EXHIBIT H
GEOLOGY AND SEISMICITY

OAR 345-021-0010(1)(h)

TABLE OF CONTENTS

ATTACHMENT

TABLES

FIGURES

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:*

__Response__: Section H.1 defines the analysis area of the Madras Solar Energy Facility (Facility). Sections H.2 through H.9 provide information from reasonably available sources regarding the geological and soil stability within the analysis area. Section H.10 provides a summary of Exhibit H findings.

H.1 ANALYSIS AREA

The analysis area for structural standards (Exhibit H) is the area within the site boundary. "Site boundary" as defined in OAR 345-001-0010(55) means "*the perimeter of the site of a proposed energy facility, its related or supporting facilities, all temporary laydown and staging areas, and all corridors and micrositing corridors proposed by the applicant*." In this Exhibit, Madras PV1, LLC (Applicant) equates the term "site boundary" with the analysis area.

H.2 GEOLOGIC REPORT AND SUMMARY OF CONSULTATION WITH OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES

OAR 345-021-0010(1)(h)(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)(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.*

__Response__: While preparing this Exhibit, Jacobs consulted Oregon Department of Geology and Mineral Industries (DOGAMI) publications and other guideline documents from the Oregon State Board of Geologist Examiners (2014). In August 2019, a Jacobs geotechnical engineer spoke with Yumei Wang at DOGAMI (Wang, pers. comm., 2019; Attachment H-1). They discussed the general details of the analysis area terrain and geology, any geologic concerns that DOGAMI might have, and Jacobs' recommendations for geotechnical exploration prior to construction. Discussion focused on conditions and hazards related to ground shaking, landslide potential, and soil conditions at the site. Section H.3 reports the findings associated with geologic conditions and hazards within the Facility site boundary.

On November 7, 2019, a Jacobs geologist spoke with Ian Madin at DOGAMI (Madin, pers. comm., 2019; Attachment H-1). They discussed new, potentially active faults that have been identified on recently available light detection and ranging (LiDAR) imagery. So far, published information and details of the fault characteristics are very limited. However, it did not appear that any new potentially active faults were identified near the proposed Facility.

H.3 GEOLOGIC CONDITIONS AND HAZARDS FINDINGS

__Response__: Topographic and geologic conditions/hazards within the Facility site boundary were evaluated by reviewing available reference materials (such as topographic maps, geologic maps, and aerial photographs) and conducting a field reconnaissance of the proposed Facility area. The findings are described in the following sections. Subsurface explorations, testing, and engineering analysis will be conducted prior to design and construction.

H.3.1 Topographic Setting

The Facility site is located just east of Lake Simtustus, south and west of Willow Creek, and approximately 0.5 mile from the eastern boundary of the Warm Springs Reservation. The top of the plateau tends to be relatively flat, but has been dissected by the Deschutes River and its tributaries into deep, steep-sided canyons.

Pelton Dam Road and Elk Road run through the site. Lake Simtustus, where the Deschutes River has been stilled by Pelton Dam, borders the west side of the site. The Willow Creek canyon borders the northern side of the site and Dry Canyon, a tributary of Willow Creek, borders the east side of the site. A short but very steep tributary named Hurbers Canyon is eroded into the northwest part of the site. Pelton Dam Road follows this drainage down to the reservoir. These drainages all flow generally northward toward the Columbia River.

The site is generally flat with a low slope to the southeast. Slopes on the plateau surface between zero and 8 percent. The canyon side slopes and Lake Simtustus and Willow Creek are very steep, with slopes between 40 and 80 percent, and local vertical cliffs. Elevations within the Facility site boundary range from approximately 2,360 feet to 2,400 feet above mean sea level.

Site drainage is relatively limited, due to the flat topography, but generally appears to drain towards the incised canyons that border the site.

H.3.2 Regional Geologic Setting

The site is located in the upper Deschutes Basin, a volcanic landscape dominated by a thick (>700 m) sequence of lava flows, pyroclastic rocks, and volcaniclastic deposits of Cascade Range origin, as well as fluvial gravels deposited between about 7 and 4 million years ago in a broad depositional basin (Smith, 1986).

H.3.3 Site Geologic Setting

Figure H-1 shows a map of the geology in the vicinity of the Facility site, adapted using GIS and a DOGAMI geologic data compilation (Ma et al., 2009). The following descriptions of the geologic units found in the area are summarized from Smith (1987) and the DOGAMI Oregon Geologic Data Compilation (Ma et al., 2009).

