited within each seismic zone. Site-specific geotechnical investigations may identify site materials, subsurface geology, or other factors that may influence site design and construction requirements and should be carefully considered during facility design. It should be noted that while some faults may be mapped entirely outside of the study area (e.g., SFZ), the ground response associated with an earthquake occurring on such a fault may be felt on sites farther away, including potential facility sites that may be located within the study area.

3.2.4.2 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 damages. 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, compaction, or consolidation of soil.

The locations of identified fault structures are shown in Figure 3 and are overlayed within the study area. The resolution at the scale required for this resource report may not identify the exact locations of fault structures in relation to potential wind energy facility sites with enough specificity to adequately screen out or locate sites in areas where rupture is not anticipated. Detailed geotechnical and hydrogeological site characterizations could identify this hazard type in advance of facility design and should be considered necessary to avoid or design with specific consideration to the hazards.

3.2.4.3 Tsunami and seiche

Tsunami and seiches are types of waves generated by the rapid displacement of water. In the ocean, tsunamis most often result from seismic events with subduction zone earthquakes, such as those along the CSZ, which lies immediately west of the coast of Washington, playing a substantial role. The mechanism for tsunamis involves the sudden, abrupt offset of the sea floor during seismic events. Additionally, while less common than subduction zone events, local earthquakes along the SFZ, another active fault in Washington, can generate tsunamis in large waterbodies (DNR 2024b). A seiche is similar to a tsunami in that it is associated with the displacement of water, but it occurs within a confined waterbody such as a lake, reservoir, bay, or river. Seiches may occur from seismic activity or from a landslide, quickly displacing water as a landmass or material enters the waterbody.

In most cases, within the study area considered for this PEIS, the geohazard impacts of tsunamis and seiches would be limited in their capacity to cause disturbances to wind energy sites. However, some locations within or proximate to mapped tsunami inundation zones, particularly in the vicinity of Grays Harbor and in the very nearshore locations in the Puget Sound and Salish Sea, may be susceptible to the impact of a tsunami wave (Dolcimascolo et al. 2021; Dolcimascolo et al. 2022). Similarly, the risks of seiche are restricted to locations immediately adjacent to waterbodies, which are scarce within the study area. These hazard areas are generally confined to immediate near-coastal regions, and their horizontal mapping extents are limited to such an extent that state-wide scale figures do not convey them with adequate resolution. A general overview of mapped tsunami hazard areas is provided for reference in Figure 4; however, detailed analysis should be conducted for potential facility locations immediately adjacent to waterbodies to assess potential inundation risks related to tsunami or seiche events.

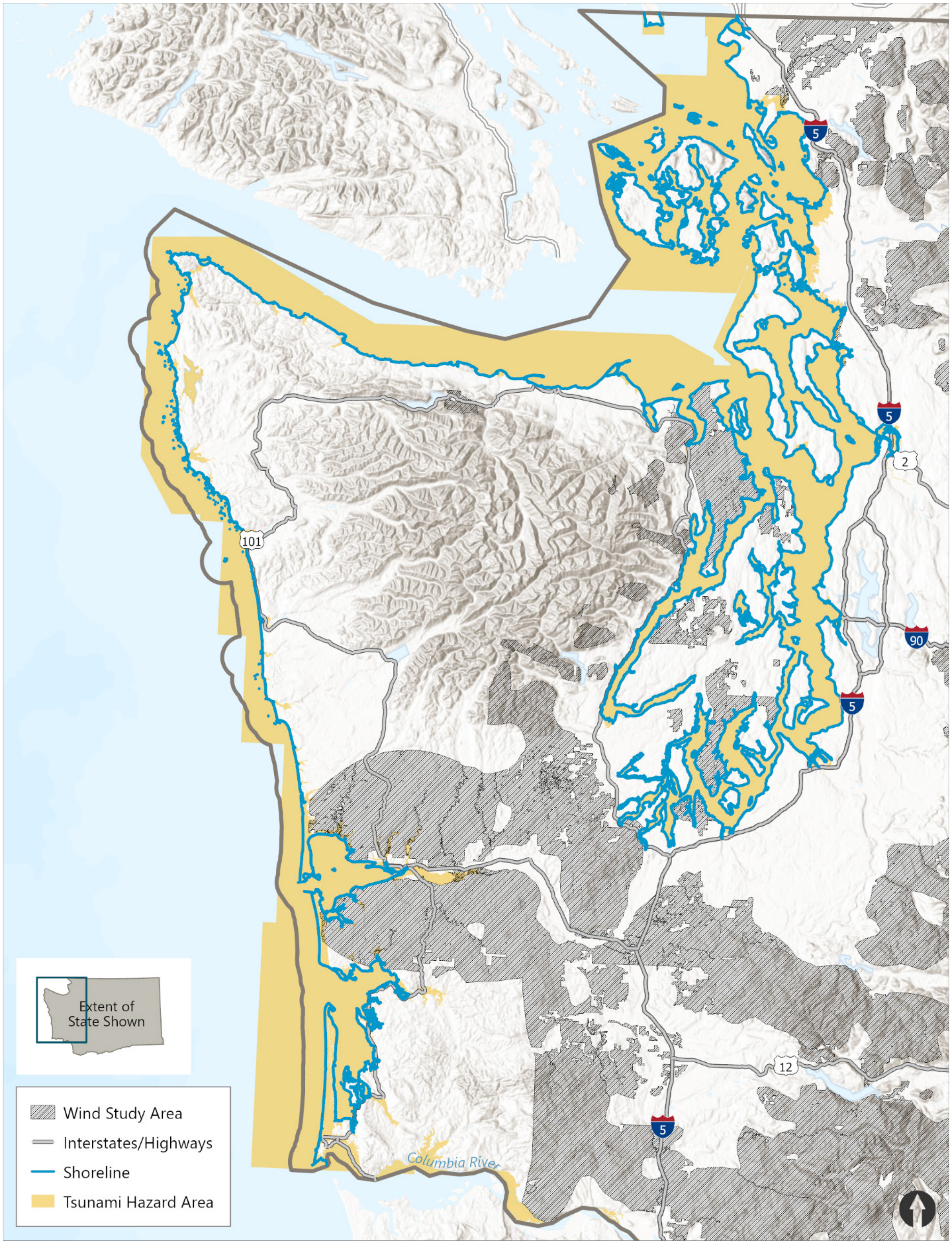

Figure 4. Tsunami hazard area

Data source: DNR 2023b

3.2.4.4 Liquefaction and cyclic softening

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 2024a). These maps included seismic site class maps, consistent with the National Earthquake Hazards Reduction Program, and liquefaction susceptibility maps. These maps are made available in GIS format on DNR's Geologic Information Portal and can be used to preliminarily identify areas of likely liquefaction sensitivity and delineate geologically hazardous areas, as shown in Figure 5. 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. Accordingly, a site-specific review and investigation program should always be conducted to assess the risk of a site for liquefaction and/or cyclic softening potential.

