Exhibit H

Geologic and Soil Stability

Wagon Trail Solar Project
December 2023

Prepared for

NEXTera ENERGY RESOURCES

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Acronyms and Abbreviations

Applicant	Wagon Trail Energy Center, LLC c/o NextEra Energy Resources, LLC
BMP	best management practice
DOGAMI	Oregon Department of Geologist and Mineral Industries
ESCP	Erosion and Sediment Control Plan
Facility	Wagon Trail Solar Project
FEMA	Federal Emergency Management Agency
IBC	International Building Code
K	erosion factor
Ksat	saturated hydraulic conductivity
kV	kilovolt
MMI	Modified Mercalli Intensity
NRCS	Natural Resources Conservation Service
OAR	Oregon Administrative Rule
OSSC	Oregon Structural Specialty Code
SLIDO	Statewide Landslide Information Database for Oregon
USGS	U.S. Geological Survey

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1.0 Introduction

Wagon Trail Energy Center, LLC c/o NextEra Energy Resources, LLC (Applicant) proposes to construct and operate the Wagon Trail Solar Project (Facility), a solar energy generation facility and related or supporting facilities in Morrow County, Oregon. This Exhibit H was prepared to meet the submittal requirements in Oregon Administrative Rule (OAR) 345-021-0010(1)(h).

2.0 Analysis Area

The analysis area for geologic and soil stability is defined in the Project Order as "the area within the site boundary, notwithstanding the distances related to an assessment of seismic hazards required by OAR 345-021-0010(1)(h)" (ODOE 2021). The analysis area for historical seismic and potentially active faults included a 50-mile buffer around the site boundary. The site boundary is defined in detail in Exhibits B and C and is shown on Figure H-1.

3.0 Geologic Report

> *OAR 345-021-0010(1)(h) Information from reasonably available sources regarding the geological and soil stability within the analysis area, providing evidence to support findings by the Council as required by OAR 345-022-0020, including:*
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> > *(A) A geologic report meeting the Oregon State Board of Geologist Examiners geologic report guidelines. Current guidelines shall be determined based on consultation with the Oregon Department of Geology and Mineral Industries, as described in paragraph (B) of this subsection.*

OAR 345-021-0010(1)(h)(A) requires submission of a geological report meeting the Oregon State Board of Geologist Examiners' (2014) geologic report guidelines. Based on consultation with the Oregon Department of Geology and Mineral Industries (DOGAMI; occurred July 28, 2021), guidelines were determined to be the 2014 Oregon State Board of Engineers Geology Reports. The results of the DOGAMI consultation discussion are included as Attachment H-1 and include a list of DOGAMI-provided references for use in this exhibit.

The Applicant has reviewed and used existing published information to characterize the geologic conditions and potential seismic hazards in the vicinity of the Facility site. These materials included local, state, and federal government databases related to soils and geologic hazards, and published soils and geologic maps. The findings are described in the following sections. Subsurface explorations, testing, and engineering analysis will be conducted prior to design and construction as described in Section 5.0.

The site boundary is located entirely within Morrow County, approximately 5 miles north of Lexington, Oregon, and approximately 12 miles northwest of Heppner. Morrow County spans from the Columbia River on its northern boundaries to the Blue Mountains on the south end. The topography in Morrow County varies from a gently rolling plain adjoining the Columbia River to broad plateaus and rounded ridges in the central part of the county, which merges with the more rugged terrain of a forested spur of the Blue Mountains in the southern part of the county (Morrow County 2017).

The Facility occupies slopes ranging from approximately zero to 24 percent, with an average slope of 5.5 percent (NRCS 2021). Elevations within the site boundary range from approximately 879 feet above mean sea level to 1,440 feet above mean sea level.

The site boundary is located on the Columbia Plateau physiographic province, which consists of a large plateau formed by a series of basalt flows. The top of the plateau tends to be relatively flat but has been dissected by ephemeral streams into steep-sided canyons. The Applicant has selected this site for solar development due to its flat topography and southern exposure to the sun. The site is bordered all around by farmland and Highway 207 to the east.

The geologic setting of the site generally consists of loess and weak tuffaceous sedimentary rock overlying basalt bedrock. Figure H-1 is a geologic map of the Facility's vicinity, adapted using U.S. Geological Survey (USGS) Geographic Information System data and DOGAMI resources (Madin et al. 2007; Franczyk et al. 2020). In some valley locations, catastrophic flood deposits (gravel and cobble bars overlain by silt) have been deposited by ancient floods. The geologic units are shown in Figure H-1 and include the Tertiary age Wanapum Basalt underlying the southern portion of the site and Tertiary age tuffaceous sedimentary rocks and tuff underlying the northern portion of the site. An area of Holocene and Pleistocene alluvial fan gravel overlies the tuffaceous sedimentary rocks and tuff in the northern portion of the site. The Wanapum Basalt is described as fine- to coarse-grained basalt with reversed magnetic polarity and varies from intact to weathered. The tuffaceous sedimentary rocks and tuff unit is described as semi-consolidated to well-consolidated lacustrine tuffaceous sandstone, siltstone, mudstone, concretionary claystone, pumicite, diatomite, air-fall and water-deposited vitric ash, palagonitic tuff and tuff breccia, and fluvial sandstone and conglomerate. In the vicinity of the Facility, this formation consists of imbricated, basaltic cobble gravel, with interbedded tuffaceous sands and silts that are weakly cemented in places. These geologic descriptions are summarized from a USGS geologic map prepared for the state of Oregon (Walker et al. 2003). Alluvial fan deposits consist of poorly sorted and partly consolidated boulder to pebble gravel, sand, silt, and clay deposited by intermittent streams. Thicknesses of the fan deposits are estimated to be between 15 and 85 feet (Madin et al. 2007).

4.0 Consultation with DOGAMI

OAR 345-021-0010(1)(h)(B) A summary of consultation with the Oregon Department of Geology and Mineral Industries regarding the appropriate methodology and scope of the seismic hazards and geology and soil-related hazards assessments, and the appropriate site-specific geotechnical work that must be performed before submitting the application for the Department to determine that the application is complete.

The Applicant consulted with DOGAMI on July 28, 2021. The general details of the Facility and the analysis area terrain and geology were discussed. Discussion focused on the most recent and most accurate data available from DOGAMI and the USGS for mapping, as well as geologic hazard evaluation. DOGAMI noted that a fault occurs within the site boundary and requires further evaluation. However, DOGAMI indicated that the fault is likely not a concern for the project development. Based on a 1981 map of the Columbia River Basalt group, several northwest/southeast trending faults are mapped within site boundary (USGS 1981). These faults appear to be part of numerous similar-trending faults mapped in the greater Columbia River Basin and are not indicated to be active within the Quaternary timeframe and were not identified in the most recent DOGAMI or USGS fault databases.

The meeting notes of the consultation discussion were used to support development of this exhibit and are included as Attachment H-1.

5.0 Site-Specific Geotechnical Investigation

OAR 345-021-0010(1)(h)(C) A description and schedule of site-specific geotechnical work that will be performed before construction for inclusion in the site certificate as conditions.

At an appropriate stage in the development, additional subsurface explorations will be completed to confirm the anticipated soil conditions and provide final design recommendations. The site-specific geological and geotechnical investigation will address subsurface exploration plans and testing plans. The geotechnical investigation will consist primarily of the following tasks:

- Reviewing available data from previous geotechnical explorations near the Facility site;
- Reviewing available geologic information from published sources;
- Reviewing data for evidence of active faults and landslides;
- Conducting a geotechnical field exploration, such as soil borings, test pits, and possibly geophysical testing; and
- Collecting additional soil samples for classification and laboratory testing, if necessary.

Geotechnical analyses will be used to calculate bearing capacity of the soils, conduct stability analyses, and provide engineering recommendations for construction of the structures.

6.0 Transmission Lines and Pipelines

OAR 345-021-0010(1)(h)(D) For all transmission lines, and for all pipelines that would carry explosive, flammable or hazardous materials, a description of locations along the proposed route where the applicant proposes to perform site specific geotechnical work, including but not limited to railroad crossings, major road crossings, river crossings, dead ends (for transmission lines), corners (for transmission lines), and portions of the proposed route where geologic reconnaissance and other site specific studies provide evidence of existing landslides, marginally stable slopes or potentially liquefiable soils that could be made unstable by the planned construction or experience impacts during the facility's operation.

The 230-kilovolt (kV) transmission line will extend approximately 0.6 mile total to connect the southern Facility collector substation to the existing Blue Ridge Substation (see Figure H-1). During final design, the Applicant plans to conduct geotechnical borings at dead end and turning structures, plus borings approximately every 1 mile of straight section of the transmission line. For the proposed route shown in Exhibit C (Figure C-2), this would equate to one boring; however, the actual number of borings will be based on final design of the transmission line route. There are no railroad crossings, major road crossings, or river crossings along the transmission line route (see Figure C-2 in Exhibit C).

The Facility does not have a pipeline. Therefore, this provision is not applicable.

7.0 Seismic Hazard Assessment

OAR 345-021-0010(1)(h)(E) An assessment of seismic hazards, in accordance with standard-of-practice methods and best practices, that addresses all issues relating to the consultation with the Oregon Department of Geology and Mineral Industries described in paragraph (B) of this subsection, and an explanation of how the applicant will design, engineer, construct, and operate the facility to avoid dangers to human safety and the environment from these seismic hazards. Furthermore, an explanation of how the applicant will design, engineer, construct and operate the facility to integrate disaster resilience design to ensure recovery of operations after major disasters. The applicant shall include proposed design and engineering features, applicable construction codes, and any monitoring and emergency measures for seismic hazards, including tsunami safety measures if the site is located in the DOGAMI-defined tsunami evacuation zone.

Morrow County has adopted a Natural Hazard Mitigation Plan that addresses hazards, vulnerabilities, and associated risks. As applicable, the Applicant has incorporated guidance as outlined in the earthquake and landslide annexes as needed for compliance with the Plan.

7.1 Methods

Topographic and geologic conditions and hazards within the site boundary were evaluated by reviewing available reference materials such as topographic and geologic maps, aerial photographs, existing geologic reports, and data provided by DOGAMI, the Oregon Water Resources Department, USGS, and the Natural Resources Conservation Service (NRCS).

This work was based on the potential for regional and local seismic activity as described in the existing scientific literature, and on subsurface soil and groundwater conditions within the site boundary based on desktop evaluations. The seismic hazard analysis consisted of the following tasks:

1. Detailed review of USGS, National Geophysical Data Center, and DOGAMI literature and databases;
2. Identification of potential seismic events for the site characterization of those events in terms of a series of design events;
3. Evaluation of seismic hazards, including potential for fault rupture, earthquake-induced landslides, liquefaction and lateral spread, settlement, and subsidence; and
4. Mitigation recommendations based on the characteristics of the subsurface soils and design earthquakes, including specific seismic events that might have a significant effect on the site, potential for seismic energy amplification at the site, and the site-specific acceleration response spectrum for the site.

7.2 Maximum Considered Earthquake Ground Motion under IBC 2018

The ground motions were developed using a probabilistic seismic hazard analysis that covered the Facility site. Though these motions are not considered site-specific, they provide a reasonable estimate of the ground motions within the site boundary. For new construction, the site should be designed for the maximum considered earthquake, according to the most recently updated International Building Code (IBC; ICC 2017) as supplemented by the Oregon Structural Specialty Code (OSSC; ICC 2019). The USGS Unified Hazard Tool (USGS 2020a) was run for the site boundary and the design event has a 2 percent probability of exceedance in 50 years (or a 2,475-year return period) (Attachment H-3). This event has a peak ground acceleration of 0.163 acceleration from gravity at the bedrock surface, at the western edge of the site boundary. The values of peak ground acceleration on rock are an average representation of the acceleration most likely to occur at the site for all seismic events (crustal, intraplate, or subduction; ATC 2020).

These desktop seismic design parameters were developed in accordance with the 2015 IBC (ICC 2014). Using the subsurface information currently available, the Facility would be designed for Site Class D, according to IBC requirements (Table H-1).

Table H-1. Seismic Design Parameters – Maximum Considered Earthquake

Site Class	Peak Horizontal Ground Acceleration on Bedrock	Soil Amplification Factor, F_a	Peak Horizontal Ground Acceleration at Ground Surface
S_D	0.163g	1.491	0.243g
g = acceleration from gravity.			