H.3.3.1 Surficial Geologic Units

Surficial geologic units in the vicinity of the Facility consist primarily of windblown loess deposits. Loess is comprised of massive, wind-deposited quartzose fine sand and silt. It mantles much of the upland surfaces and hillslopes of the Deschutes Plateau. Because this unit is thin or absent within the Facility site boundary, it is not shown on the geologic map.

A thin layer of loess mantles the basalt. Near the west, north, and eastern edges of the plateau surface (close to the tributary canyons), most of the silty loess has been eroded away and the basalt surface is exposed. Based on observations from the site visit and the site-specific soil survey (CES, 2018), the loess is typically tan to light brown and composed of silt-sized particles. The thickness of the loess interpreted to be between 8 and 40 inches thick, based test pits excavated during the soil survey (CES, 2018).

Colluvial deposits that consist of locally-derived angular boulders, cobbles, and soil mantle compose the steep canyon walls. These deposits are discontinuous and are not shown on the geologic map. However, these deposits were observed during the site visit.

H.3.3.2 Bedrock Geologic Units

The plateau upon which the site rests is underlain by the Pliocene- and Pleistocene-age Deschutes formation. This formation consists primarily of basalt flows with interbedded volcaniclastic sediments. The plateau surface is capped by the 5 million-year old Basalt of Tetherow Butte (Tdtb on Figure H-1). Beneath this basalt capstone lies the Deschutes formation, which consists of a thick (up to several hundred meters) series of interbedded volcaniclastic sandstones, conglomerates, and debris-flow breccias interbedded with silicic ignimbrites, and air-fall lapillistones that filled ancient basins.

H.3.3.3 Structural Geology

Regionally, the rock units have a very low dip to the east toward center of the basin Deschutes Basin. Smith (1987) mapped a northeast-trending syncline on the plateau approximately 5 miles north of the site. Based on site observations and geologic mapping, the basalt flows that underlie the site are almost nearly flat-lying, with no observable folding or faulting. Localized small-scale geologic structures in the basalt could include vertical fractures, which are common near the tops of basalt flows.

H.3.3.4 Groundwater/Springs

Groundwater is deep in the vicinity of the Facility site, because of its elevation above the Deschutes River and the tributaries. These have downcut deep canyons, which lower the regional water table. However, shallow perched zones of groundwater appear to exist, as indicated by springs and wetlands observed in the canyon walls. Based on a well log search, the closest wells logs were located approximately 1 to 2 miles south of the site, but on relatively the same plateau surface (OWRD, 2019). The static water level ranged from 176 feet to more than 600 feet below ground surface.

H.4 SITE-SPECIFIC GEOTECHNICAL WORK

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.*

Response:

H.4.1 Geotechnical Review

Existing published information was reviewed and used to characterize the current geologic conditions and potential seismic hazards in the vicinity of the Facility site. These materials included local, state, and federal government aerial photography, site photographs, published geologic maps, and site-specific soil survey (CES, 2018).

For this Application for Site Certificate, a seismic hazard assessment was conducted to characterize seismicity in the vicinity of the Facility site and evaluate potential seismic impacts. 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 Facility site boundary based on geotechnical subsurface investigations. The seismic hazard assessment included the following tasks:

1. Detailed review of literature and databases
2. Compilation and evaluation of existing subsurface data obtained for the vicinity of the Facility site; these data were used to characterize the subsurface soils and construct a subsurface profile
3. Identification of the potential seismic events appropriate for the site and characterization of those events in terms of a series of design events
4. Based on the characteristics of the subsurface soils and design earthquakes, preparation of conclusions and recommendations that included:
   a) Specific seismic events that might have a significant effect on the area within the Facility site boundary
   b) The potential for seismic energy amplification within the Facility site boundary
   c) A site-specific acceleration response spectrum for the area within the Facility site boundary
   d) The potential for earthquake-induced fault displacement, landslides, liquefaction, settlement, and subsidence

Josh Butler, P.E., and Greg Warren, P.G. (Jacobs) conducted the geotechnical review and geologic assessment for this Exhibit. Mr. Butler and Mr. Warren have prepared numerous Oregon Energy Facility Siting Council and industrial siting applications for energy facilities throughout Oregon, Washington, Wyoming, California, and Colorado. In addition, they have conducted many geotechnical investigations and evaluations, and have prepared data and design reports for wind, geothermal, and solar energy facilities.