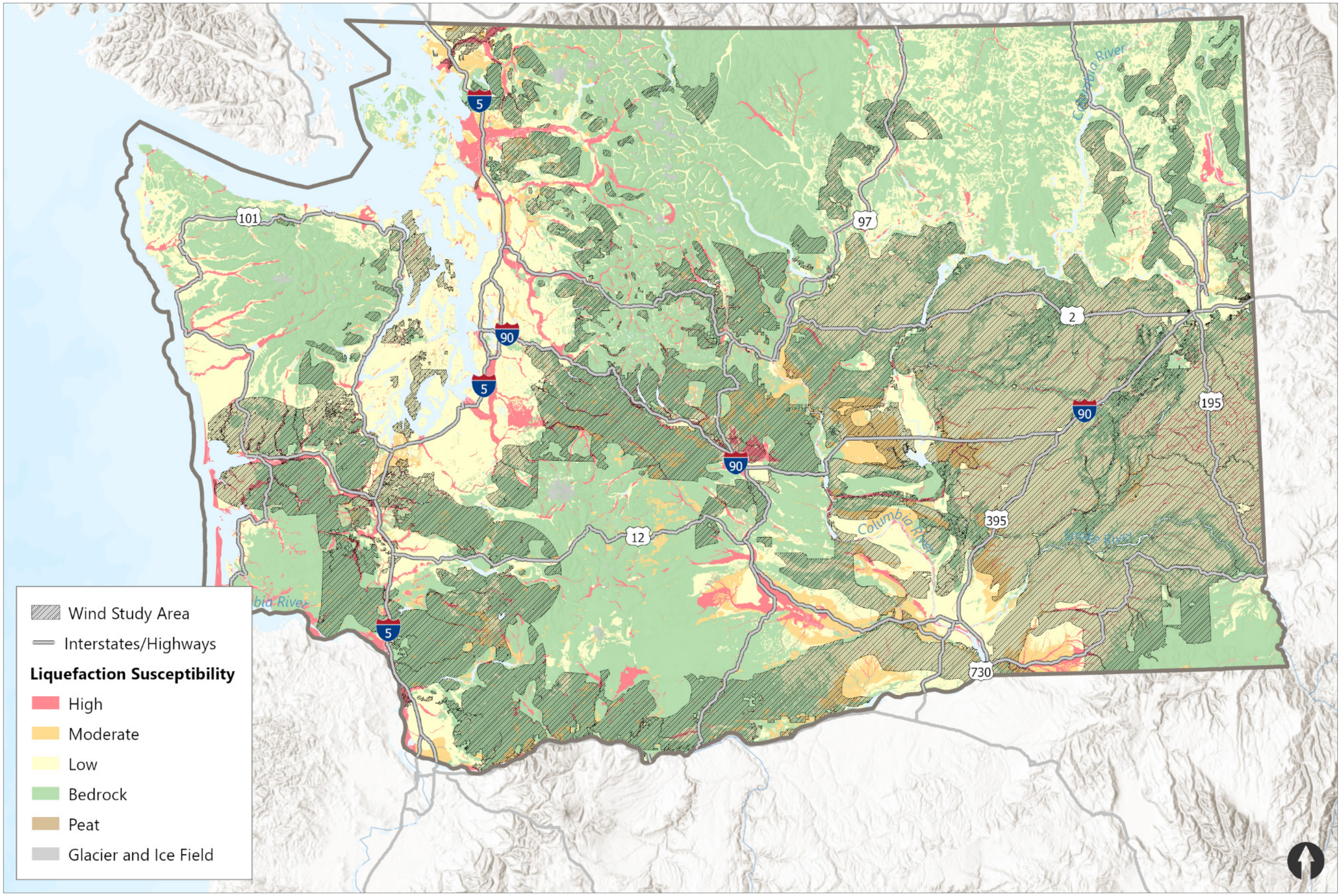

Figure 5. Liquefaction susceptibility

Data source: DNR 2023b

3.2.4.5 Volcanic hazards

The USGS recognizes active or potentially active volcanoes in and around Washington at Mt. Saint Helens, Glacier Peak, Mt. Ranier, Mt. Adams, Mt. Baker, and Mt. Hood (USGS 2024b). Effects of a volcanic eruption may be far reaching and cause significant impacts on wind 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

Airborne ash is commonly ejected from Cascade volcanoes during eruptions, which may deposit large quantities of falling ash that may be heavy enough to threaten building or vehicular damage and potentially damage wind facility equipment. 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.

Flows/slides

Various types of flows and slides pose substantial risks to surrounding areas and infrastructure, particularly in regions with active Cascade volcanoes. USGS and DNR maps identify several volcanic flow or slide hazard areas that are within the wind study area. While some of these hazard types would be confined to existing natural drainage features and are not likely to directly impact potential wind facilities, the effects of these events may directly or indirectly impact wind energy infrastructure These phenomena are discussed below. Understanding the characteristics and behaviors of these hazards is crucial for effective risk mitigation.

- **Lahar:** This is a superheated mud, ash, and debris flow that is most commonly generated during volcanic eruption. Lahars are typically restricted to areas immediately adjacent and downslope of volcanic areas This type of flow may extend into parts of the study area. Potential lahar flow paths have been added to state geohazard maps for active Cascade volcanoes.
- **Debris flows:** Also known as mudflows or debris avalanches, these are rapid movements of water, rock, soil, and other debris down steep slopes. The steep slopes of Cascade 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 impacts and indirect impacts (such as blocking or diverting existing surface waters).
- **Lava flows:** These are streams of molten rock that move slowly across Earth's surface during volcanic eruptions. While lava flows from Cascade volcanoes typically move slowly, they can still pose risks to vegetation, infrastructure, and communities in their path. Past eruptions of volcanoes like Mt. Rainier and Mt. Hood have produced lava flows that affected surrounding areas.

- **Pyroclastic flows:** These are fast-moving avalanches of hot gas, ash, and volcanic rock fragments that can travel at extremely high speeds down the slopes of volcanoes. These flows are typically associated with explosive volcanic eruptions and can travel long distances, engulfing anything in their path with intense heat and volcanic ash. Although pyroclastic flows are less common from Cascade volcanoes compared to other volcanic hazards, they remain a threat to nearby communities during explosive eruptions.

Seismicity

Seismicity in the regions within the study area can be influenced by the volcanic systems of the Cascade Range. Large-scale landslides, such as those during the eruption of Mt. St. Helens in May 1980, may occur if sections of a volcano collapse during an eruption. Moreover, volcanic activity can induce seismic events, potentially triggering earthquakes and landslides

3.2.4.6 Landslides

Landslides can pose catastrophic threat 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 on 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. It is important to note that landslides can also begin outside the boundary of a particular facility and travel through the site.

Existing slide mass deposits and landslide susceptibility areas are documented for most of the study area and provide an effective starting point for evaluating the potential environmental impacts from landslides. Among the common drivers of landslide hazard risks are slope angle and geology or soil types, which are considered in the development of landslide susceptibility maps shown in Figure 6. Other drivers of landslide risk include wildfire burn areas or commercial timberlands in areas where burned vegetation or clearcutting practices have removed the mechanical stabilizing effects of root structures, precipitation interception, or changed the slope equilibrium when timber is removed. Post-wildfire debris flow areas have been identified and mapped with some certainty throughout the state, but proximity to commercial forest land, specifically in areas that have been or could be clearcut, would need to be evaluated on a case-by-case basis. Landslide susceptibility maps are included in Figure 6. These maps show the approximate locations of commercial timberlands, wildfire burn areas and other steep slope areas, where landslide risk may be elevated.