The following additional parameters for the maximum considered earthquake may be used for structural design:

- Short period (0.2-second) spectral response acceleration, S_{MS} = 0.576g for Site Class S_D
- 1-second period spectral response acceleration, S_{M1} = 0.337g for Site Class S_D

The design spectral response acceleration parameters, S_{DS} and S_{D1}, for both short period and 1-second period are determined by multiplying the maximum considered earthquake spectral response accelerations (S_{MS} and S_{M1}) by a factor of 2/3.

7.2.1 Earthquake Sources

Seismicity in northern Oregon is generated from the convergence of the Juan de Fuca plate and the North American plate at the Cascadia Subduction Zone. These plates converge at a rate between 1 and 2 inches per year and accumulate large amounts of stress that are released abruptly in earthquake events. The four sources of earthquakes and seismic activity in this region are crustal, intraplate, volcanic, and the Cascadia Subduction Zone (DOGAMI 2010).

Regionally, seismicity has been attributed to crustal deformation resulting from the Cascadia Subduction Zone and volcanism. Faults are considered active if there has been displacement in the last 10,000 years, and potentially active if there has been movement over the Quaternary period (last 1.6 million years). Overall, earthquakes in Oregon are associated with active faults in four regional zones of seismicity: the Cascade Seismic Zone, Portland Hills (Portland, Oregon-Vancouver, Washington metropolitan area) Zone, South-Central (Klamath Falls) Zone, and Northeastern Oregon Zone (Niewendorp and Neuhaus 2003). There are no active faults mapped within the site boundary, as indicated on Figure H-2. Figure H-2 was created using the DOGAMI Oregon HazVu Statewide Geohazards Viewer earthquake hazard layer (DOGAMI 2021) and the USGS Geologic Hazards Science Center (USGS 2020a, 2020b, 2020c). As previously discussed, several northwest/southeast trending faults are mapped within the site boundary based on a map of the Columbia River Basalt Group (USGS 1981). These faults appear to be part of numerous similar-trending faults mapped in the greater Columbia River Basin and are not indicated to be active within the Quaternary timeframe or identified on the most recent DOGAMI or USGS fault mapping databases. The site-specific geotechnical investigation will include additional information on these mapped faults and any potentially active faults within the site boundary. The investigation will include a description of the potentially active faults, their potential risk to the facility, and any additional mitigation that will be undertaken by the Applicant to ensure safe design, construction, and operation of the facility.

Probabilistic seismic hazard deaggregation at 475-year intervals is shown in Attachment H-2, and at 2,475-year intervals in Attachment H-3.

7.2.2 Recorded Earthquakes

Figure H-2 displays the location and approximate magnitude of all recorded earthquakes within 50 miles of the Facility site boundary. The historical seismic events are grouped by magnitude and are displayed using different-sized icons based on the strength of the event. Because of the high number of events in the vicinity of the Facility site, several of the icons overlap in the figure. The National Earthquake Information Center data show two earthquake epicenters of from 2.5 to 2.9 magnitude along the southeastern site boundary (Figure H-2). A table listing significant historical earthquakes and the year they occurred within 50 miles of the Facility is provided in Attachment H-4 (USGS 2020a, 2020b).

Attachment H-4 and Figure H-2 provide a summary of all recorded earthquakes known to have caused Modified Mercalli Intensity (MMI) III shaking intensity or greater within the Facility site boundary, regardless of epicentral origin. For reference, an intensity of MMI III is associated with shaking that is "noticeable indoors but may not be recognized as an earthquake." An intensity of MMI V is "felt by nearly everyone; many awakened" (USGS 2020b).

The Ground Response Spectra Assessment on Attachment H-5 lists the design response spectrum based on the 2015 IBC, which corresponds with the 2014 OSSC (ATC 2020). Response spectra are provided for the maximum considered earthquake at the location of the Facility. For the maximum considered earthquake, separate response spectra modified by the amplification factors for Site Class D are provided. However, examination of the geology mapped for the site suggests that shallow bedrock formations (Wanapum Basalt) may exist at certain locations, where the Site Class B response spectra would apply. Site Class will be determined based on results of the site-specific geotechnical investigation and will be applied to final design.

7.2.3 Hazards Resulting from Seismic Events

Potential seismic hazards associated with a design seismic event for the Facility include seismic shaking or ground motion, fault displacement, instability from landslides or subsurface movement, and adverse effects from groundwater or surface water. These hazard risks are anticipated to be low, as discussed below.

7.2.4 Seismic Shaking or Ground Motion

The design seismic event will have a 2,475-year recurrence interval. The structures will be designed for this unlikely event so that no permanent structural damage will occur. The Facility's structures will be designed to withstand the maximum risk-based design earthquake ground motions developed for the Facility site. The State of Oregon has adopted the IBC 2018 code for structural design. Specifically, this is Section 1613 (Earthquake Loads) of the 2019 OSSC, which is in Chapter 16. It should be noted that building codes are frequently updated; the IBC specifically is updated every 3 years. The Applicant will design, engineer, and construct the Facility in accordance with the current version of the latest IBC, OSSC, and building codes adopted by the State of Oregon at the time of construction. Therefore, it is incumbent on the design engineers to ensure that the designs are in accordance with the current versions of the latest codes as adopted by the State of Oregon at the time of construction.

Based on geotechnical and geological information, a Site Class for the soil/bedrock at the site is assigned. For this desktop analysis, a Site Class D (stiff soil) is appropriate for the Facility. As stated above, the Site Class will be determined based on results of the site-specific geotechnical investigation and will be applied to final design.

Based on site-specific geotechnical analyses, the original equipment manufacturer will provide the structural engineer with site specific foundation loads and requirements. The structural engineer then completes the foundation analyses based on the design site-specific parameters. Generally, these include the following loads for solar foundation design: extreme loads, load cases for up-lift, shear failure, tension loads (for pile foundations), earthquake loads, fatigue loads, subsoil properties, spring constants, verification procedures, and maximum allowable inclination.

The geotechnical studies and analyses provide site-specific parameters including, but not necessarily limited to, moisture content and density, soil/bedrock bearing capacity, bedrock depth, settlement characteristics, structural backfill characteristics, soil improvement (if required), and dynamic soil/bedrock properties including shear modulus and Poisson's Ratio of the subgrade. The foundation design engineer uses these parameters to design a foundation suitable for the Facility and verifies that the foundation/soil interaction meets or exceeds the minimum requirements stated by the original equipment manufacturer for the Facility.

7.2.5 Fault Rupture

The probability of a fault displacement within the site boundary is considered moderate to high because there is a mapped potentially active fault within 25 miles of the site boundary and historic faulting located within the site boundary (Figure H-2). North-northwest of the site boundary approximately 15 miles near Blalock Flat, south of the Columbia River and west of Arlington, Oregon is the north-northwest-striking strike slip faults of the Yakima Fold Belt. As previously discussed, several northwest/southeast-trending faults are mapped within the site boundary based on a map of the Columbia River Basalt Group (USGS 1981). These faults appear to be part of numerous similar-trending faults mapped in the greater Columbia River Basin and are not indicated to be active within the Quaternary timeframe or identified on the most recent DOGAMI or USGS fault mapping databases.

Numerous 2.5 to 2.9 magnitude earthquakes and two 3.0 to 3.9 earthquakes are located in this area (Exhibit H-2). Moderate to strong shaking could be expected at the Facility site during an earthquake event (DOGAMI 2021). Unknown faults could exist, or new fault ruptures could form during a significant seismic event, but the likelihood of either occurrence is low based on the lack of active faults identified during previous geologic investigations.

7.2.6 Liquefaction

Liquefaction is a phenomenon in which saturated, cohesionless soils temporarily lose their strength and liquefy when subjected to dynamic forces such as intense and prolonged ground shaking and seismic activity. The soils in the site boundary are not saturated and are generally cohesive in nature. In addition, as documented in Exhibit J, no wetlands were delineated within the site boundary and only four ephemeral streams were identified within the site boundary. Available water well records in the site boundary generally indicate water levels range from 60 feet to over 400 feet below ground surface (OWRD 2021). Alluvial fan deposits are located within the Facility's northeast site boundary extending northeasterly approximately 5 miles past the site boundary. These deposits are indicated to be unsaturated. Based on earthquake activity within 25 miles north/northwest of the site boundary and the presence of the alluvial fan deposits, low to moderate liquefaction hazard is possible (DOGAMI 2021). Additional geotechnical studies will be conducted to determine potential liquefaction hazards.

7.2.7 Seismically Induced Landslides

Seismicity in the region has the potential to trigger landslides and mass wasting processes within the site boundary; however, the potential is considered low and limited to the steepest areas surrounding drainages. As previously discussed, slopes within the site boundary range from approximately zero to 24 percent with an average slope of 5.5 percent. Known landslides are shown on Figure H-1. More detailed discussion of the location and type of landslides is included in Section 8.1.

7.2.8 Subsidence

Subsidence is the sudden sinking or the gradual downward settling of the land surface, and is often related to groundwater drawdown, compaction, tectonic movements, mining, or explosive activity. Subsidence due to a seismic event is highly unlikely. In most areas, of the site boundary the bedrock is relatively shallow, and the overlying soils and alluvial fan deposits are not saturated.

7.2.9 Seismic Hazard Mitigation

The State of Oregon uses the 2018 IBC, with current amendments by the OSSC (ICC 2019). Pertinent design codes as they relate to geology, seismicity, and near-surface soil are contained in the IBC Chapter 16, Section 1613, with slight modifications by the current amendments of the State of Oregon. The Facility will be designed to meet or exceed the minimum standards required by these design codes.

A site-specific geotechnical exploration will be conducted to collect pertinent data for the design of the Facility to mitigate potential hazards that could be created during a seismic event. The hazard of a surficial rupture along a fault trace is anticipated to be low, given the low probability that a fault rupture would actually displace the ground surface at the location of any of the solar panel arrays or transmission structures. No mitigation for potential fault rupture is anticipated; the risk to human safety and the environment will be minimal, as the Facility will be located in a sparsely populated area. No structures will be built on steep slopes that could be prone to instability, thus avoiding potential impacts. Design guidelines related to disaster resilience are further described in Section 8.6.

8.0 Non-Seismic Geological Hazards

> *OAR 345-021-0010(1)(h)(F) An assessment of geology and soil-related hazards which could, in the absence of a seismic event, adversely affect or be aggravated by the construction or operation of the facility, in accordance with standard-of-practice methods and best practices, that address all issues relating to the consultation with the Oregon Department of Geology and Mineral Industries described in paragraph (B) of this subsection. An explanation of how the applicant will design, engineer, construct and operate the facility to adequately avoid dangers to human safety and the environment presented by these hazards, as well as:*
>
> > *(i) An explanation of how the applicant will design, engineer, construct and operate the facility to integrate disaster resilience design to ensure recovery of operations after major disasters.*
> >
> > *(ii) An assessment of future climate conditions for the expected life span of the proposed facility and the potential impacts of those conditions on the proposed facility.*

Morrow County has adopted a Natural Hazard Mitigation Plan that addresses hazards, vulnerabilities, and associated risks. As applicable, the Applicant has incorporated guidance as outlined in the landslide, volcano, flood, and windstorm annexes as needed for compliance with the Plan.

Nonseismic geologic hazards in the Columbia Plateau region typically include landslides, volcanic eruptions, collapsing soils, and erosion potential. The area within the Facility site boundary consists of relatively flat-lying basalt with a very thin or absent cover of loess. The solar arrays and associated equipment, roads, and transmission line will be constructed on the flat-lying part within the site boundary and will avoid steep side slopes and drainages that could potentially be subject to landslides and soil creep. A discussion of potential geologic hazards is presented below.

8.1 Landslides

No active landslides are identified in the Statewide Landslide Information Database for Oregon (Burns et al. 2014) within the site boundary (Figure H-1). The closest mapped landslides in the Statewide Landslide Information Database for Oregon (SLIDO) database are located approximately 4.5 miles to the southeast of the site boundary (see Figure H-1).