H.4.2 Additional Geotechnical Work

At an appropriate stage in the development, additional subsurface explorations must be completed to confirm the anticipated soil and rock conditions and provide final design recommendations. The final design geotechnical investigation will consist primarily of the following tasks:

- Reviewing available data from previous geotechnical explorations in the vicinity of the Facility site
- Reviewing available geologic information from published sources
- Conducting a geotechnical field exploration within the Facility site boundary, including soil borings, test pits, and possibly geophysical testing
- Collecting additional soil samples for classification and laboratory testing and conducting laboratory tests on selected soil samples, 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.

H.5 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.*

Response: The proposed Facility does not involve construction of a new transmission line, as it will interconnect with an existing transmission line that runs through the site. Additionally, the Facility does not have a pipeline. Therefore, this provision is not applicable.

H.6 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.*

H.6.1 Maximum Considered Earthquake Ground Motion

Response: The 2019 U.S. Geological Survey (USGS) National Seismic Hazard Mapping project (USGS, 2019a) developed ground motion models using a probabilistic seismic hazard analysis that covered the area within the Facility site boundary. Though these models are not considered site-specific, they provide a reasonable estimate of the ground motions within the Facility site boundary. Based on the USGS data, the 500-year and 5,000-year earthquakes have bedrock peak ground accelerations of 0.08g and 0.24g, respectively, where “g” is the acceleration of gravity.

For new construction, the site should be designed for the maximum considered earthquake, according to the International Building Code (International Code Council, 2012; referenced as IBC) as amended by the Oregon Structural Specialty Code (International Code Council and State of Oregon, 2019; OSSC). The 2019 code was adopted effective October 1, 2019, and will be phased in over a 3-month period. This code adheres to the 2015 National Earthquake Hazards Reduction Program Seismic Design Provisions (Federal Emergency Management Agency, 2015), and the 2019 USGS Seismic Hazard Mapping project (USGS, 2019a). This event has a 2 percent probability of exceedance in 50 years (or an approximately 2,475-year return period). For the Facility, this event has an estimated peak ground acceleration (PGA) of 0.18g at the bedrock surface based on the USGS Seismic Hazard Mapping project. This value of PGA on rock is an average representation of the acceleration for all potential seismic sources (crustal, intraplate, or subduction) mapped as active at the time of the study (USGS, 2019a).

Seismic design parameters were developed in accordance with the IBC. Based on existing subsurface information (including a preliminary review of borings drilled for adjacent facilities, geologic mapping, and nearby well logs), the Facility will be conservatively designed for Site Class B (S_B; rock profile), according to IBC requirements. Once site-specific geotechnical subsurface information is collected, the actual site class determination may improve or worsen. Final site class determination cannot be made until further site exploration is performed. Table H-1 summarizes the current recommended seismic design parameters for the Maximum Considered Earthquake (MConE) event.

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

Site Class	Controlling Earthquake Magnitude	Peak Horizontal Ground Acceleration on Bedrock	Soil Amplification Factor, Fa	Peak Horizontal Ground Acceleration at Ground Surface
S_B (475-year return)	6.0	0.08g	1.00	0.08g
S_B (2,475-year return)	6.0	0.18g	1.00	0.18g

Notes:

Earthquake magnitude in this table is a mean representation of all known seismic sources. The peak ground acceleration is assumed to be roughly 40 percent of the 0.2-second spectral acceleration, following the recommendations of the IBC.

Fa = sail amplification factor
g = acceleration from gravity

<u>10-Percent Exceedance in 50 Years (475-Year Return Interval):</u>

- Short period (0.2-second) spectral response acceleration at the ground surface, S_{MS} = 0.16g for Site Class S_B
- 1-second period spectral response acceleration at the ground surface, S_{M1} = 0.06g for Site Class S_B

<u>2-Percent Exceedance in 50 Years (2,475-Year Return Interval):</u>

- Short period (0.2-second) spectral response acceleration at the ground surface, S_{MS} = 0.39g for Site Class S_B
- 1-second period spectral response acceleration at the ground surface, S_{M1} = 0.15g for Site Class S_B

The design spectral response accelerations for both the short period and the 1-second period (S_{DS} and S_{p1}, respectively) are determined by multiplying the spectral response accelerations (S_{MS} and S_{M1}) by a factor of 2/3.