Within the study area, the mapped landslide features of historic and recent landslides are extensive. In many cases, existing slide masses have been mapped during geologic field survey efforts. In some cases, existing landslides and landslide hazard risks have been identified by

DNR mapping through determining probabilistic landslide activity based on slope angle, as determined by a digital elevation model, compiled by LiDAR information. DNR maintains hazard maps showing both field and remote, probabilistically mapped landslides and landslide hazard areas, which can serve as a screening tool for site-specific studies; however, it is anticipated that a more focused approach to identification and management of this hazard type, including field reconnaissance and geotechnical investigations, would occur during site selection and the design of future site-specific facilities. Two large existing landslides and landslide hazard areas in Chelan (Malaga Landslide, considered inactive) and Klickitat (Cascade Landslide Complex, considered active) counties are presented in Figure 7 as samples of the DNR landslide inventory.

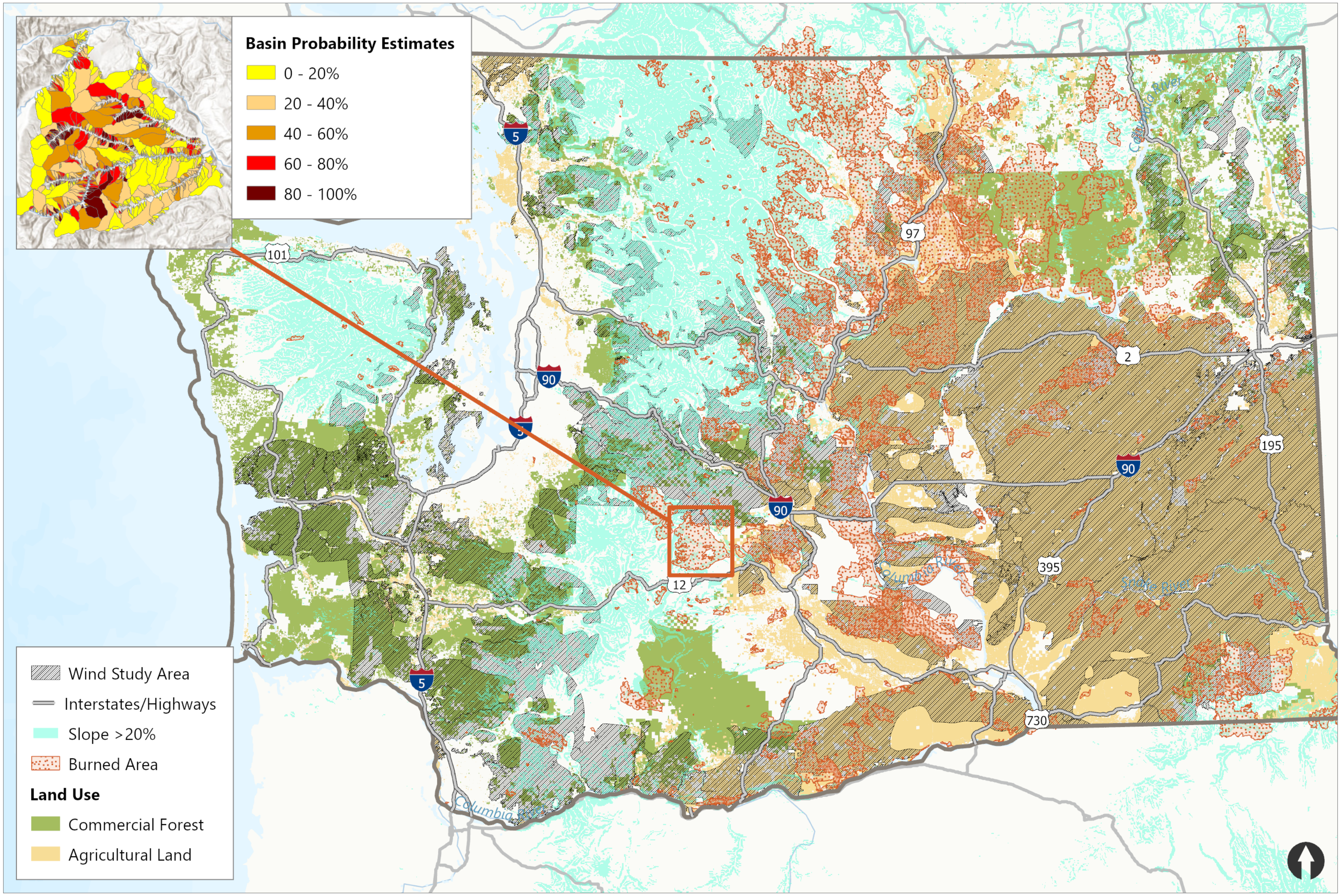

Figure 6. Landslide susceptibility

Data sources: DNR 2023b; Ecology 2024; USGS 2024c

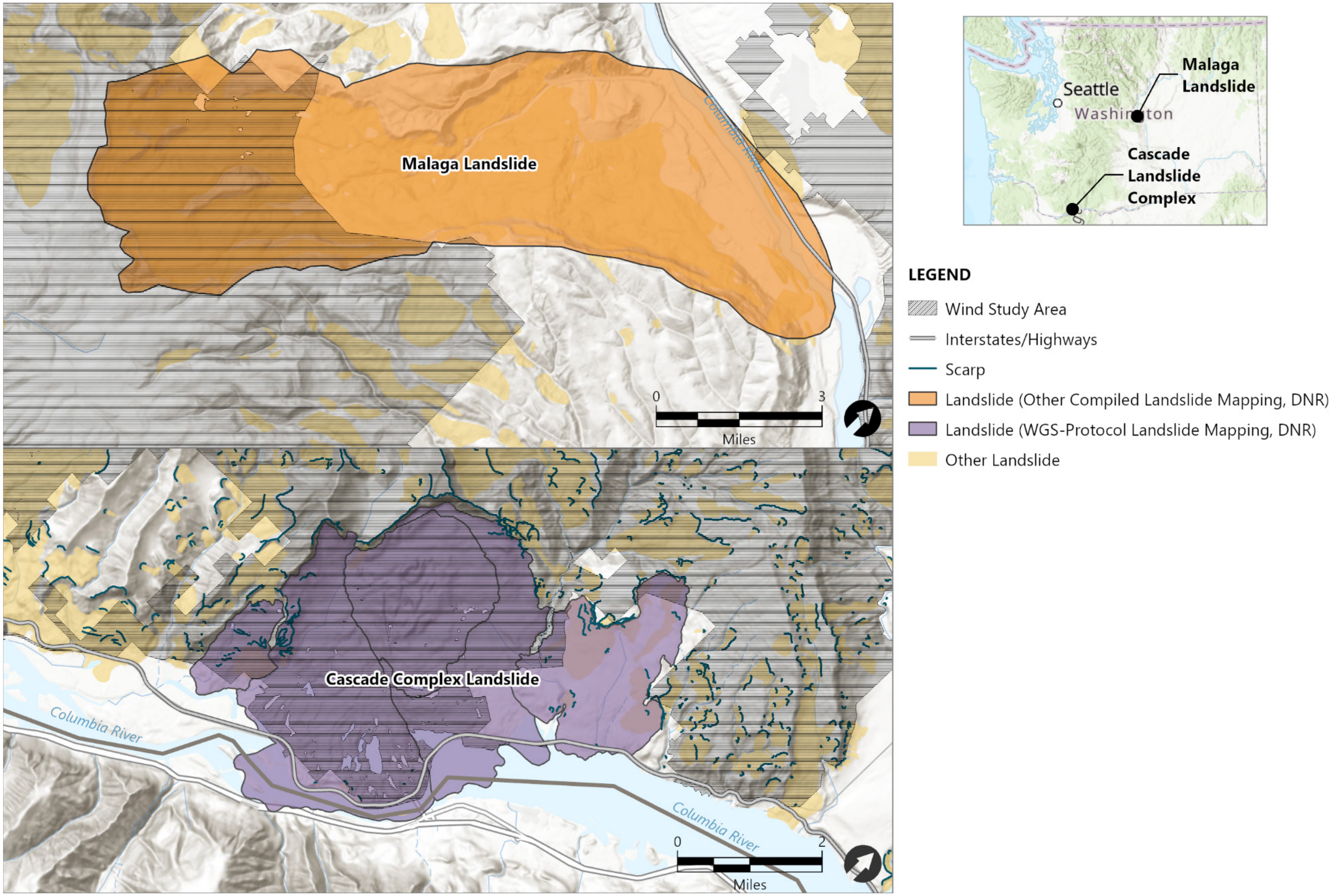

Figure 7. Landslide inventory

Data sources: DNR 2023b

3.3 Potentially required permits and approvals

The following permits and approvals related to earth resources would be required for investigation, construction, operation, or decommissioning of typical wind energy facilities and activities:

- Hydraulic Project Approval per Washington Administrative Code (WAC) 220-660-050 for facilities that may impact water bodies, including streams, rivers, and wetlands, if deemed necessary following discussions with the Washington Department of Fish and Wildlife
- Geotechnical investigation permits to allow for subsurface exploration
- Land use/zoning approvals and fill and grade permits granted by local jurisdictions