The solar arrays and associated equipment and roads, including the access road and service roads, will be situated on flat-lying areas and avoid steep slopes (see Figure C-2 in Exhibit C). The transmission line will be located in areas with slopes that, based on geologic mapping and site reconnaissance observations, are formed in flat-lying basalt flows with very little soil cover. If slope stability issues are identified during the final design geotechnical investigations, either the structures will be relocated during the micrositing process or remedial measures to improve slope stability will be implemented.

8.2 Volcanic Activity

Volcanic activity in the Cascade Range is driven by the subduction of the Juan de Fuca plate beneath the North American plate. The closest volcano to the site boundary is Mount Hood located approximately 100 miles away to the west. Most of the potential volcanic hazard impacts would occur within a 50-mile radius of the erupting volcano. Depending on the prevailing wind direction at the time of the eruption and the source of the eruption, ash fallout in the region surrounding the Facility may occur. Because of the distance to the nearest volcano, impacts to the Facility from volcanic activity would be indirect and likely be limited to ash fallout. In addition, the Facility is not located near any streams that would likely be subject to pyroclastic flows from a volcanic eruption from these close volcanoes. It is unlikely that there would be any adverse effects from volcanic activity on the construction or operation of the Facility.

8.3 Erosion

Erosion can be caused by increasing exposure to wind or water. The erosion factor (K) indicates the susceptibility of a soil to sheet and rill erosion by water. The K-factor is one of six factors used in the Universal Soil Loss Equation and the Revised Universal Soil Loss Equation to predict the average annual rate of soil loss by sheet and rill erosion in tons-per-acre-per-year. The estimates are based primarily on percentage of silt, sand, and organic matter, as well as soil structure and saturated hydraulic conductivity (Ksat). Values of K range from 0.02 to 0.69. Other factors being equal, the higher the value, the more susceptible the soil is to sheet and rill erosion by water. Data from the NRCS Web Soil Survey (NRCS 2021) indicate that the soils within the site boundary have a K that ranges from 0.10 to 0.55. For the range of K at the Facility, the soils could be considered slightly to moderately severe in erodibility, and subject to sheet erosion and rill erosion by water (NRCS 2021).

To reduce the potential for soil erosion, a construction Erosion and Sediment Control Plan (ESCP) will be developed for the Facility. The ESCP will include both structural and nonstructural best management practices (BMP). Examples of structural BMPs include the installation of silt fences or other physical controls to divert flows from exposed soils, or otherwise limit runoff and pollutants from exposed areas within the Facility site boundary. Examples of nonstructural BMPs include management practices such as implementation of materials handling, disposal requirements, and spill prevention methods.

The Applicant will obtain a National Pollutant Discharge Elimination System Construction Stormwater Discharge General Permit 1200-C prior to construction via the ODEQ Your DEQ Online platform[1] and has attached a draft ESCP to Exhibit I which will be finalized prior to construction

[1] https://ordeq-edms-public.govonlinesaas.com/pub/login?web=1

and included as part of the permit application. In addition, Exhibit I contains a comprehensive list of best management practices to avoid wind and water erosion and soil impacts.

8.4 Flooding

To evaluate flood hazards, the DOGAMI Statewide Flood Hazard Database for Oregon – Federal Emergency Management Agency (FEMA), National Flood Hazard data (FEMA 2018), and Flood Insurance Study inundation zones (DOGAMI 2018) were compared to the site boundary. The site boundary is not within an identified FEMA 100-year or 500-year floodplain (Figure H-3).

Seasonal thunderstorms can result in concentrated stormwater runoff and localized flooding. The engineered access roads and drainages will direct stormwater runoff away from structures and into drainage ditches and culverts as required in the ESCP. The Facility will be designed and constructed to meet the requirements of the zoning ordinances and building codes that establish flood protection standards for all construction, to avoid dangers to the infrastructure, as well as human safety and the environment, including criteria to ensure that the foundation will withstand flood forces. Therefore, the risks and potential impacts to the Facility as well as human safety and the environment from flood hazards are expected to be low.

8.5 Shrinking and Swelling Soils

Changes in soil moisture cause certain clay minerals in soils to either expand or contract. The amount and type of clay minerals in the soil influence the change in volume. Structures or roads built on shrinking or swelling soils could be damaged by the change in volume of the soil. Linear extensibility (shrink-swell potential) refers to the change in length of an unconfined clod as its moisture content is decreased from a moist state to a dry state.

There are no soils identified in the site boundary with potential for shrinking and swell (see Exhibit I). Prior to construction, the Applicant will include, as part of the geotechnical investigation, an investigation of the swell and collapse potential of loess soil in the site boundary. Based on the results of the investigation, the Applicant will include mitigation measures including, as necessary, over-excavating and replacing loess soil with structural fill; wetting and compacting; deep foundations; or avoidance of specific areas.

The solar structures will be supported by steel posts; post depth will vary depending on soil conditions but is typically 5 to 20 feet below the surface. If soil conditions require it, concrete foundations will be used. Assuming steel posts are used, they will be driven into bedrock.

8.6 Disaster Resilience

The State of Oregon uses the 2018 IBC, with current amendments by the OSSC (ICC 2019) and local agencies. Pertinent design codes as they relate to geology, seismicity, and near-surface soils are contained in IBC Chapter 16, Section 1613, with slight modifications by the current amendments of the State of Oregon and local agencies. The Facility will be designed to meet or exceed the minimum standards required by these design codes. The Applicant acknowledges that DOGAMI encourages, but does not require, applicants to design and build for disaster resilience and future climate conditions using science, data, and community wisdom. With this in mind, the Applicant has extensive experience building energy facilities (see Exhibit D) and from a structural perspective, designs projects to withstand non-seismic geologic hazards such as the potential for changes in rainfall or temperature. Additional elements such as wind speeds, snow, and dust, among others, are also considered in project designs depending on the location in the country.

A qualified engineer will assess and review the seismic, geologic, and soil hazards associated with the construction of the Facility. Construction requirements will be modified, as needed, based on the site-specific characterization of seismic, geologic, and soil hazards. The Facility will be designed, engineered, and constructed to meet all current standards to adequately avoid potential dangers to human safety presented by seismic hazards. Substation and operations and maintenance building structures will be designed in accordance with the current version of the OSSC. Substation equipment will be specified in accordance with the latest version of the Institute of Electrical and Electronics Engineers 693. The Facility will be located in a sparsely populated area; therefore, the risks to human safety and the environment due to seismic hazards will be minimal.

The Facility will be designed, engineered, and constructed to meet or exceed all current standards. The Applicant proposes to design, engineer, and construct the Facility to avoid dangers to human safety–related and non-seismic hazards in many ways, including conducting site-specific geotechnical evaluations for the facilities. Typical mitigation measures for non-seismic hazards include avoiding potential hazards, conducting subsurface investigations to characterize the soils to adequately plan and design appropriate mitigation measures, creating detailed geologic hazard maps to aid in laying out facilities, and providing warnings in the event of hazards. Solar facilities are designed to be modular, with different circuits and disconnect switches between inverters. This allows for portions of a facility to be taken offline for repair following a disaster, while the remainder of the solar arrays can continue to operate in a reduced capacity. The Applicant plans to follow the industry practice of installing excess cabling between strings to allow for splicing and repairs in the event of a disaster. Should Facility elements like the access roads or solar panels be damaged, they will be assessed, and repairs made to recover operations after a major storm event.

8.7 Climate Change

The University of Washington conducted a study to assess climate vulnerability and adaptation in the Columbia River Plateau, the region where the Facility is located (Michalak et al. 2014). The study involved downscaling five climate models (CCM3, CGM3.1, GISS-ER, MIROC3.2, and Hadley). Climate projections were downscaled to approximately a 1-kilometer resolution for over 40 different direct (mean annual temperature/precipitation) and derived (number of growing-degree days, actual and potential evapotranspiration) climate variables (Michalak et al. 2014). The downscaling of the climate models for this area led to future projections of greater annual average and summer temperatures, and more severe storm events and wildfires, among other changes. These specific changes are expected to increase stress to power lines in the region.

Reinforcing the local electric grid with solar power, battery energy storage, and a new transmission line will provide resilience to the overall energy grid in this part of Oregon. This reinforcement will be direct, by upgrading the system, which is anticipated to experience higher loads under rising temperatures and the related increases in power demand for summer cooling. It is also indirect, by supporting the delivery of power generated through a larger variety of sources, minimizing the potential reduction in hydro power's role under future conditions. All aspects of this Facility support resiliency in the face of future climate change. In addition, the Facility will be designed to withstand extreme events as explained above in Section 8.6.

9.0 Conclusions

The risk of seismic hazards to human safety at the Facility is considered low. The Applicant has adequately characterized the area within the Facility site boundary and surrounding vicinity in accordance with OAR 345-022-0020(1)(a) and has considered seismic events and amplification for the Facility's specific subsurface profile. The probability of a large seismic event occurring while the Facility is occupied is much lower than for a normal building or facility. This very low probability results in minimal risk to human safety. The risk to human safety is slightly higher at the O&M building, which is required to be designed to current seismic standards for structural safety.

The Applicant has demonstrated that the Facility can be designed, engineered, and constructed to avoid dangers to human safety in case of a design seismic event by adhering to recently updated IBC requirements, per OAR 345-022-0020(1)(b). These standards require that, for the design seismic event, the factors of safety used in the Facility design exceed certain values. For example, in the case of slope design, a factor of safety of at least 1.1 is normally required during the evaluation of seismic stability. This factor of safety is introduced to account for uncertainties in the design process and to ensure that performance is acceptable. Given the relatively low level of risk for the Facility, adherence to the IBC requirements will ensure that appropriate protection measures for human safety are taken.

The Applicant has provided appropriate site-specific information and demonstrated (in accordance with OAR 345-022-0020[1][c]) that the construction and operation of the Facility, in the absence of a seismic event, will not adversely affect or aggravate the geological or soil conditions within the Facility site boundary or surrounding vicinity. The risks posed by non-seismic geologic hazards are considered to be low because the Facility can be designed to avoid or minimize the hazards of landslides and soil erosion. Landslide and slope stability issues will be identified during final design and mitigated. Erosion hazards resulting from soil and wind action will be minimized with the implementation of an engineered construction ESCP.

Finally, the Applicant has demonstrated that the Facility can be designed, engineered, and constructed to avoid dangers to human safety resulting from the geological and soil hazards within the Facility site boundary, pursuant to OAR 345-022-0020(1)(d). Site-specific studies will be conducted, geotechnical work will be completed to inform final design, and adequate measures will be implemented to control erosion. Accordingly, given the relatively small risks these hazards pose to human safety, standard methods of practice (including implementation of the current IBC) will be adequate for the design and construction of the Facility.