H.6.2 Earthquake Sources

<u>Response</u>: The potential seismic hazards in the vicinity of the Facility site result from three seismic sources: Cascadia Subduction Zone (CSZ) interplate events, CSZ intraslab events, and crustal events (Geomatrix, 1995).

Two of the potential seismic sources, interplate and intraslab events, are related to the subduction of the Juan de Fuca plate beneath the North American plate. Interplate events are caused by the frictional interface between these two tectonic plates. Intraslab events, which originate within the subducting Juan de Fuca plate, are generally associated with normal faulting that results from bending stresses built up within the plate as it is subducted beneath the North American plate. The combination of these factors is often referred to as the CSZ source mechanism. The CSZ is located beneath western Oregon, Washington, and British Columbia. The two source mechanisms associated with the CSZ are currently thought to be capable of producing maximum earthquakes with moment magnitudes of approximately 9.0 and 7.2 for the interplate and intraslab events, respectively (Geomatrix, 1995; USGS, 2019a, 2019b).

Earthquakes caused by movements along crustal faults, generally in the upper 10 to 15 miles of the earth's crust, result in the third seismic source mechanism. In the vicinity of the Facility site, earthquakes occur within the crust of the North American tectonic plate when built-up stresses near the surface are released through fault rupture.

No potentially active faults are mapped within the Facility site boundary (Figure H-2). A number of late-Quaternary-age, potentially active faults are mapped within the vicinity (50 miles) of the Facility site, as shown on Figure H-2 (Weldon et al., 2003). The Consultant has also contacted DOGAMI geologists Ian Madin and Jason McClaughry to determine whether additional preliminary faulting has been mapped near the site. At the time this Exhibit was submitted, no additional faults had been mapped, but discussions are ongoing. If additional preliminary faults are found near the Facility, an update to this text and Figure H-2 will be made. The text that follows provides a brief discussion of these, and Table H-2 summarizes the major characteristics of each fault.

The Warm Springs fault zone is mapped approximately 20 km west of the Facility site boundary. This fault system consists of a 30-km-wide zone of mostly west-dipping, north-trending normal faults that offset early Pleistocene, Pliocene, and Miocene volcanic rocks and sediments along the eastern margin of the Cascade Range. Fault scarps with heights of 3 to 12 m have been identified along some strands of the Warm Springs fault zone; the geomorphic expression of the youngest scarps in the zone suggest latest movement in the middle and late Quaternary (Personius, 2002a).

The Metolius fault zone is mapped approximately 30 miles west-southwest of the site, and it is comprised of several mostly southwest-dipping, northwest-trending normal faults that offset volcanic rocks and sediments along the eastern margin of the Cascade Range. The structural setting of the Metolius fault zone is open to interpretation, but the fault zone probably forms part of the eastern boundary of the Cascades graben in a structural transition zone at the northern end of the Brothers fault zone (Personius, 2002b).

The Sisters fault zone is mapped approximately 40 miles south-southwest of the site, and consists of numerous northeast- and southwest-dipping, northwest-striking normal faults that offset Miocene to upper Pleistocene volcanic rocks and sediments along the eastern margin of the Cascade Range. Most of the fault strands that comprise the Sisters fault zone were last displaced in the middle and late Quaternary, but two fault strands north of Tumalo may offset glacial outwash deposits and thus may have been active in the late Quaternary (Personius and Haller, 2016).

Table H-2. Summary of Potentially Active Faults

Fault	Distance to Facility (km)[a]	Fault Length (km)[b]	Most Recent Movement (years before present)	Slip-Rate Category
Warm Springs fault zone	20	34	middle and late Quaternary (<750 ka)	Less than 0.2 mm/yr
Metolius fault zone	30	29	middle and late Quaternary (<750 ka)	Less than 0.2 mm/yr
Sisters fault zone	40	33	late Quaternary (<130 ka)	Less than 0.2 mm/yr

[a] Closest mapped distance to Facility.

[b] Maximum length of individual segment mapped within the fault zone.