- Stormwater permits to address runoff from construction, operation, and decommissioning activities
- Road access permits, particularly relevant for developments in forested and mountainous regions, may be required from DNR or other relevant authorities.
- Washington State Department of Ecology's Sand and Gravel Permit for the extraction of sand, gravel, and other minerals from state-owned aquatic lands or for operations exceeding certain thresholds, such as those related to the volume of material extracted, area of land disturbed, or depth of excavations
- DNR's Surface Mining Permit for extraction of materials such as sand, gravel, or rock from state- or privately-owned lands, to ensure compliance with environmental regulations, reclamations standards, and land use planning requirements. A map detailing aggregate resource locations is included in Figure 8.
- For projects that require a federal permit or license, the following may be required:
    - Section 401 Water Quality Certification
    - Federal Consistency Certification with relation to the Coastal Zone Management Act if within one of the 15 coastal counties

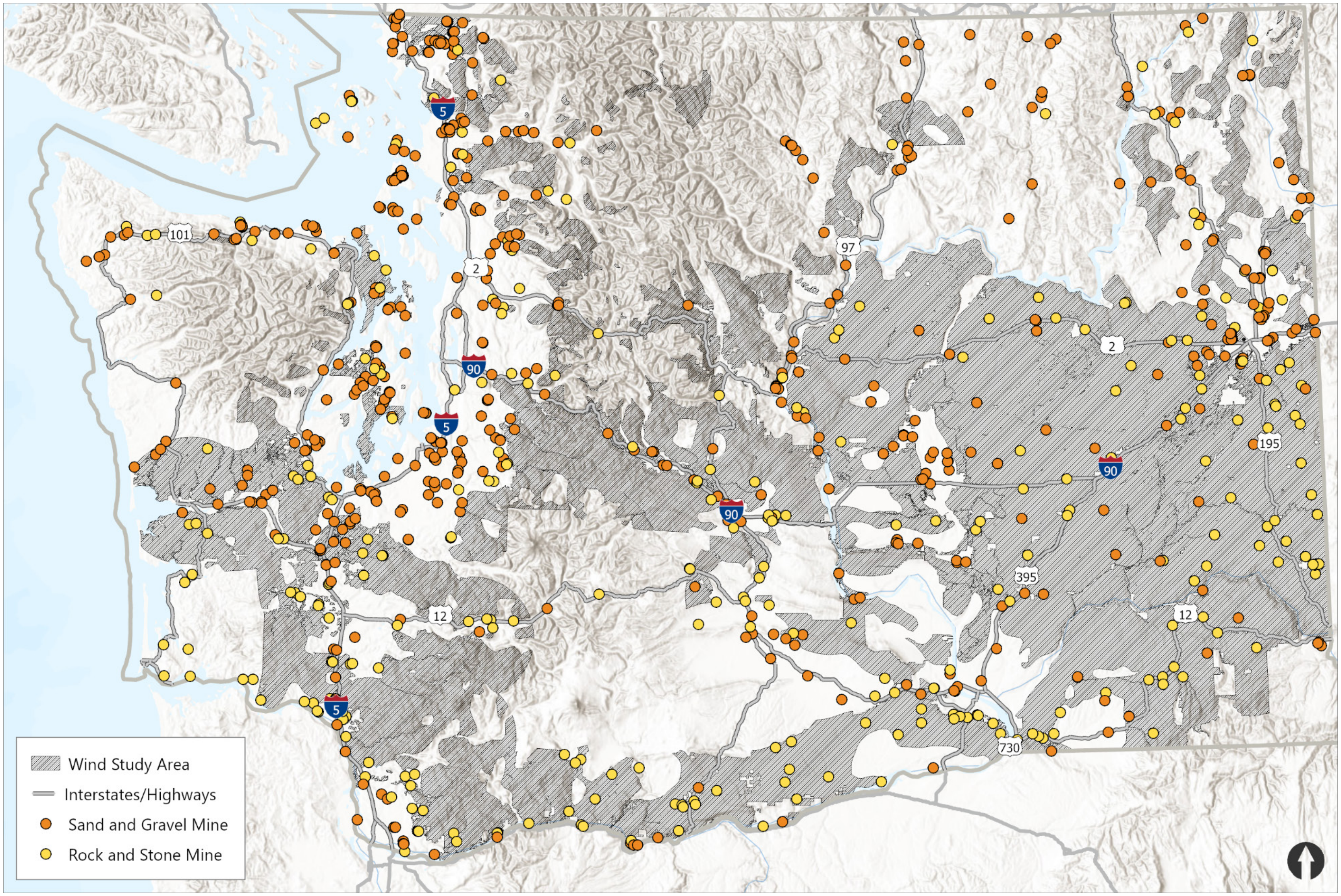

Figure 8. Aggregate resource locations

Data source: DNR 2023b

3.4 Small to medium utility-scale facilities of 10 MW to 250 MW (Alternative 1)

The extent and magnitude of impacts on soil and geological resources would vary depending on the geographical region of the facility, as well as the size of the facility. In general, facility size correlates to the potential for impacts because of the relative scale of facility footprints, quantities of construction materials, and scale of supporting infrastructure. Smaller facilities require fewer roads, structures, and generation-tie transmission lines (gen-tie lines), and less overall soil disturbance. Regardless of facility scale, if unmanaged stockpiles or improper excavation, soil and material handling, or management practices occurred, the construction of a facility may result in erosion or sediment transport into waterways.