10.0 Submittal Requirements and Approval Standards

10.1 Submittal Requirements

Table H-2. Submittal Requirements Matrix

Requirement	Location
OAR 345-021-0010(1)(h) Information from reasonably available sources regarding the geological and soil stability within the analysis area, providing evidence to support findings by the Council as required by OAR 345-022-0020, including:	Section 3.0
(A) A geologic report meeting the Oregon State Board of Geologist Examiners geologic report guidelines. Current guidelines shall be determined based on consultation with the Oregon Department of Geology and Mineral Industries, as described in paragraph (B) of this subsection.	Section 3.0
(B) A summary of consultation with the Oregon Department of Geology and Mineral Industries regarding the appropriate methodology and scope of the seismic hazards and geology and soil-related hazards assessments, and the appropriate site-specific geotechnical work that must be performed before submitting the application for the Department to determine that the application is complete.	Section 4.0
(C) A description and schedule of site-specific geotechnical work that will be performed before construction for inclusion in the site certificate as conditions.	Section 5.0
(D) For all transmission lines, and for all pipelines that would carry explosive, flammable or hazardous materials, a description of locations along the proposed route where the applicant proposes to perform site specific geotechnical work, including but not limited to railroad crossings, major road crossings, river crossings, dead ends (for transmission lines), corners (for transmission lines), and portions of the proposed route where geologic reconnaissance and other site specific studies provide evidence of existing landslides, marginally stable slopes or potentially liquefiable soils that could be made unstable by the planned construction or experience impacts during the facility's operation.	Section 6.0
(E) An assessment of seismic hazards, in accordance with standard-of-practice methods and best practices, that addresses all issues relating to the consultation with the Oregon Department of Geology and Mineral Industries described in paragraph (B) of this subsection, and an explanation of how the applicant will design, engineer, construct, and operate the facility to avoid dangers to human safety and the environment from these seismic hazards. Furthermore, an explanation of how the applicant will design, engineer, construct and operate the facility to integrate disaster resilience design to ensure recovery of operations after major disasters. The applicant shall include proposed design and engineering features, applicable construction codes, and any monitoring and emergency measures for seismic hazards, including tsunami safety measures if the site is located in the DOGAMI-defined tsunami evacuation zone.	Section 7.0

Requirement	Location
(F) An assessment of geology and soil-related hazards which could, in the absence of a seismic event, adversely affect or be aggravated by the construction or operation of the facility, in accordance with standard-of-practice methods and best practices, that address all issues relating to the consultation with the Oregon Department of Geology and Mineral Industries described in paragraph (B) of this subsection. An explanation of how the applicant will design, engineer, construct and operate the facility to adequately avoid dangers to human safety and the environment presented by these hazards, as well as:	Section 8.0
(i) An explanation of how the applicant will design, engineer, construct and operate the facility to integrate disaster resilience design to ensure recovery of operations after major disasters.	Section 8.6
(ii) An assessment of future climate conditions for the expected life span of the proposed facility and the potential impacts of those conditions on the proposed facility.	Section 8.7

10.2 Approval Standards

Table H-3. Approval Standard

Requirement	Location
OAR 345-022-0020 Structural Standard	
(1) Except for facilities described in sections (2) and (3), to issue a site certificate, the Council must find that:	–
(a) The applicant, through appropriate site-specific study, has adequately characterized the seismic hazard risk of the site; and	Section 7.0
(b) The applicant can design, engineer, and construct the facility to avoid dangers to human safety and the environment presented by seismic hazards affecting the site, as identified in subsection (1)(a);	Sections 7.0 and 8.0
(c) The applicant, through appropriate site-specific study, has adequately characterized the potential geological and soils hazards of the site and its vicinity that could, in the absence of a seismic event, adversely affect, or be aggravated by, the construction and operation of the proposed facility; and	Section 8.0
(d) The applicant can design, engineer and construct the facility to avoid dangers to human safety and the environment presented by the hazards identified in subsection (c).	Section 8.0
(2) The Council may not impose the Structural Standard in section (1) to approve or deny an application for an energy facility that would produce power from wind, solar or geothermal energy. However, the Council may, to the extent it determines appropriate, apply the requirements of section (1) to impose conditions on a site certificate issued for such a facility.	N/A
(3) The Council may not impose the Structural Standard in section (1) to deny an application for a special criteria facility under OAR 345-015-0310. However, the Council may, to the extent it determines appropriate, apply the requirements of section (1) to impose conditions on a site certificate issued for such a facility.	N/A

11.0 References

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Walker, George W., Norman S. McLeod, Robert J. Miller, Gary L. Raines, and Katherine A. Connors. 2003. Spatial Digital Database for the Geologic Map of Oregon. Open File Report 2003-67. Available online at: http://pubs.er.usgs.gov/publication/ofr200367

Figures

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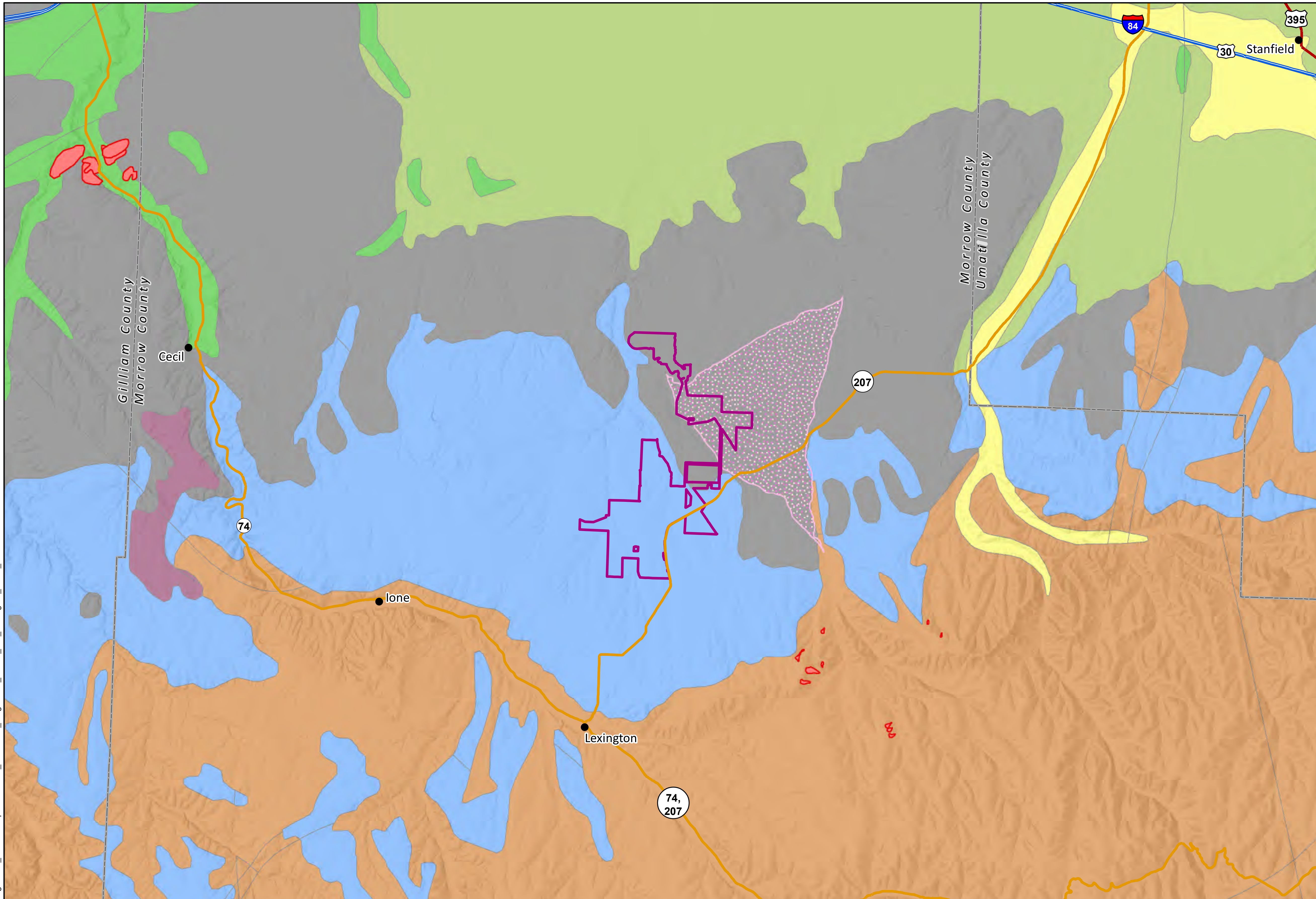


Wagon Trail Solar Project

Figure H-1 Geological Map

MORROW COUNTY, OREGON

- Site Boundary
- City/Town
- Interstate Highway
- US Highway
- State Highway
- County Boundary

Deposits

- Fan
- Landslide

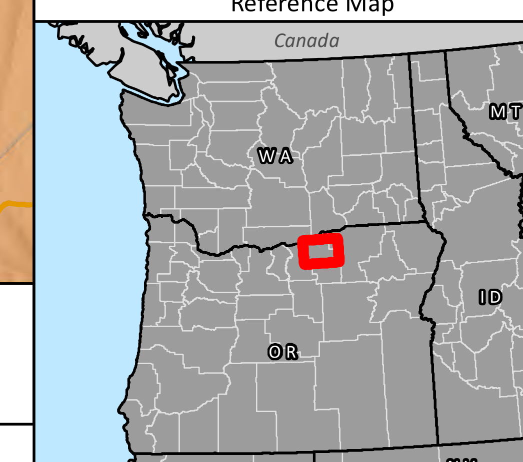
Surface Geology

Qal	*Alluvial Deposits*
QTs	*Qts Sedimentary Rocks (Pleistocene AND Pliocene)*
Qgs	*Glaciofluvial, Lacustrine, and Pediment Sedimentary Deposits (Pleistocene)*
Tcg	*Grande Ronde Basalt (Middle and Lower Miocene)*
Tcs	*Saddle Mountains Basalt (Upper and Middle Miocene)*
Tcw	*Wanapum Basalt (Middle Miocene)*
Ts	*Tuffaceous Sedimentary Rocks and Tuff (Pliocene and Miocene)*

TETRA TECH

NEXTera ENERGY RESOURCES

Reference Map



Data Source:
Surface Geology: Smith, R.L., and Roe, W.P., 2015, Oregon Geologic Data Compilation (OGDC)-Release 6: Oregon Department of Geology and Mineral Industries Digital Data Series OGDC-6.
Madin, I.P. and Geitgey, R.P. 2007. Preliminary Geologic Map of the Umatilla Basin, Marrow and Umatilla Counties, Oregon. DOGAMI Open-File Report O-07-15.https://digital.osl.state.or.us/islandora/object/osl:72600.
Deposits:William J. Burns, Statewide Landslide Information Database of Oregon (SLIDO) Release 1: Oregon Dept. of Geology & Mineral Resources

N **1:200,000** **WGS 1984 UTM Zone 11N**

0 1 2 4 6 8 Miles

NOT FOR CONSTRUCTION

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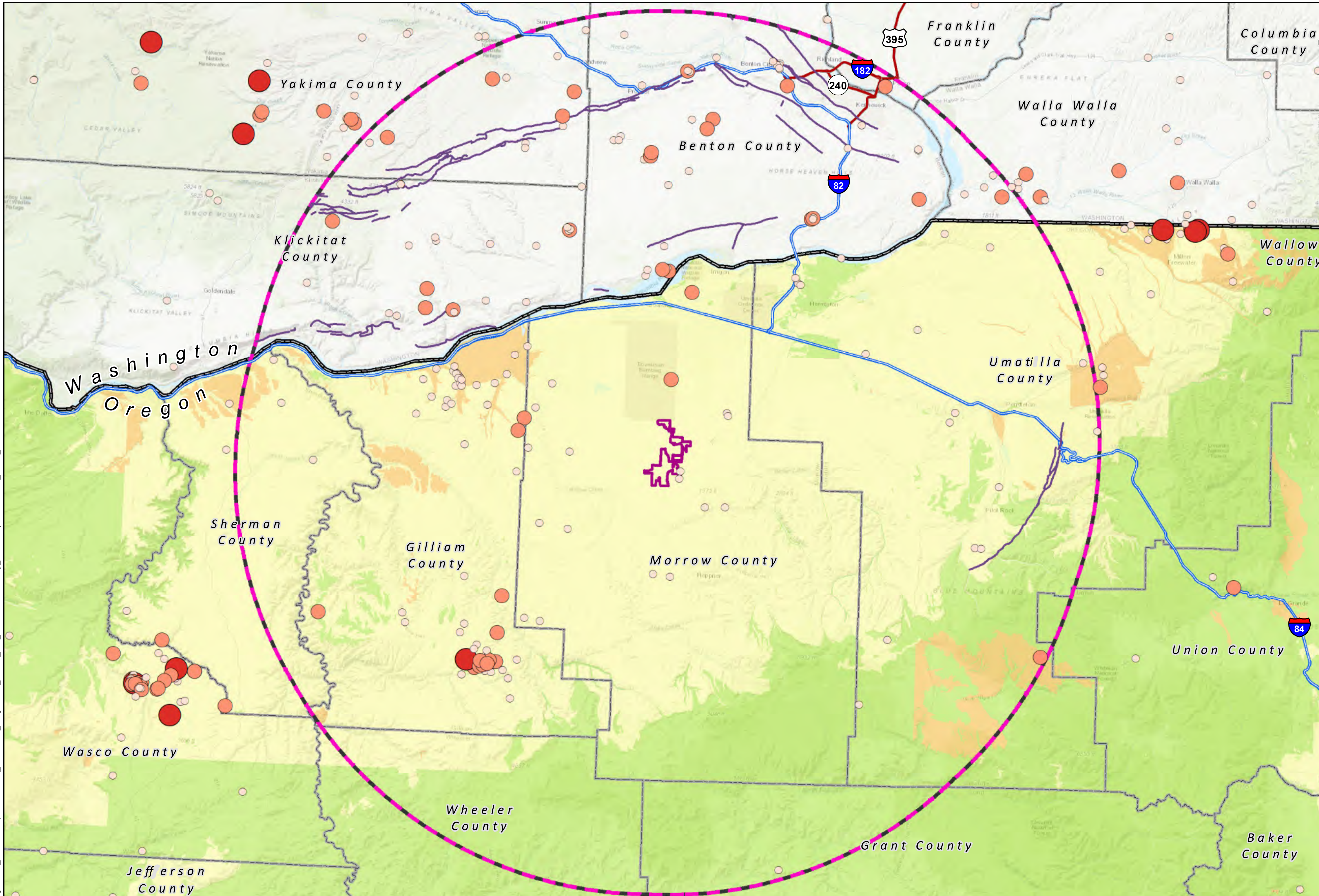
Wagon Trail Solar Project