Notes:

ka = thousand years
km = kilometer
mm = millimeter
yr = year

The PGA within the Facility site boundary resulting from a seismic event on one of these source mechanisms was estimated using information from the USGS seismic hazard mapping database (USGS, 2019a). This information includes estimated PGA at a theoretical soft rock/stiff soil interface for different probabilities of exceedance. The USGS database also provides the seismic deaggregation information for the seismic hazard, including estimates of the mean earthquake moment magnitude and mean epicentral distance associated with a given probability of exceedance at a given location.

The Maximum Probable Earthquake (MPE) is considered to be an earthquake that has a 10 -percent probability of exceedance in 50 years (a nominal 475-year recurrence interval). The MConE is considered to be an earthquake with a nominal 2,475-year recurrence interval (a 2-percent probability of exceedance in 50 years). Figures H-3 and H-4 show the probabilistic seismic hazard deaggregation for the MPE and MConE events, respectively.

The Maximum Credible Earthquake (MCE) is the maximum event that each source is believed to be capable of producing. To provide an estimate of the MCE events from each principal source mechanism, the maximum moment magnitude for each crustal fault was estimated using the relationship developed by Wells and Coppersmith (1994), which relates magnitude to fault length (USGS, 2019a) and distance from the Facility site boundary. The USGS also provides a range of magnitude in their database for some fault sources (USGS, 2014). These analysis parameters were summarized for the potentially active fault near the Facility site boundary (shown in Table H-2). In addition to these estimated magnitudes for crustal faults, Table H-3 summarizes the magnitudes for the random, unnamed crustal event from the USGS gridded hazard and from the CSZ intraslab and interplate events.

Table H-3. Maximum Credible Earthquake Source Characterization Parameters

Earthquake Source	Maximum Moment Magnitude	Epicentral Distance (miles [km])
Random Hazard (Shallow Gridded WUS)	6.0	9 [15]
Crustal	6.8 to 7.4	12 to 25 [20 to 40]
Intraslab	7.2	>110 [>175]
Interplate	9.0 to 9.2	>140 [>225]

Notes:

The magnitudes for all crustal events are determined from the USGS National Seismic Hazard Maps – Source Parameters (USGS, 2014), and also from fault length/distance by Wells and Coppersmith (1994).

WUS = Western United States gridded (random) crustal source

H.6.3 Recorded Earthquakes

Response: Figure H-2 displays the location, approximate magnitude, and year of all recorded earthquakes within 50 miles of the Facility site boundary. These historical seismic events have been 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.

Figure H-2 provides 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 distance from the Facility site boundary. 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, 2013). The largest recorded earthquake within 50 miles (80 kilometers [km]) of the Facility site boundary was the magnitude 4.6 event that occurred in 1976 approximately 34 miles (54 km) northeast of the Facility site boundary (USGS, 2019b). This earthquake caused intensity MMI III shaking within the Facility site boundary. The greatest historical event known for the area is the January 26, 1700, Cascadia megathrust earthquake, which occurred along North America's west coast between Vancouver Island and northern California (USGS, 2005). This is the only event with the potential to have caused an estimated intensity of MMI V-VI level of shaking within the Facility site boundary. There are as many as 40 other significant historical events that occurred more than 50 miles from the site (from 1872 through 2005) which may have resulted in an intensity of MMI III within the Facility site boundary, with magnitudes ranging from 4.5 to 8.3. These events were located in Oregon, Washington, California, and Nevada.

Significant historical earthquakes were evaluated by screening information from earthquake databases provided by the USGS Earthquake Hazards Program, Earthquake Search Databases (USGS, 2019b), DOGAMI (Madin, 1994), Berg and Baker (1963), and NGDC/WDS (2019). For earthquakes that were reported in terms of magnitude, a relationship between PGA and MMI

(Kramer, 1996; Wald et al., 1999) was used to define a PGA associated with an MMI III event. A distance-attenuation relationship was then used to determine the combination of earthquake magnitude and distance producing an intensity of MMI III at the Facility. The Abrahamson & Silva 2008 next generation attenuation (NGA) model was used to develop the magnitude-distance information (Campbell et al., 2009) for seismic events in the northwest United States capable of producing accelerations at the Facility strong enough to produce MMI III intensity shaking.