3.4.1 Soil resources

3.4.1.1 Impacts from construction

Site characterization activities completed in advance of construction would typically include the following activities: desktop studies, surveying, surface mapping, subsurface investigations (e.g., borings), and minimally invasive geophysical survey techniques. Likely impacts during field activities include soil compaction, creation of ruts, and erosion due to the passage of vehicles and equipment during field investigation activities, localized site clearing for subsurface investigation activities, and limited earthwork associated with test pit excavations, if required. In mountainous terrain, site grading, as well as clearing (removal of surface materials) and grubbing (removal of subsurface vegetation materials), may be required if existing access routes are unavailable or unsuitable for the equipment.

Impacts on soil resources during construction would primarily be a result of ground-disturbing activities and include a range of impacts at and proximate to a planned utility-scale onshore wind facility. These activities may include grading for site access and development, clearing and grubbing, installation of subsurface infrastructure (e.g., foundations, pilings, deep foundations, utility trenches), stockpiling of site soils, importing off-site soils and removing site soils, placement and compaction of low-permeability materials, the development of an on-site concrete processing or batch plant, and the use of aggregate resources and structural concrete from local suppliers.

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. 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. 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 may contribute to unstable conditions as a result of facility development.

Construction activities would increase the potential for fluid (fuel, oil, hydraulic fluid, etc.) releases or spills and the potential application of herbicides and dust control stabilizers that would introduce contaminants into local soils if not controlled with best management practices (BMPs) and other preventative measures.

Construction of access roads, wind turbine bases, and subsurface utility installation may require substantial excavation of soil and rock materials, depending on the site, which may need to be hauled off site. Additionally, development of a wind energy site could require importing aggregate and/or soil borrow for construction of roadways, concrete production, and general site grading. 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 time frame. Impacts to aggregate resources are further discussed in the *Energy and Natural Resources Report* (Hammerschlag 2024). A map detailing aggregate surface mining resource sites is included in Figure 8.

Site characterization and construction would result in localized ground disturbance, likely 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 medium-sized facilities than smaller ones, due to the increased disturbance area and potentially greater number of larger vehicles and equipment. Due to the limited spatial extents of the considered impacts, their relatively short duration, and the generally negligible to low magnitude of the impacts within those extents, most facility construction would result in **less than significant impacts** to soil resources. Permits and regulations preclude the use of potentially hazardous chemicals or herbicide applications, and other permits or regulations would require safe handling practices for hazardous chemicals and herbicides; however, the potential for an unintentional spill would remain. Spills to soil would likely be of small quantity and able to be cleaned up. Spills have the potential to cause reduced soil aeration and water infiltration; however, due to the likely limited extent, magnitude, and duration of these impacts, most facility construction would result in **less than significant impacts**.

3.4.1.2 Impacts from operation

Following construction, the anticipated impacts from ongoing operations and maintenance are anticipated to be minimal. The use of maintenance vehicles and equipment would generally be limited to access roads and designated areas that were developed during construction, and little to no new ground disturbance is anticipated. 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.

Site operations would result in potential 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.

Similar to construction, permits and regulations require safe handling practices or 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 quantity and within containment areas or able to be cleaned up.

Due to the limited spatial extents of the considered impacts, requirements for hazardous chemical containment, as well as the negligible to low magnitude and probability of impacts, operations would result in **less than significant impacts** to soil resources.

3.4.1.3 Impacts from decommissioning

Decommissioning of a wind energy generation facility may result in temporary impacts associated with site clearing and cleanup, including grading, demolition, and material off haul. Impacts from these activities, or from repowering a facility by replacing wind turbine components, may be similar to those generated during construction, as described in Section 3.4.1.1; however, they would be of lesser intensity and duration because of the availability of previously developed access routes and staging areas. For decommissioning, 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, generally quicker in moist, cool environments west of the Cascades and slower in drier, more variable temperature zones east of the Cascades.

Facility decommissioning or repowering would result in localized ground disturbance and changes in local drainage patterns. Decommissioning may also result in the potential limited borrow of construction materials but is unlikely to result in slope stability impacts or subsidence.

Similar to construction, permits and regulations require safe handling practices or preclude the use of potentially hazardous chemicals and herbicides; however, the potential for a spill would remain. Spills to soil would likely be of small quantity and within containment areas or able to be cleaned up.

Due to the limited spatial extents of the considered impacts, their relatively short duration, requirements for hazardous chemical containment, and the negligible to low magnitude and probability of impacts, site decommissioning would result in **less than significant impacts** to soil resources.

3.4.2 Geologic hazards

Impacts from construction

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

The site characterization phase would include desktop and field studies to identify and assess the geologic hazards. Due to the short duration and limited footprint of field activities, the risk of impacts on site characterization by or from geologic hazards is considered low.

The effects of geologic hazards during construction are generally limited to those associated with potentially increasing slope instability and landslide risks, as described in Section 3.2.4.6. 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 utility-scale wind energy facilities would not entail long duration construction cycles, and the likelihood of a significant seismic or volcanic event during construction is very low. Channelized volcanic hazards, such as pyroclastic flows or lahars, are not likely to impose direct or widespread impacts within the study area. Additionally, 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, transportation routes, 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 significant seismic event during construction is very low, and the damage to facilitates and impacts to construction operations associated with an event are dependent on the stage of construction and the severity of the event. An event midway through construction may result in collapse of temporary construction support systems or toppling of unsecured equipment or materials. Such an event would increase the potential for limited fluid (fuel, oil, hydraulic fluid, etc.) releases or spills, including any herbicides and dust control stabilizers that are stored on site. These types of impacts are further discussed in the *Environmental Health and Safety Resource Report* (ESA 2024).

Due to the low likelihood that regional geologic hazards would be realized (e.g., earthquake) or local geologic hazards triggered (e.g., landslide) during site characterization and construction, impacts are further unlikely and of small scale and would be considered **less than significant impacts**.

3.4.2.1 Impacts from operation

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 utility-scale wind facility are required to be designed to some level of seismic performance, if earthquake ground shaking intensity exceeds design standards, damage to facility infrastructure may occur. Additionally, ground shaking may dislodge or topple materials stored on site in support of operations and maintenance activities, which could result in a small-scale fluid release or spill.