Figure H-2
Historical Seismicity and Potentially Active Faults

MORROW COUNTY, OREGON



- Site Boundary
- Analysis Area (50-mile Buffer)
- Interstate Highway
- Primary Highway
- County Boundary
- State Boundary
- Undifferentiated Quaternary Fault

Earthquakes by Magnitude

- 2.5 - 2.9
- 3.0 - 3.9
- 4.0 - 4.9

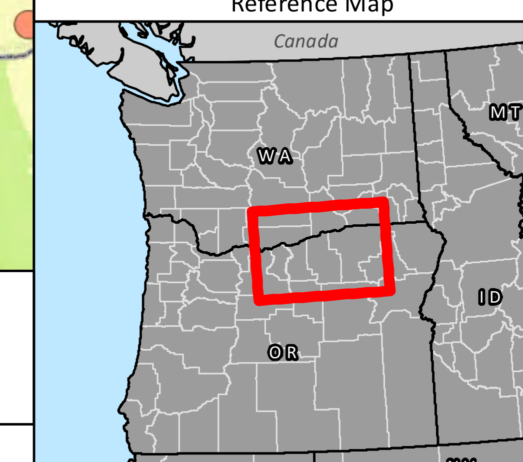
Radon Potential

- Low
- Moderate
- High

TETRA TECH

NEXTera ENERGY RESOURCES

Reference Map



Data Source:

Fault lines: USGS. 2020. U.S. Quaternary Fault. USGS Geologic Hazards Center Golden, CO. Available online at: https://usgs.maps.arcgis.com/apps/webappviewer/index.html?id=5a6038b3a1684561a9b0aadf88412fcf

Earthquake by Magnitude: USGS. 2020. Earthquake Hazards Program, Search Earthquake Catalog. Available online at: https://earthquake.usgs.gov/earthquakes/search/

Radon Potential: DOGAMI. 2018. Radon Potential in Oregon. Oregon Department of Geology and Mineral Industries Portland, OR. Available online at: https://www.oregongeology.org/pubs/ofr/p-O-18-01.htm

DOGAMI . 2021. Oregon HazVu: Statewide Geohazards Viewer earthquake hazard layer. Available online at: https://gis.dogami.oregon.gov/maps/hazvu/. Accessed October 06, 2021.

N 1:750,000 WGS 1984 UTM Zone 11N

0 1 2 4 6 8 Miles

NOT FOR CONSTRUCTION

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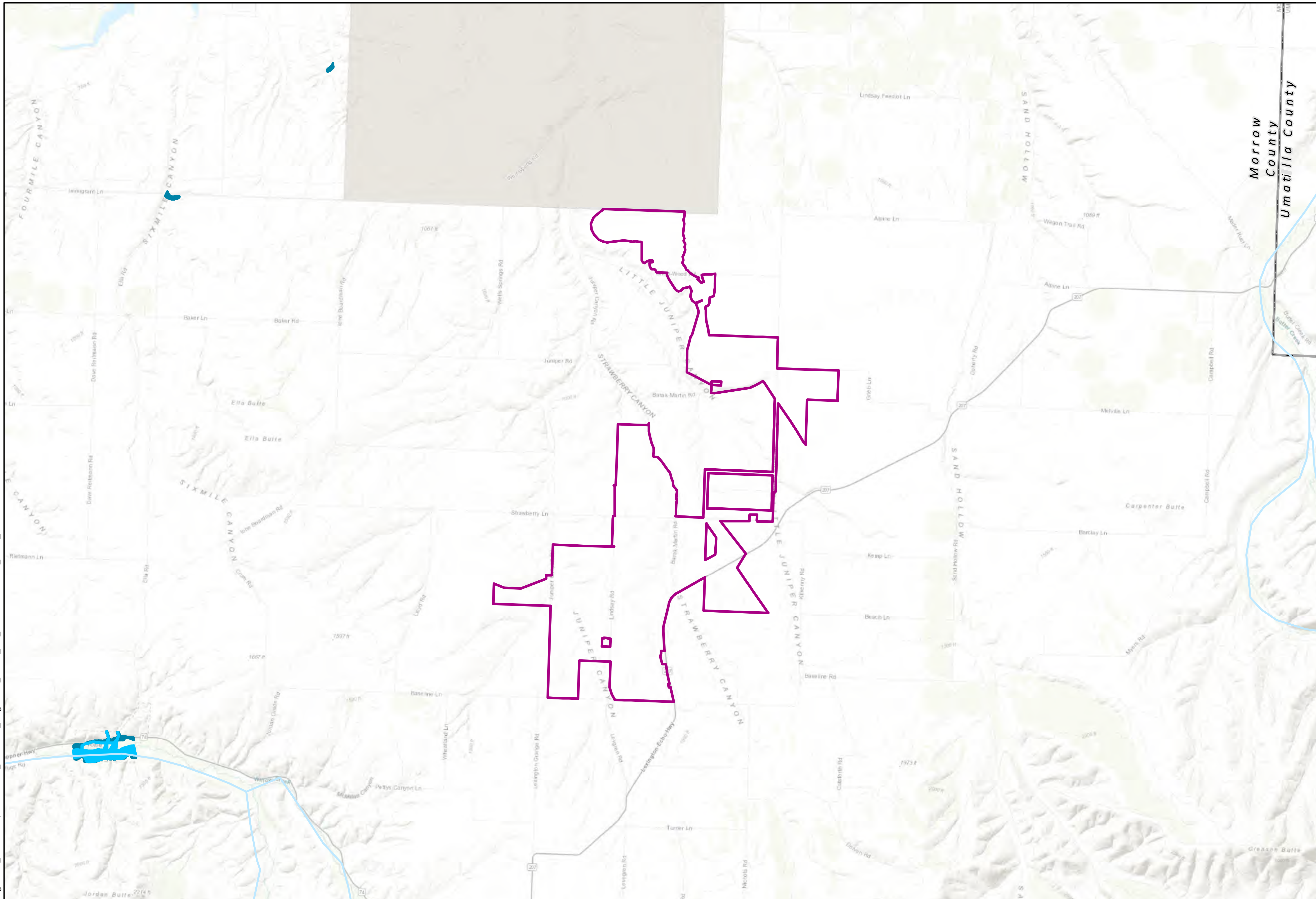
Wagon Trail Solar Project

Figure H-3
Special Flood Hazard Areas

MORROW COUNTY, OREGON



- Site Boundary
- County Boundary
- River/Stream

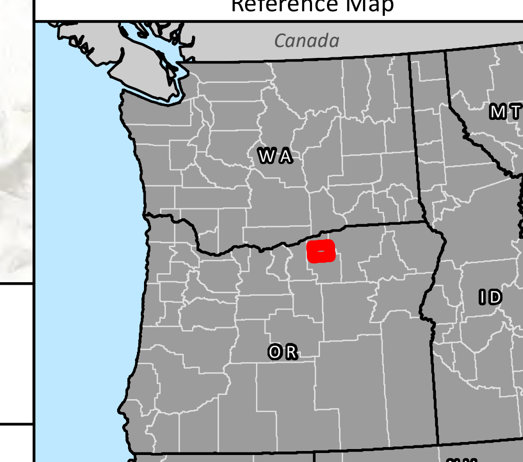
Special Flood Hazard Areas

- 500-year Flood Zone
- Floodway

TETRA TECH

NEXTera ENERGY RESOURCES

Reference Map



Data Source:
Special Flood Hazard: FEMA (Federal Emergency Management Agency). 2021. FEMA National Flood Hazard Layer. Available online at: https://www.fema.gov/national-flood-hazard-layer-nfhl.

1:100,000 **WGS 1984 UTM Zone 11N**

0 0.5 1 2 3 4 Miles

NOT FOR CONSTRUCTION

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Attachment H-1. Evidence of Consultation with DOGAMI

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Meeting Notes

Wagon Trail Solar Facility – DOGAMI Consultation

July 28, 2021
Teleconference
3:00 p.m. – 4:00 p.m.

Attendees: Jason McClaughry/DOGAMI
Chase McVeigh-Walker/ODOE
Kathleen Sloan/ODOE
Chris Powers/NextEra
Anneke Solsby/NextEra
Carrie Konkol/Tetra Tech
Rachel Miller/Tetra Tech

Meeting Purpose	OAR 345-021-0010(1)(h)(B) requires pre-application consultation with DOGAMI for new energy facilities
Project Overview	Project description was discussed, including reference to figures submitted as part of the Notice of Intent. The permitting approach, Application for Site Certificate (ASC), and applicable schedule was discussed. Applicant is anticipating submittal of the preliminary ASC in late summer or early fall of 2021.
Site Characteristics	Draft ASC Exhibit H figures were shared and discussed. DOGAMI recommended updates to the figures with the following resources: • The updated GIS Data – Oregon Geologic Data Compilation • USGS updated fault data • DOGAMI indicated that there are north-northwest-striking strike slip faults in the Yakima Fold Belt. Some of these may be potentially active. One of these is present in the area near Blalock on the Columbia River. Moderate shaking could be expected at the proposed site during an earthquake event and low to moderate liquefaction hazard at the proposed site is indicated. • The Oregon HazVu GIS resource has information on floodplains, earthquake hazards, and landslide hazards and this resource should be used. • Liquefaction could be an issue due to the local faulting and the fan deposits in the northeastern portion of the project area. • Be aware of potential radon issues – though not really an issue for a solar facility. • Jason indicated that the fault issue was his major concern, although he indicated he did not see any red flags in terms of the project from the perspective of geologic hazards at this point.
Geotechnical Requirements	DOGAMI referenced their Notice of Intent comments (see attached comments from 1/22/2021), and later provided an updated list of resources via email (see attached list provided on 8/6/2021) as a follow-up to this meeting.

Helpful geologic resources for Geotechnical site investigations in Oregon:
V1, June 10th, 2021

DOGAMI (Oregon Department of Geology and Mineral Industries). 2021a. Geologic Map of Oregon, Oregon Geologic Data Compilation release 7 (OGDC-7). Available online at: https://www.oregongeology.org/geologicmap/index.htm

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DOGAMI. 2018. Oregon HazVu: Statewide Geohazards Viewer. Available online at: https://www.oregongeology.org/hazvu/index.htm

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Attachment H-2. Probabilistic Seismic Hazard Deaggregation at 475-year Intervals

U.S. Geological Survey - Earthquake Hazards Program

Unified Hazard Tool

Please do not use this tool to obtain ground motion parameter values for the design code reference documents covered by the U.S. Seismic Design Maps web tools (e.g., the International Building Code and the ASCE 7 or 41 Standard). The values returned by the two applications are not identical.