H.6.4 Median Ground Response Spectrum

Response: Figure H-5 compares the USGS-derived, IBC 2012/American Society of Civil Engineers 7 design spectral response accelerations for the MConE and MPE (for Site Class B), with the MCE spectral response occurring on the crustal fault source mechanisms identified in Table H-2. The NGA modal inputs for the crustal fault sources are summarized in Table H-3. The CSZ interplate and intraslab sources are not included in Figure H-5 because they are too distant from the Facility to exceed the design spectra. Weighting of each of these models follows the 2014 USGS National Seismic Hazards Mapping guidance (USGS, 2014). Figure H-5 compares the response on the bedrock surface between the design spectra and the median response spectra from the principal crustal sources. Therefore, all plots in Figure H-5 are presented at the bedrock surface (or the B/C Site Class boundary identified within the IBC, where no site-specific amplification is applied to spectral accelerations).

H.6.5 Seismic Hazards Expected to Result from Seismic Events

Response: For facilities designed to the current IBC and OSSC guidelines for Site Class B, the design seismic event will have a 2-percent chance of exceedance in the next 50 years (or an event with an approximate 2,475-year recurrence interval). For this event, the Facility will be designed for no life-threatening structural damage from either the vibrational response of the structure or from secondary hazards associated with ground movement or failure (such as landslides, lateral spreading, liquefaction, fault displacement, or subsidence). It is generally assumed that if significant structural damage can be prevented, the risk to human safety will be minimal.

Seismic hazards associated with a design seismic event could potentially include ground shaking and instability from landslides or subsurface movement. Impacts on the Facility from these hazards are anticipated to be low, as discussed below.

Potential for Fault Displacements. The probability of a fault displacement within the Facility site boundary is considered to be nonexistent because of the absence of known or mapped potentially active faults in the immediate area and, particularly, within the Facility site boundary. 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.

Based on recently available LiDAR imagery, previously unmapped faults that are interpreted to be Quaternary-age and potentially active have been identified southwest of the Facility site boundary, on the west side the Metolius River valley, and east of the site between Mitchell and Dayville. However, no previously unmapped faults were identified in the immediate vicinity, or within or near the site boundaries (Madin, pers. comm., 2019). Therefore, hazards from potential for fault displacement are still considered low.

Potential for Ground Shaking. Ground shaking is expected within the Facility site boundary given the seismic setting. However, the probability of damage to structures from ground shaking is considered to be low because the seismic hazard potential is relatively low and, based on preliminary information, the area within the Facility site boundary is likely classified as Site Class B (International Code Council, 2012). Facility components will be designed for the seismic potential of the area. Little or no structural damage is anticipated from MMI III intensity shaking, which is the predominant level of ground shaking anticipated within the Facility site boundary based on the historical record. Higher intensity shaking (MMI IV or MMI V) is not anticipated to cause significant damage to the Facility components. For comparison, MMI VII shaking is considered to result in “negligible damage in buildings of good design and construction.” The period of historical record (1700 to present) is relatively brief from a geologic standpoint, and larger events (including greater intensity shaking) within the Facility site boundary are a possibility. Based on the historical record from 1700 to present, no earthquakes at the Facility site would have resulted in MMI VII intensity shaking.

Liquefaction Potential. Based on review of existing reports that describe the soils and subsurface conditions within the Facility site boundary, and also site observations that indicate a thin to discontinuous loess cover and shallow and/or exposed bedrock within the Facility site boundary, liquefaction potential is estimated to be nonexistent because of the lack of groundwater or saturated sediments, and the shallow basalt bedrock that underlies the Facility site boundary.

Behavior of Subsurface Materials. Risk of landslides or seismically induced landslides within the Facility site boundary is anticipated to be low because of the flat terrain of the site and shallow, stable bedrock. Slopes within the Facility site boundary are generally less than 8 percent and the site is underlain by a solid basalt flow. No landslides have been mapped or were observed within the Facility site boundary.

Adverse Effects from Groundwater or Surface Water. The Facility site lies on thin silty soils overlying basalt. Groundwater is typically several hundred feet deep. No perennial streams are on or within the Facility boundary and no flood hazard exists. Surface runoff flows toward the edges of the plateau and drains down the steep canyon walls.

Because of the potential for seismic-induced hazards within the Facility site boundary, mitigation measures to address these hazards in the siting, design, and construction of the Facility are necessary in order to protect against ground shaking and instability. The design of the Facility components can readily accommodate the level of seismic energy described in Section H.6.4, Median Ground Response Spectrum.

H.7 NONSEISMIC HAZARD ASSESSMENT

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.*

Response: 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 silty loess. The solar array will be constructed on the flat-lying part within the Facility site boundary and will avoid steep side slopes and drainages that could potentially be subject to landslides and soil creep. A discussion of potential nonseismic geologic hazards is presented below.