Potential ashfall hazards during operation cannot be entirely 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.

Due to the low likelihood that regional geologic hazards would be realized, particularly in excess of code-based design standards (e.g., earthquake ground shaking above seismic design standards), and the small scale of local geologic hazards (e.g., sloughing along slopes) during the operation phase, impacts are further unlikely and of small scale and would be considered **less than significant impacts**.

3.4.2.2 Impacts from decommissioning

The potential that regional geologic hazards would be realized (e.g., earthquake) or local geologic hazards triggered (e.g., landslide) during the decommissioning phase (including the potential for repowering the facility) is similar to the construction and would have **less than significant impacts**.

3.4.3 Actions to avoid and reduce impacts

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.

3.4.3.1 Siting and design considerations

Siting and design considerations are crucial for mitigating potential impacts on earth resources. Developers can adopt various actions to avoid, minimize, and mitigate resource impacts, ensuring the sustainability of the facility. The following considerations should be made when selecting potential sites:

- Conduct detailed geotechnical engineering, soil, and hydrologic studies to characterize site conditions.
- Avoid geologic hazards and hazard areas, such as mapped landslide hazard areas, surface fault rupture hazard areas, and volcanic flow hazard areas.
- Select sites with minimal impact on soil health and stability to avoid soil erosion and compaction.
- Prioritize locations with suitable topography and soil characteristics to minimize the need for extensive land grading and excavation, reducing soil disturbance. By focusing on sites with more gentle slopes, developers can mitigate erosion risks and preserve soil stability, because steep slopes are more prone to soil erosion and landslides.
- Select areas with favorable soil characteristics, such as well-drained soils with good permeability, to minimize soil disturbance during construction activities by reducing the likelihood of soil compaction and waterlogging. These soil properties facilitate efficient water infiltration and drainage, mitigating erosion risks and preserving soil structure and fertility throughout the facility's life cycle.
- Design facility to account for current seismic design parameters and building codes, including the latest version of the International Building Code and American Society of Civil Engineers Minimum Design Loads and Associated Criteria for Buildings and Other Structures 7-10 and 7-16 (ASCE 2013, 2017).
- Limit construction of new roads. Design new roads based on federal, state, and county requirements and based on local climate conditions, soil moisture, and erosion potential.
- Identify the level of seismic design, material types, and development strategies needed based on the potential risk of earthquakes.
- Utilize existing infrastructure and aggregate resources, rather than generating new resources.

3.4.3.2 Permits, plans, and best management practices

In addition to site location selection, BMPs during the development and operation utility-scale wind energy facilities may be implemented to prevent or mitigate adverse impacts on earth resources. BMPs include, but are not limited to, the following:

- Conduct thorough geotechnical assessments to evaluate soil characteristics, stability, and bearing capacity for wind facility siting and foundation design.
- Provide and maintain stabilized entrance and exit points for roads during construction, consistent with details provided by the Washington State Department of Transportation, as well as local jurisdictions.
- Minimize facility footprint and land disturbances, including limiting clearing and maintaining existing vegetation to the extent possible.

- Adopt site design and layout strategies that minimize alterations to natural topography and landforms, preserving the integrity of the landscape.
- Implement grading and excavation techniques that minimize soil disturbance and compaction, such as level grading or cut-and-fill operations with minimal earthmoving.
- Surface roads or other vehicular access or parking areas with crushed aggregate materials.
- Limit vehicular traffic and speed on aggregate or soil road surfaces.
- Construct and maintain erosion control in all disturbed areas and along roadways (silt fence, sediment traps, erosion control surfaces) and prevent any transportation of soil materials via erosion, particularly into surficial waters or wetlands.
- Utilize earthen dikes, swales, and lined ditches to control localized runoff within the extents of the site, not only the developed or disturbed areas.
- Reuse suitable excavated materials to replace in disturbed areas once construction has been completed.
- Dispose of unused excavated materials in suitable, designated areas where erosion of stockpiled or placed materials may be controlled.
- Cover material stockpiles with tarps or plastic sheeting to prevent wind erosion and minimize dust emissions from construction materials, such as gravel and sand.
- Implement vegetative cover or mulching to stabilize exposed soil and reduce erosion risks.
- Establish revegetation programs using native plant species to restore disturbed areas and prevent soil erosion.
- Construct stormwater management facilities, such as retention ponds or vegetative swales, to control stormwater runoff and prevent soil erosion and sedimentation.
- 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.
- Following construction activities or decommissioning, re-establish original grades and material types to restore natural functionality.
- To the extent possible, utilize low-emission vehicles and equipment within the wind energy facility to minimize air pollution and reduce the contribution of vehicle emissions to dust contamination.
- Comply with all relevant regulations related to spill control. Permitting requirements include the development and implementation of spill response and control plans, which aim to prevent spills or leaks of hazardous materials from occurring and minimize their impact if they do occur. Adhering to these permitting requirements would effectively reduce the likelihood and consequences of uncontrolled contaminant releases.
- Develop, implement, and maintain an erosion management plan, vegetation management plan, and emergency management plan to address issues that may arise that increase erosion potential, vegetation changes, or other emergency circumstances.
- Utilize weight dispersion mats or weight dispersion equipment to reduce disturbances to native soil structure and vegetation.

- Measure pre-construction conditions, create and maintain as-built construction documents, and develop a site restoration plan for site restoration following decommissioning.
- Replant any disturbed areas with native plants soon after earthwork is complete.

3.4.4 Unavoidable significant adverse impacts

Through compliance with laws and with implementation of the effective siting and design strategies, BMPs, and site-specific recommendations, as described in Section 3.4.3, appropriate actions to avoid and mitigate impacts are available to reduce impacts such that there would be **no significant and unavoidable adverse impacts** anticipated related to earth resources.

3.5 Large utility-scale facilities of 251 MW to 1,500 MW (Alternative 2)

3.5.1 Impacts from construction, operation, and decommissioning

Environmental impacts from large utility-scale facilities related to site characterization, construction, operation, and decommissioning would be similar to the impacts discussed for small to medium facilities, with consideration for greater potential for impacts with a larger facility. Specific differences related to all phases of work are discussed in the following sections.

3.5.1.1 Soil resources

In contrast to small- and medium-scale facilities, the large-scale facilities are characterized by a larger footprint and more extensive infrastructure requirements. Consequently, the impacts on soil resources could be larger in scale.

The increased size of the facility results in an increased disturbance area associated with the construction of more roads, towers, gen-tie lines, and buildings that would heighten the risk of soil erosion and sediment transport into adjacent waterbodies. Similarly, the potential for unintentional spills to soil is amplified due to the larger volume of chemical usage, vehicle fluids, and surface treatments associated with the operation and maintenance of large-scale facilities.

These impacts parallel those for small to medium-scale facilities but could be larger because of the greater magnitude of disturbance and operational activities in the larger footprint. Impacts from site characterization, construction, operation, and decommissioning would increase with a larger-scale facility as a function of total disturbed areas. Similar to small- to medium-scale facilities, permits and regulations require safe handling practices or 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 quantity and within containment areas or able to be cleaned up.