Input

Edition

Dynamic: Conterminous U.S. 2014 (v…

Latitude

Decimal degrees

45.595

Longitude

Decimal degrees, negative values for western longitudes

-119.604

Site Class

760 m/s (B/C boundary)

Spectral Period

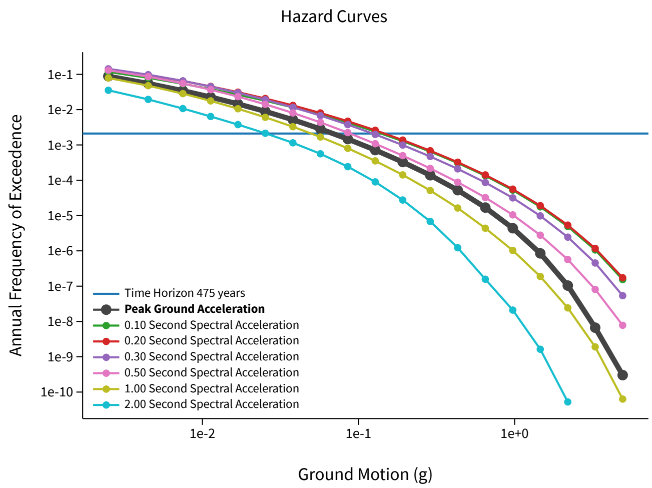
Peak Ground Acceleration

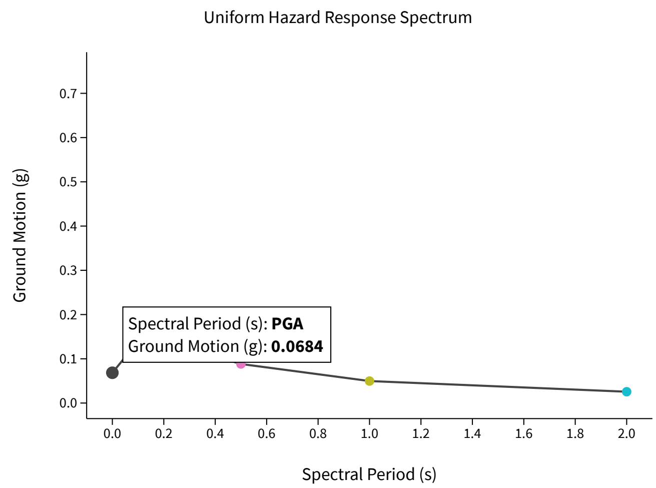
Time Horizon

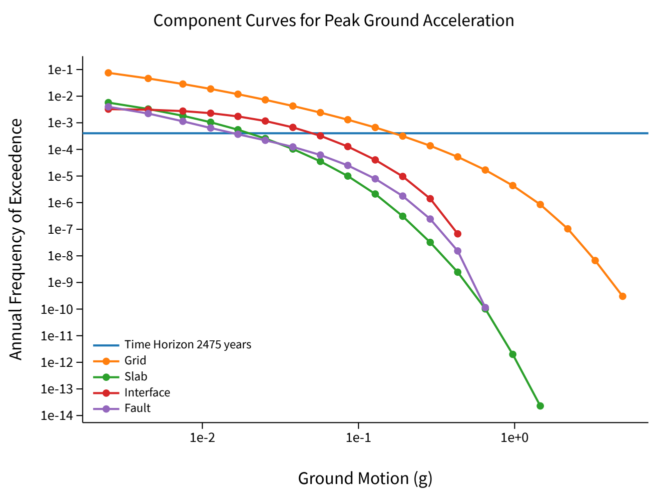
Return period in years

475

Hazard Curve





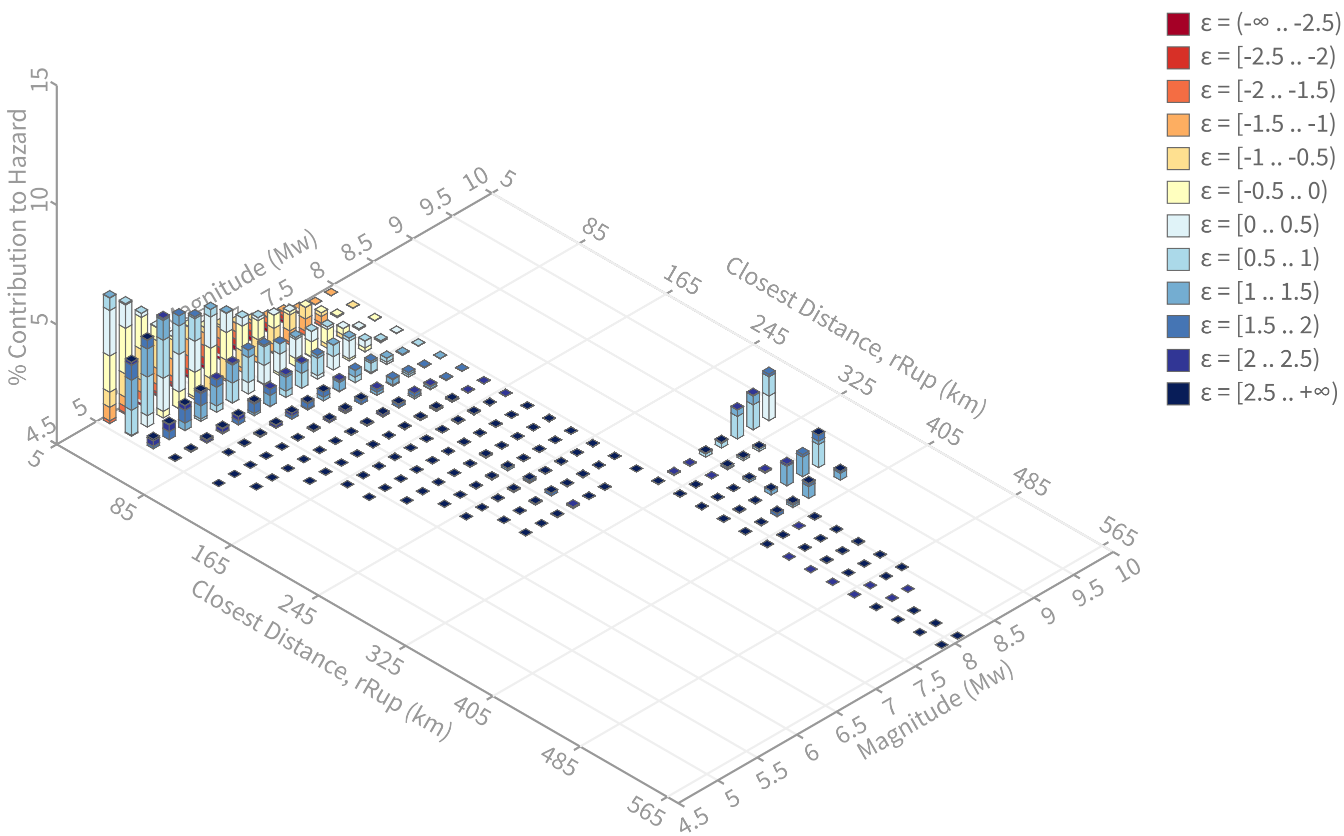


View Raw Data

Deaggregation

Component

Total



Summary statistics for, Deaggregation: Total

Deaggregation targets

Return period: 475 yrs
Exceedance rate: 0.0021052632 yr^{-1}
PGA ground motion: 0.068440444 g

Recovered targets

Return period: 480.39457 yrs
Exceedance rate: 0.0020816222 yr^{-1}

Totals

Binned: 100 %
Residual: 0 %
Trace: 0.87 %

Mean (over all sources)

m: 6.41
r: 68.67 km
ε_0: 0.17 σ

Mode (largest m-r bin)

m: 5.1
r: 11.85 km
ε_0: -0.16 σ
Contribution: 5.26 %

Mode (largest m-r-ε_0 bin)

m: 5.3
r: 13.67 km
ε_0: -0.24 σ
Contribution: 1.91 %

Discretization

r: min = 0.0, max = 1000.0, Δ = 20.0 km
m: min = 4.4, max = 9.4, Δ = 0.2
ε: min = -3.0, max = 3.0, Δ = 0.5 σ

Epsilon keys

ε0: [-∞ .. -2.5)
ε1: [-2.5 .. -2.0)
ε2: [-2.0 .. -1.5)
ε3: [-1.5 .. -1.0)
ε4: [-1.0 .. -0.5)
ε5: [-0.5 .. 0.0)
ε6: [0.0 .. 0.5)
ε7: [0.5 .. 1.0)
ε8: [1.0 .. 1.5)
ε9: [1.5 .. 2.0)
ε10: [2.0 .. 2.5)
ε11: [2.5 .. +∞]

Deaggregation Contributors

Source Set ↳ Source	Type	r	m	ε_0	lon	lat	az	%
WUSmap_2014_fixSm.ch.in (opt)	Grid							11.64
noPuget_2014_fixSm.ch.in (opt)	Grid							11.64
WUSmap_2014_fixSm.gr.in (opt)	Grid							11.48
noPuget_2014_fixSm.gr.in (opt)	Grid							11.48
noPuget_2014_adSm.ch.in (opt)	Grid							7.72
WUSmap_2014_adSm.ch.in (opt)	Grid							7.71
noPuget_2014_adSm.gr.in (opt)	Grid							7.63
WUSmap_2014_adSm.gr.in (opt)	Grid							7.62
sub0_ch_bot.in	Interface							4.44
Cascadia Megathrust - whole CSZ Characteristic		307.04	9.11	0.71	123.413°W	46.300°N	286.27	4.44
sub0_ch_mid.in	Interface							3.07
Cascadia Megathrust - whole CSZ Characteristic		360.36	8.92	1.13	124.137°W	46.300°N	284.23	3.07
WUSmap_2014_fixSm_M8.in (opt)	Grid							2.84
noPuget_2014_fixSm_M8.in (opt)	Grid							2.84
noPuget_2014_adSm_M8.in (opt)	Grid							1.89
WUSmap_2014_adSm_M8.in (opt)	Grid							1.88

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Attachment H-3. Probabilistic Seismic Hazard Deaggregation at 2,475-year Intervals

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U.S. Geological Survey - Earthquake Hazards Program

Unified Hazard Tool

Please do not use this tool to obtain ground motion parameter values for the design code reference documents covered by the U.S. Seismic Design Maps web tools (e.g., the International Building Code and the ASCE 7 or 41 Standard). The values returned by the two applications are not identical.

Input

Edition

Dynamic: Conterminous U.S. 2014 (v…

Latitude

Decimal degrees

45.595

Longitude

Decimal degrees, negative values for western longitudes

-119.604

Site Class

760 m/s (B/C boundary)