H.7.1 Landslides

DOGAMI released a publication series called Statewide Landslide Information Database for Oregon, Release 2 (SLIDO-2) (Burns et al., 2014). The purpose of this document was to establish a statewide database of previously mapped landslide-related features. The landslide-related features in this report include landslides, debris flows or alluvial fans, and colluvium or talus. The document also estimated landslide susceptibility. The primary sources of this historical landslide information are geologic reports and geologic hazard studies published by the USGS, DOGAMI, and, to a lesser extent, regional studies published by U.S. National Forests and thesis studies in the state. The landslide database from Burns et al. (2014), which is compiled in GIS format, was used to overlay landslide susceptibility on Figure H-1.

Additionally, DOGAMI's LiDAR database was referenced (DOGAMI, 2019) to evaluate the GIS information and the landslide potential at the Facility site vicinity. No LiDAR coverage of the flat plateau surface is available. However, the surrounding slopes have lidar hillshade imagery. No geologically young slumps or landslides were visible on the LiDAR imagery near the Facility boundaries. The solid basalt layer that forms the rim of the canyon is visible on the LiDAR. Erosional rills in the colluvial deposits are visible east of the side, along the west wall of Dry Canyon. These are shallow erosional rivulets from runoff and do not represent mass movements

Figure H-1 also shows the landslide susceptibility from the SLIDO database, based on slope angles. High landslide susceptibility is indicated along the steep slopes of Willow Creek and Dry Creek drainages. No morphologically young landslides or slumps or instability were observed in the vicinity during the site visit.

The field reconnaissance confirmed the lack of landslide terrain within the Facility site boundary. Steep canyon walls and low cliffs are present along Threemile Canyon. The colluvium, scree, and talus deposits that mantle the Willow Creek canyon walls around the Facility site boundary may be subject to slow downhill movement or creep; however none of the facility components (roads/support structures/solar arrays) will be located on these slopes.

Micrositing considerations along the perimeter of the Facility will necessitate reductions in standard block size and be used to locate structures to avoid landslides or unstable slope breaks.

H.7.2 Volcanic Eruptions

The Pacific Northwest region is home to a large number of active volcanoes along the Cascade Mountain Range. The closest volcanoes to the Facility are listed below, with distances from each mountain to the Facility site boundary:

- Mount Jefferson—45 km (28 miles)
- Three Sisters 75 km (46 miles)
- Mount Hood—85 km (53 miles)
- Newberry Volcano 105 km (65 miles)

Mount Jefferson is the closest volcano to the Facility. Mount Jefferson has erupted repeatedly for hundreds of thousands of years, with its last eruptive episode during the last major glaciation which culminated about 15,000 years ago. Geologic evidence shows that Mount Jefferson is capable of large explosive eruptions. The largest such eruption occurred between 35,000 and 100,000 years ago, and caused ash to fall as far away as the present-day town of Arco in southeast Idaho. Although there has not been an eruption at Mount Jefferson for some time, experience at explosive volcanoes elsewhere suggests that Mount Jefferson cannot be regarded as extinct. If Mount Jefferson erupts again, areas close to the eruptive vent will be severely affected, and even areas tens of miles downstream along river valleys or hundreds of miles downwind may be at risk.

Newberry Volcano is the largest volcano in the Cascades volcanic arc. Unlike familiar cone-shaped Cascades volcanoes, Newberry was built into the shape of a broad shield by repeated eruptions over the past 400,000 years. Throughout its eruptive history, Newberry has produced ash and tephra, pyroclastic flows, and lava flows that range in composition from basalt to rhyolite. About 75,000 years ago, a major explosive eruption and collapse event created a large volcanic depression at its summit that now hosts two caldera lakes. Newberry last erupted about 1,300 years ago, and present-day hot springs and geologically young lava flows indicate that it is still an active volcano. The presence of lakes add to the danger of eruptions in the caldera. When magma mixes with water, the result can produce highly explosive tephra eruptions. Tephra was generated in the eruption that created the cinder cone of Lava Butte, and the earlier phase of the Big Obsidian eruption that deposited windblown ash as far away as Idaho.