Due to the limited spatial extents of the considered impacts, requirements for hazardous chemical containment, as well as the negligible to low magnitude and probability of impacts, construction, operation, and decommissioning would result in **less than significant impacts** to soil resources.

3.5.1.2 Geologic hazards

Geologic hazards described in Section 3.4.2 also apply to large facilities. The relative risk of geologic hazard impacts associated with seismicity and volcanic activity do not appreciably vary with facility scale; however, the risk of impacts due to landslide hazards may vary with facility scale, depending on site development requirements, local geology, and long-term operational strategies. Accordingly, the risk of facility impacts due to landslide hazards is increased for large facilities relative to small to medium facilities. Following appropriate requirements when constructing on steep slopes and conducting surveys to identify potential areas of landslides would reduce the risk.

Similar to small to medium facilities, there would be **less than significant impacts** from geologic hazards.

3.5.2 Actions to avoid and reduce impacts

Available means of reducing impacts for large facilities are the same as those identified in Section 3.4.3 for small to medium facilities.

3.5.3 Unavoidable significant adverse impacts

Through compliance with laws and with implementation of the effective siting and design strategies, BMPs, and site-specific recommendations, as described in Section 3.4.3, appropriate actions to avoid and mitigate impacts are available to reduce impacts such that there would be **no significant and unavoidable adverse impacts** anticipated related to earth resources.

3.6 Wind energy facility and co-located battery energy storage system (Alternative 3)

3.6.1 Impacts from construction, operation, and decommissioning

Environmental impacts for facilities with battery energy storage systems (BESSs) would be similar to facilities without BESSs. Specific differences are discussed in the following sections.

3.6.1.1 Soil resources

The types of impacts on soil resources are the same as those anticipated for facilities without BESSs; however, the integration of utility-scale wind energy facilities with one or two BESSs introduces specific impacts that differ from standalone onshore wind facilities.

The addition of BESS components necessitates the construction of storage facilities, additional electrical infrastructure, and operational management systems, potentially leading to a larger overall footprint and subsequently more soil disturbance, particularly during the construction and installation phases. State regulations require fire and spill containment measures for spills and fire for lithium-ion, flow, and zinc-hybrid batteries (WAC 51-54A-0322 and 51-54A-1207). Although the likelihood is remote, in the event of a BESS failure, there is a risk of environmental contamination. Emergency response would not typically use water for battery fires, so soil contamination would be limited to the BESS site. Cleanup actions include removal and proper disposal of contaminated soils. Impacts from BESS failure are covered in more detail within the *Environmental Health and Safety Resource Report*. Spills would be required to be cleaned up.

Similar to facilities without a co-located BESS, construction, operation, and decommissioning would result in **less than significant impacts** to soil resources.

3.6.1.2 Geologic hazards

Geologic hazards described in Section 3.4.2 apply directly to facilities with a co-located BESS. The risk of facility impacts due to ashfall increases with the inclusion of the co-located BESS. These include equipment vulnerability due to ash particle infiltration, insulation challenges from ash accumulation, air intake blockages affecting cooling systems, and safety risks to maintenance personnel handling ash-contaminated equipment (ACP 2023).

Similar to facilities without a BESS, there would be **less than significant impacts** on geologic hazards.

3.6.2 Actions to avoid and reduce impacts

Available means of reducing impacts are the same as those identified in Section 3.4.3. Additional considerations, particularly pertaining to the integration of BESSs include the following:

- Implement secondary effective spill and leak containment measures around BESS components for all battery types 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.
- Develop comprehensive training programs and safety protocols for personnel involved in BESS operations and maintenance. Proper training can help minimize the risk of accidents and ensure prompt and effective response in case of emergencies.
- Develop detailed emergency response plans specific to BESS operations to mitigate the consequences of potential failures. Robust plans include protocols for containment, cleanup, and remediation in the event of soil contamination or environmental incidents.
- Implement regular maintenance schedules and inspections for BESS components to ensure optimal performance and early detection of potential issues. Routine maintenance can help prevent failures and minimize the risk of environmental contamination.

3.6.3 Unavoidable significant adverse impacts

Through compliance with laws and with implementation of the effective siting and design strategies, BMPs, and site-specific recommendations, as described in Section 3.4.3, appropriate actions to avoid and mitigate impacts are available to reduce impacts such that there would be **no significant and unavoidable adverse impacts** anticipated related to earth resources from facilities with a co-located BESS.

3.7 Wind Energy facilities combined with agricultural land use (Alternative 4)

3.7.1 Impacts from construction, operation, and decommissioning

Onshore wind energy facilities integrated with agricultural land uses may include locating the facilities in lands that have existing agricultural uses, or a new agricultural use could be added to a site. Agricultural uses may include crops, rangeland, or pollinator habitat. Activities could include maintenance of existing or addition of new infrastructure, roads, fences, and gates, and the operation of agricultural machinery.

Environmental impacts related to site characterization, construction, operation, and decommissioning from wind energy facilities combined with agricultural land use would be similar to the impacts discussed in Sections 3.4 and 3.5. Specific differences are discussed in the following sections.

3.7.1.1 Soil resources

Wind energy generation facilities typically require minimum spacing between generation equipment for optimal power generation capabilities. In some locations, land use types where a potential facility may be located are currently utilized or zoned as agricultural lands. Vegetative cover should be carefully selected to stabilize surface soils and to reduce interactions with pollinators, insects, birds, and bats that may be negatively affected by the presence of operational wind energy generation equipment (refer to the *Biological Resources Report* [Anchor QEA 2024] for more information).

The specific impacts of agricultural use may depend heavily on the region in which the generation site is located and the type of agricultural use, water usage, and management requirements. Water may be used for dust control. Farming equipment or vehicles required for construction, operation, and decommissioning of wind energy facilities may increase the likelihood of spill of contaminants such as herbicides, fuels, hydraulic fluids, solvents, or cleaning agents into the soil. Impacts from site characterization, construction, operation, and decommissioning would be similar to those described for facilities without agricultural land use. Facilities combined with agricultural uses would still result in **less than significant impacts** to soil resources during all phases.

3.7.1.2 Geologic hazards

Geologic hazards described as common to all facilities in Section 3.4.2 apply to wind energy facilities combined with agricultural land use. There are no additional geologic hazard impact considerations associated with the inclusion of co-located agricultural land use.

Similar to facilities without agricultural uses, there would be **less than significant impacts** on geologic hazards.

3.7.2 Actions to avoid and reduce impacts

Available means of reducing impacts are the same as those identified in Section 3.4.3. Additionally, the following strategies can be applied to mitigate the impacts of co-located agriculture:

- Integrate soil conservation practices into the design and management of agricultural activities, such as employing no-till farming techniques beneath turbines and infrastructure to maintain soil structure, lessen erosion risks, and support soil fertility.
- Consider ideal co-location vegetation to maximize soil stabilization but not increase pollinator and insect populations in the immediate vicinity of sites.
- Optimize tower design and spacing to address challenges like insufficient sunlight and planting requirements.