Spectral Period

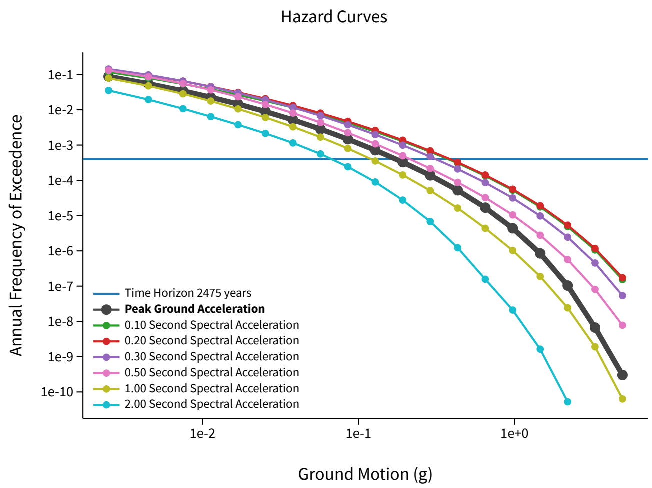
Peak Ground Acceleration

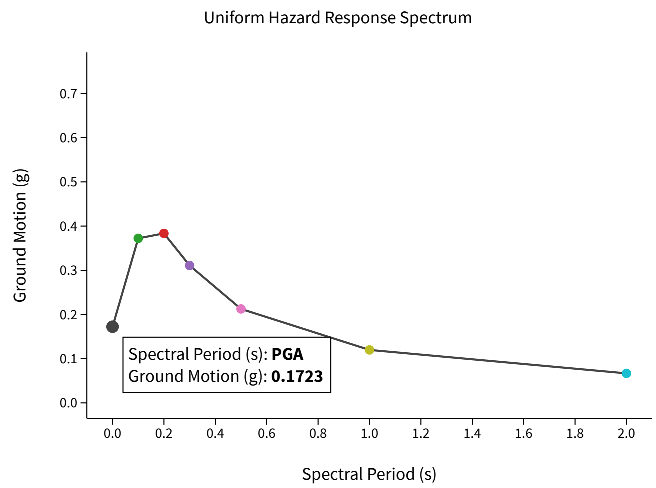
Time Horizon

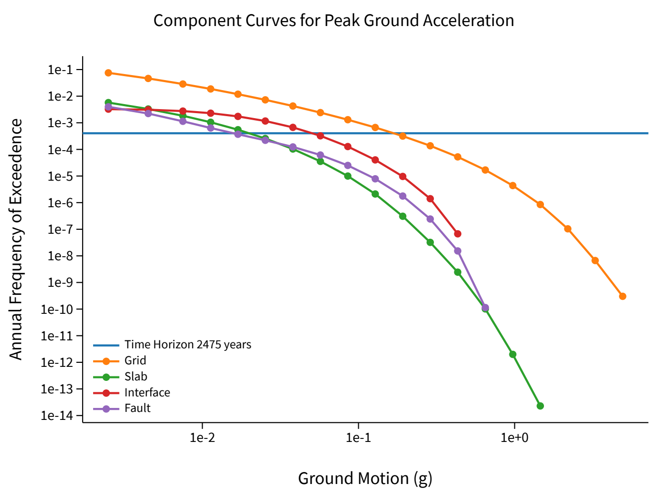
Return period in years

2475

Hazard Curve





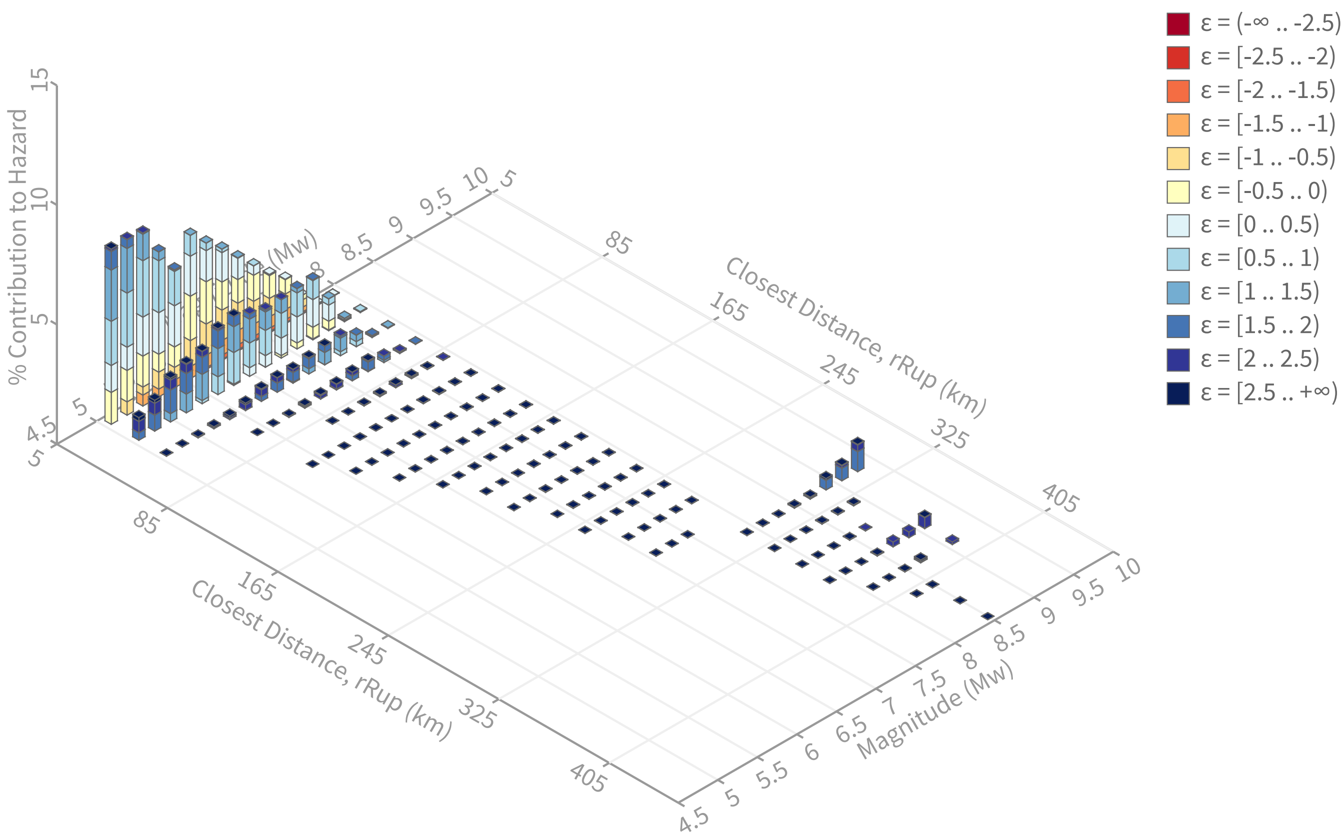


View Raw Data

^ Deaggregation

Component

Total



Summary statistics for, Deaggregation: Total

Deaggregation targets

Return period: 2475 yrs
Exceedance rate: 0.0004040404 yr^{-1}
PGA ground motion: 0.17231166 g

Recovered targets

Return period: 2539.9766 yrs
Exceedance rate: 0.00039370442 yr^{-1}

Totals

Binned: 100 %
Residual: 0 %
Trace: 0.38 %

Mean (over all sources)

m: 6.28
r: 30.84 km
ε_0: 0.52 σ

Mode (largest m-r bin)

m: 5.3
r: 10.39 km
ε_0: 0.58 σ
Contribution: 7.35 %

Mode (largest m-r-ε_0 bin)

m: 5.5
r: 13.53 km
ε_0: 0.76 σ
Contribution: 2.36 %

Discretization

r: min = 0.0, max = 1000.0, Δ = 20.0 km
m: min = 4.4, max = 9.4, Δ = 0.2
ε: min = -3.0, max = 3.0, Δ = 0.5 σ

Epsilon keys

ε0: [-∞ .. -2.5)
ε1: [-2.5 .. -2.0)
ε2: [-2.0 .. -1.5)
ε3: [-1.5 .. -1.0)
ε4: [-1.0 .. -0.5)
ε5: [-0.5 .. 0.0)
ε6: [0.0 .. 0.5)
ε7: [0.5 .. 1.0)
ε8: [1.0 .. 1.5)
ε9: [1.5 .. 2.0)
ε10: [2.0 .. 2.5)
ε11: [2.5 .. +∞]

Deaggregation Contributors

Source Set ↳ Source	Type	r	m	ε_0	lon	lat	az	%
WUSmap_2014_fixSm.ch.in (opt)	Grid							12.73
PointSourceFinite: -119.604, 45.599		4.92	5.62	-0.65	119.604°W	45.599°N	0.00	1.39
noPuget_2014_fixSm.ch.in (opt)	Grid							12.73
PointSourceFinite: -119.604, 45.599		4.92	5.62	-0.65	119.604°W	45.599°N	0.00	1.39
WUSmap_2014_fixSm.gr.in (opt)	Grid							12.69
PointSourceFinite: -119.604, 45.599		4.92	5.62	-0.65	119.604°W	45.599°N	0.00	1.39
noPuget_2014_fixSm.gr.in (opt)	Grid							12.69
PointSourceFinite: -119.604, 45.599		4.92	5.62	-0.65	119.604°W	45.599°N	0.00	1.39
noPuget_2014_adSm.ch.in (opt)	Grid							8.54
WUSmap_2014_adSm.ch.in (opt)	Grid							8.53
noPuget_2014_adSm.gr.in (opt)	Grid							8.52
WUSmap_2014_adSm.gr.in (opt)	Grid							8.50
WUSmap_2014_fixSm_M8.in (opt)	Grid							3.14
noPuget_2014_fixSm_M8.in (opt)	Grid							3.14
sub0_ch_bot.in	Interface							2.18
Cascadia Megathrust - whole CSZ Characteristic		307.04	9.15	1.83	123.413°W	46.300°N	286.27	2.18
noPuget_2014_adSm_M8.in (opt)	Grid							2.11
WUSmap_2014_adSm_M8.in (opt)	Grid							2.10

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Attachment H-4. Significant Historical Earthquakes Within 50 Miles of the Proposed Facility

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Year	Month	Day	Latitude	Longitude	Moment Magnitude	Miles From Site Boundary
1969	04	19	45.897499	-119.703499	2.8	18.42
1970	12	09	46.270168	-119.951164	2.8	46.21
1970	11	29	46.225166	-120.115334	3.0	46.42
1970	10	02	45.712166	-120.640167	2.7	47.31
1970	09	29	45.760502	-119.145500	2.5	23.93
1970	04	04	46.228333	-120.080002	2.7	45.83
1971	01	04	46.230835	-119.363167	3.1	43.35
1972	08	27	45.532833	-120.016167	2.5	15.63
1972	08	21	45.575165	-119.988998	2.6	14.47
1973	12	29	46.048832	-119.657997	2.8	28.76
1975	07	01	45.627998	-120.001999	3.5	16.04
1975	07	01	45.605331	-120.016167	3.6	16.20
1975	06	28	46.092167	-119.722168	2.7	31.89
1975	06	28	46.098999	-119.706001	3.8	32.30
1975	06	28	46.105331	-119.703667	3.3	32.73
1975	06	15	46.234001	-119.113167	3.1	48.55
1975	05	09	45.632999	-118.556000	2.7	49.73
1976	10	10	45.270332	-120.499496	3.6	43.34
1976	07	26	45.646832	-119.973831	2.9	14.98
1977	03	31	45.901833	-119.654167	2.9	18.61
1977	03	11	45.899166	-119.665665	3.1	18.42
1978	12	22	45.891335	-119.328163	2.6	23.21
1978	03	04	46.060333	-118.855499	2.8	47.47
1978	02	20	45.896500	-119.650002	3.2	18.24
1979	03	01	46.047501	-118.905670	2.7	45.10
1979	02	17	46.164165	-119.932663	3.6	38.98
1980	12	18	45.833000	-120.007332	2.8	21.69
1980	03	12	46.124668	-119.025665	2.6	44.92
1980	03	04	45.939999	-119.664001	2.6	21.24
1981	06	14	45.961666	-120.507004	3.2	46.69
1982	11	23	45.997334	-119.288666	3.2	30.23
1982	10	30	45.999001	-119.287498	2.7	30.36
1982	10	12	45.995998	-119.288170	2.8	30.17
1983	10	21	45.660000	-118.915665	2.7	32.52
1984	10	04	46.105499	-120.025665	2.9	37.10
1984	09	07	46.074165	-119.607002	2.5	30.54
1984	08	10	46.125168	-119.787834	2.5	34.57
1984	06	18	45.230835	-118.687500	3.1	49.76
1984	05	14	46.123501	-119.204666	2.5	39.75
1984	04	30	46.040501	-119.878166	2.8	30.06
1984	03	23	45.995998	-119.292168	3.3	30.06
1984	01	18	45.359833	-119.664833	2.5	10.82
1985	12	19	46.250000	-119.613503	2.8	42.67
1985	12	03	46.165501	-119.603333	2.9	36.85
1985	11	18	46.251835	-119.618332	2.9	42.79
1985	08	02	45.443001	-119.953331	2.6	14.20
1985	04	30	45.881668	-119.320503	2.5	22.94
1985	04	17	45.879002	-119.315331	2.6	22.97
1985	03	20	45.963165	-119.904663	3.1	25.68
1985	03	01	45.805000	-119.015999	2.6	30.90
1985	02	27	45.961334	-119.906334	2.6	25.61
1985	02	10	45.704498	-119.634499	3.9	4.98
1985	01	31	45.954498	-118.836830	2.7	43.64
1985	01	31	45.964500	-119.902496	2.8	25.72
1985	01	28	45.967335	-119.911003	2.6	26.08

Year	Month	Day	Latitude	Longitude	Moment Magnitude	Miles From Site Boundary
1986	12	08	45.976665	-118.953003	2.6	40.13
1986	11	10	45.199665	-119.997169	2.5	26.93
1986	03	02	46.311501	-119.783836	2.8	47.27
1986	02	05	46.253666	-119.616333	2.8	42.92
1986	02	04	46.043999	-118.809998	3.2	48.39
1986	01	29	46.254002	-119.615501	2.9	42.94
1986	01	16	46.251499	-119.617996	3.0	42.77
1987	09	29	45.176167	-120.061165	2.7	30.11
1987	09	08	45.191166	-120.071999	3.1	29.65
1988	11	21	45.269669	-119.944168	2.5	21.51
1988	10	19	45.139668	-119.138664	2.6	35.83
1988	09	29	45.849834	-120.259666	3.5	32.52
1988	08	18	45.223999	-120.099503	2.7	28.91
1988	08	06	45.435001	-119.882332	2.5	11.55
1988	07	23	45.260166	-120.132835	2.6	28.47
1988	07	11	45.244667	-120.142166	2.9	29.50
1988	03	17	46.132332	-119.782997	2.6	35.02
1988	02	28	45.571167	-119.884666	2.6	9.44
1988	02	20	45.216331	-120.105667	2.7	29.49
1988	02	14	45.577000	-120.149330	2.5	22.21
1988	02	07	45.355999	-119.621666	2.5	11.14
1988	02	03	46.223000	-119.734001	2.5	40.94
1989	12	28	45.481667	-119.489166	2.5	7.15
1989	08	18	45.274502	-119.982666	2.7	22.45
1989	03	27	45.815834	-120.261497	3.1	31.58
1989	02	21	45.738834	-120.030830	2.6	19.23
1989	02	10	46.113834	-120.024498	2.6	37.58
1990	12	17	46.031834	-120.336502	2.5	42.67
1990	11	02	46.031834	-120.337997	2.5	42.73
1990	08	15	45.255501	-119.071663	2.6	32.76
1990	03	02	45.642666	-118.928337	2.8	31.78
1991	04	20	45.344501	-120.137833	2.8	25.38
1991	04	04	46.081833	-118.833504	2.5	49.26
1991	03	25	46.124832	-119.801003	2.5	34.67
1992	08	07	45.860332	-119.589500	3.9	15.89
1992	03	10	44.842999	-119.328331	2.5	49.01
1993	12	18	45.191833	-120.073166	2.9	29.65
1993	12	16	45.195835	-120.089836	3.0	29.98
1994	11	17	45.701168	-120.177498	2.7	25.29
1994	11	03	45.694000	-120.171837	2.6	24.92
1994	10	06	45.680668	-120.163498	2.7	24.38
1994	09	25	45.530499	-118.800331	2.6	38.07
1994	09	22	45.691502	-120.163330	2.9	24.49
1994	05	24	45.809834	-120.188499	2.6	28.20
1995	11	02	46.150002	-119.564331	3.1	35.91
1995	08	29	46.208168	-119.905502	3.1	41.47
1996	02	13	45.529999	-119.606499	2.9	0.64
1997	11	11	45.851002	-120.564667	2.8	46.11
1997	10	13	46.113998	-120.376167	3.1	47.90
1997	09	10	45.654335	-120.197998	2.7	25.61
1997	08	17	45.648335	-120.186333	2.8	24.94
1997	05	13	45.543167	-119.603333	2.7	0.45
1997	04	17	45.188499	-120.082001	3.2	30.11
1997	03	28	45.200500	-120.056168	2.6	28.66
1997	03	23	45.246334	-120.049332	3.1	26.09

Year	Month	Day	Latitude	Longitude	Moment Magnitude	Miles From Site Boundary
1997	03	23	45.195168	-120.050835	3.1	28.77
1997	03	22	45.197334	-120.067169	3.9	29.17
1997	03	22	45.214001	-120.073669	2.7	28.53
1997	03	21	45.643501	-119.487999	2.5	5.56
1998	09	05	45.648167	-119.490837	2.9	5.65
1998	08	12	45.166332	-120.018501	2.8	29.42
1998	04	28	45.258835	-120.280998	2.7	34.46
1998	04	14	45.480331	-119.539497	2.6	5.34
1998	04	14	45.275833	-120.288834	2.7	34.14
1998	03	01	46.317333	-119.881836	2.6	48.48
1998	02	03	45.813835	-120.192169	3.1	28.48
1999	12	21	45.754501	-120.000168	2.7	18.35
1999	09	04	45.177502	-120.077164	2.9	30.53
1999	08	31	45.186333	-120.090836	3.5	30.51
1999	07	24	45.928165	-119.213669	2.6	28.82
1999	03	21	45.180332	-120.032333	2.9	29.02
2000	12	29	45.886833	-119.708336	2.6	17.71
2000	08	17	45.312000	-120.041496	3.2	22.75
2000	08	03	45.208668	-120.073334	2.8	28.79
2000	07	28	45.170166	-120.135002	2.6	32.78
2000	02	29	45.189499	-120.118332	2.5	31.25
2000	02	21	45.682835	-120.124832	2.5	22.55
2000	02	15	45.687668	-120.079170	2.6	20.44
2000	02	01	45.186668	-120.117996	2.8	31.38
2000	02	01	45.189999	-120.112663	3.6	31.04
2000	01	30	45.181667	-120.109169	2.8	31.34
2000	01	30	45.183167	-120.102837	3.4	31.06
2000	01	30	45.193333	-120.111832	2.6	30.84
2000	01	30	45.197166	-120.124832	4.1	31.09
2000	01	13	45.690834	-119.934669	2.6	13.71
2000	01	05	45.704166	-120.049500	2.8	19.30
2001	06	18	45.189667	-120.110168	2.6	30.97
2001	06	15	45.201668	-120.107666	2.5	30.28
2002	12	30	46.272999	-119.402000	2.7	45.64
2002	10	25	45.184334	-120.065002	2.5	29.79
2002	10	25	45.192665	-120.093666	2.7	30.27
2002	10	14	45.131168	-120.011330	2.6	31.26
2002	01	31	45.685165	-120.166000	2.7	24.54
2003	12	01	45.421333	-118.857330	2.5	36.98
2003	09	12	45.420666	-118.842163	2.8	37.70
2003	06	01	45.194000	-120.113167	2.8	30.85
2003	05	18	45.193832	-120.120331	2.7	31.10
2003	05	16	45.627834	-120.274834	2.6	28.76
2003	01	24	46.261665	-119.385002	2.7	45.09
2003	01	17	45.680168	-120.177498	2.9	25.04
2004	03	31	45.694168	-120.167168	2.6	24.70
2004	03	08	45.642334	-120.200500	2.5	25.49
2004	02	28	46.036335	-119.020500	3.3	40.70
2005	11	10	46.146332	-119.931000	2.5	37.80
2005	07	18	46.266998	-119.391167	2.5	45.37
2005	02	01	46.276833	-119.545998	2.5	44.71
2006	08	21	45.803501	-120.353333	2.6	35.39
2007	11	30	45.713833	-120.182167	2.8	25.69
2007	05	02	45.799999	-120.333664	2.6	34.42
2007	01	31	46.266998	-119.385330	2.5	45.44

Year	Month	Day	Latitude	Longitude	Moment Magnitude	Miles From Site Boundary
2007	01	08	45.685501	-120.162003	2.7	24.36
2008	07	29	45.637001	-120.615334	2.7	45.14
2008	05	18	46.167667	-119.550163	3.7	37.19
2008	04	10	45.689167	-120.260002	2.5	29.09
2008	03	31	45.696835	-120.169670	2.8	24.86
2009	11	30	45.706165	-120.185165	2.6	25.72
2009	08	16	45.932999	-120.104332	2.8	29.80
2009	08	11	45.932999	-119.987999	2.6	26.07
2009	07	20	45.659000	-120.237503	2.5	27.53
2009	06	04	46.270168	-119.383331	2.5	45.68
2009	05	15	45.538334	-120.528831	2.7	40.51
2009	05	10	45.833000	-120.110168	2.5	25.69
2009	05	06	45.702332	-120.175499	2.6	25.21
2010	10	27	45.934666	-120.242165	2.5	34.93
2010	10	19	45.940498	-120.244835	2.6	35.28
2010	07	29	45.648499	-120.095337	2.7	20.77
2010	03	31	45.924667	-120.310501	2.5	37.24
2010	03	01	45.708668	-120.227837	2.5	27.78
2012	10	26	46.259666	-119.384003	2.5	44.97
2012	03	12	46.164833	-119.171165	2.6	43.02
2014	04	07	46.122334	-119.025497	2.7	44.80
2017	02	15	45.752834	-118.595337	2.9	48.92
2018	10	09	46.103168	-120.420670	2.9	48.96

Attachment H-5. Ground Response Spectra Assessment (Site Class D)

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ATC Hazards by Location

Search Information

Coordinates: 45.5122139, -119.6726806

Elevation: 1371 ft

Timestamp: 2020-12-16T21:47:37.529Z

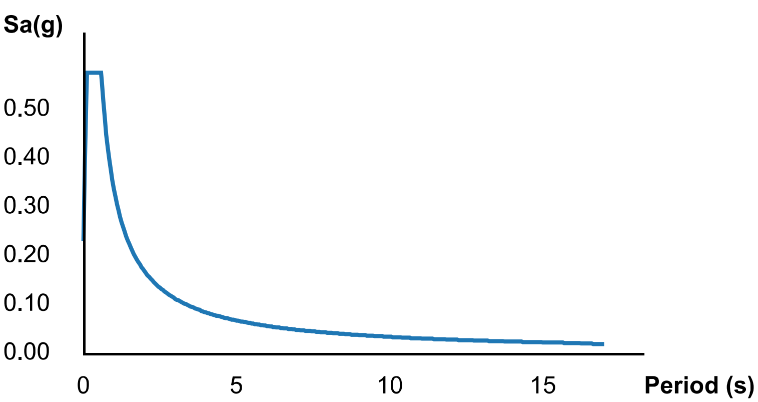
Hazard Type: Seismic

Reference Document: IBC-2015

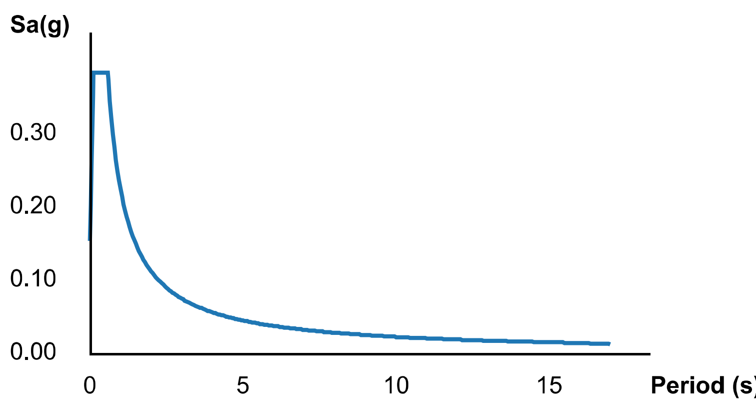
Risk Category: IV

Site Class: D

MCER Horizontal Response Spectrum



Design Horizontal Response Spectrum



Basic Parameters

Name	Value	Description
S_S	0.387	MCE_R ground motion (period=0.2s)
S_1	0.154	MCE_R ground motion (period=1.0s)
S_{MS}	0.576	Site-modified spectral acceleration value
S_{M1}	0.337	Site-modified spectral acceleration value
S_{DS}	0.384	Numeric seismic design value at 0.2s SA

S_{DS}	[illegible]	Numeric seismic design value at 0.2s SA
S_{D1}	0.225	Numeric seismic design value at 1.0s SA

Additional Information

Name	Value	Description
SDC	D	Seismic design category
F_a	1.491	Site amplification factor at 0.2s
F_v	2.183	Site amplification factor at 1.0s
CR_S	0.919	Coefficient of risk (0.2s)
CR_1	0.899	Coefficient of risk (1.0s)
PGA	0.163	MCE_G peak ground acceleration
F_{PGA}	1.475	Site amplification factor at PGA
PGA_M	0.24	Site modified peak ground acceleration
T_L	16	Long-period transition period (s)
SsRT	0.387	Probabilistic risk-targeted ground motion (0.2s)
SsUH	0.421	Factored uniform-hazard spectral acceleration (2% probability of exceedance in 50 years)
SsD	1.5	Factored deterministic acceleration value (0.2s)
S1RT	0.154	Probabilistic risk-targeted ground motion (1.0s)
S1UH	0.172	Factored uniform-hazard spectral acceleration (2% probability of exceedance in 50 years)
S1D	0.6	Factored deterministic acceleration value (1.0s)
PGAd	0.6	Factored deterministic acceleration value (PGA)

The results indicated here DO NOT reflect any state or local amendments to the values or any delineation lines made during the building code adoption process. Users should confirm any output obtained from this tool with the local Authority Having Jurisdiction before proceeding with design.

Disclaimer

Hazard loads are provided by the U.S. Geological Survey Seismic Design Web Services.

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