3.7.3 Unavoidable significant adverse impacts

Through compliance with laws and with implementation of the effective siting and design strategies, BMPs, and site-specific recommendations, as described in Section 3.4.3, appropriate actions to avoid and mitigate impacts are available to reduce impacts such that there would be **no significant and unavoidable adverse impacts** anticipated related to the earth resources.

3.8 No Action Alternative

Under the No Action Alternative, the city, county, and state agencies would continue to conduct environmental review and permitting for utility-scale wind energy development under existing state and local laws on a facility-by-facility basis.

The potential for ground-disturbing activities and geologic hazard impacts for future utility-scale wind energy developments under the No Action Alternative would be the same as those noted for Alternatives 1 through 4, depending on facility size and design, and would be **less than significant**.

4 References

ACP (American Clean Power), 2023. *First Responders Guide to Lithium-Ion Battery Energy Storage System Incidents*. Available at: http://cleanpower.org.

Anchor QEA, 2024. *Biological Resources Report for Programmatic Environmental Impact Statement on Utility-Scale Onshore Wind Energy Facilities in Washington State*. Prepared for the Washington State Department of Ecology. September 2024.

ASCE (American Society of Civil Engineers), 2013. *Minimum Design Loads for Buildings and Other Structures (7-10)*. Available at: https://ascelibrary.org/doi/book/10.1061/9780784412916.

ASCE, 2017. *Minimum Design Loads and Associated Criteria for Buildings and Other Structures (7-16)*. Available at: https://sp360.asce.org/personifyebusiness/Merchandise/Product-Details/productId/233133882.

Cakir, R., and T.J. Walsh, 2007. *Seismic Design Category Maps for Residential Construction in Washington*. Washington Department of Natural Resources. November 2007.

DNR (Washington Department of Natural Resources), 2023a. "Geologic Provinces of Washington." Accessed March 2024. Available at: https://www.dnr.wa.gov/programs-and-services/geology/explore-popular-geology/geologic-provinces-washington.

DNR, 2023b. Washington Geologic Information Portal. Accessed March 2024. Available at: https://geologyportal.dnr.wa.gov/2d-view#natural_hazards?-14334696,-13165515,5825030,6390053.

DNR, 2024a. "Earthquakes and Faults." Accessed March 2024. Available at: https://www.dnr.wa.gov/programs-and-services/geology/geologic-hazards/earthquakes-and-faults.

DNR, 2024b. "Tsunamis." Accessed March 2024. Available at: https://www.dnr.wa.gov/programs-and-services/geology/geologic-hazards/Tsunamis.

Dolcimascolo, A., D.W. Eungard, C. Allen, R.J. LeVeque, L.M. Adams, D. Arcas, V.V. Titov, F.I. González, C. Moore, C.E. Garrison-Laney, and T.J. Walsh, 2021. *Tsunami Hazard Maps of The Puget Sound and Adjacent Waters—Model Results from an Extended L1 Mw 9.0 Cascadia Subduction Zone Megathrust Earthquake Scenario*. Washington Geological Survey Map Series 2021-01.

Dolcimascolo, A., D.W. Eungard, C. Allen, R.J. LeVeque, L.M. Adams, D Arcas, V.V. Titov, F.I. González, and C. Moore, 2022. *Tsunami Inundation, Current Speeds, and Arrival Times Simulated from a Large Seattle Fault Earthquake Scenario for Puget Sound and Other Parts of the Salish Sea*. Washington Geological Survey Map Series 2022-03.

Ecology, 2024. EIM Groundwater Search Map, Land Classification. Accessed March 2024. Available at: https://apps.ecology.wa.gov/eim/search/Map/Map.aspx?MapType=Groundwater&MapLocationExtent=-13873343.3370332%2C5711716.75429741%2C-13028904.807647%2C6275212.03415398.

EFSEC (Energy Facility Site Evaluation Council), 2023. *Horse Heaven Wind Farm – Final Environmental Impact Statement*. October 2023. Available at: https://www.efsec.wa.gov/energy-facilities/horse-heaven-wind-project/horse-heaven-sepa.

ESA (Environmental Science Associates), 2024. *Environmental Health and Safety Resource Report for Programmatic Environmental Impact Statement on Utility-Scale Onshore Wind Energy Facilities in Washington State.* Prepared for the Washington State Department of Ecology. September 2024.

Ewart, J.W., A.K. Diefenbach, and D.W. Ramsey, 2018. *2018 Update to the U.S. Geological Survey National Volcanic Threat Assessment*. Scientific Investigations Report 2018-5140. Prepared for the United States Geological Survey.

Hammerschlag (Hammerschlag LLC), 2024. *Energy and Natural Resources Report for Programmatic Environmental Impact Statement on Onshore Wind Energy Facilities in Washington State*. Prepared for the Washington State Department of Ecology. September 2024.

ICC (International Code Council, 2024. *International Building Code*. Washington, DC.

Moa, E.H.Y., and Y.I. Go, 2023. "Large-Scale Energy Storage System: Safety and Risk Assessment." *Sustainable Energy Research* 10(13). Available at: https://sustainenergyres.springeropen.com/articles/10.1186/s40807-023-00082-z.

Myers, B., and C Driedger, 2008. *Eruptions in the Cascade Range During the Past 4,000 Years*. General Information Product 63. Prepared for the United States Geological Survey.

NRCS (Natural Resources Conservation Service), 2019. Web Soil Survey. Accessed March 2024. Available at: https://websoilsurvey.nrcs.usda.gov/app/HomePage.htm.

Prowell, I., and P. Veers, 2009. *Assessment of Wind Turbine Seismic Risk: Existing Literature and Simple Study of Tower Moment Demand*. SAND2009-1100. March 2009.

USGS (U.S. Geological Survey), 2024a. "What Are the Effects of Earthquakes?" Available at: https://www.usgs.gov/programs/earthquake-hazards/what-are-effects-earthquakes#:~:text=Ground%20shaking%20is%20a%20term,from%20the%20causative%20fault%20increases.

USGS, 2024b. “Why Study Cascade Volcanoes?” Available at: https://www.usgs.gov/observatories/cascades-volcano-observatory/why-study-cascade-volcanoes.

USGS, 2024c. USGS Post-Fire Debris Flow Hazard Assessment Viewer. Accessed March 2024. Available at: https://usgs.maps.arcgis.com/apps/dashboards/c09fa874362e48a9afe79432f2efe6fe.

Wirth, E.A., S.W. Chang, and A.D. Frankel, 2018. *2018 Report on Incorporating Sedimentary Basin Response into the Design of Tall Buildings in Seattle, Washington*. U.S. Geological Survey. OFR 2018–1149. Available at: https://pubs.usgs.gov/of/2018/1149/ofr20181149.pdf.

Wirth, E.A., J.E. Vidale, A.D. Frankel, T.L. Pratt, N.A. Marafi, M. Thompson, and W.J. Stephenson, 2019. “Source-Dependent Amplification of Earthquake Ground Motions in Deep Sedimentary Basins.” *Geophysical Research Letters* 46:6443–6450. Available at: https://doi.org/10.1029/2019GL082474.