The most recent eruptions from South Sister produced tephra that fell more than 2 m thick (7 feet) within 2 km (1 mile) of the vent and deposited a coating of ash at locations as far as 40 km (25 miles) south and east of the vents (extending into Bend).

Impacts on the Facility from volcanic eruptions would be direct and could include blasts or ash/tephra fall (Walder, 1999). Because of the Facility's location on a plateau, hundreds of feet above river valleys, no indirect effects (such as mudflows, flooding, and sedimentation) are expected.

Relatively small tephra particles can rise more than 10 kilometers (30,000 feet) upward and be carried downwind and blanket areas for tens to hundreds of miles). Tephra plumes can create tens of minutes to hours of darkness, even on sunny days, as they pass overhead, and tephra fall can reduce visibility. In addition, deposits of tephra can short-circuit or break electric transformers and power lines, especially if the tephra is wet, as well as cause roofs of buildings to collapse. In several historical examples, accumulation of more than 10 centimeters (4 inches) of wet tephra caused roofs to collapse. Tephra can clog filters and increase wear on vehicle engines. Tephra clouds also commonly generate lightning that can interfere with electrical and communication systems and start fires.

The USGS Volcano Hazards Program monitors and studies active and potentially active volcanoes, assesses their hazards, and conducts research on how volcanoes work in order for the USGS to issue "timely warnings" of potential volcanic hazards to emergency-management professionals and the public. Thus, in addition to collecting and interpreting the best possible scientific information, the program works to effectively communicate its scientific findings and volcanic activity alerts to authorities and the public.

As of July 5, 2019, Cascade Range volcanoes were at a “normal” alert levels and at normal background levels of activity. Monitoring systems show that activity at Cascade Range volcanoes remained at background levels throughout the week (USGS, 2019c).

H.7.3 Soil Erosion Potential

The soils within the Facility site boundary could be subject to wind and water erosion, particularly when the vegetation is removed. The Erosion factor (K) indicates the susceptibility of a soil to sheet and rill erosion by water. Factor K 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 and on soil structure and saturated hydraulic conductivity). 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 Natural Resources Conservation Service (NRCS, 2019) indicate that the predominant soils within the Facility site boundary, the Madras loam erodibility rating of 0.37, which indicates moderate water erosion potential.

Wind Erodibility Groups (WEGs) consist of soils that have similar properties (primarily textural classes) that affect their resistance to soil blowing if cultivated or disturbed. The groups are used to predict the susceptibility of soil to blowing and the amount of soil lost as a result of blowing. The Madras loam soils are assigned to a WEG of 6, which means these soils are expected to have moderate to high wind erosion potential. The wind erodibility index is a numerical value indicating the susceptibility of soil to wind erosion, or the tons per acre per year that can be expected to be lost to wind erosion. The Madras loam is rated as potential to lose 47 tons per acre.

No major areas of soil erosion or runoff were observed during the site visit within the Facility boundaries. Soil data indicate that the potential for wind and water erosion within the Facility site boundary is generally moderate or high. Because of steady, relatively high wind speeds, and brief but intense rainfall events, areas of vegetation removal could potentially expose soils to accelerated water and wind erosion during construction until they are stabilized. Excavations for roads or other Facility structures could also temporarily expose the excavated spoils to wind and water erosion during construction. Mitigation measures to account for the high wind erosion (fugitive dust abatement) are described in Exhibit I.

H.7.4 Collapsing Soils/Piping

Silty soils with little or no plasticity can be subject to collapsing or piping when they are wetted. The surficial soils within the Facility typically have 25 percent clay, and are generally less than 20 to 40 inches in depth. Therefore, piping or collapse of these soils is not likely. Piping can have a detrimental effect on embankments or foundations constructed on loess.

The solar structures will be supported by steel posts. The post depth will vary depending on soil conditions, but are typically 8 feet below the surface. If soil conditions require it, concrete foundations will be used. The site visit observations and site-specific soil survey (CES, 2018) indicated that the soil is generally thin and shallow rock is exposed over much of the area within the Facility site boundary. Soil collapse or piping potential is anticipated to be low or nonexistent.

Assuming steel posts are used, they will be driven into bedrock and soil collapse will not affect the structures.

Each tracker table will be bolted to steel posts driven into the ground to serve as the foundation. The post depths will vary depending on soil conditions, which will be confirmed via a detailed geotechnical investigation, but are typically driven to a depth of at least 8 feet below the surface. Approximately 1,000 posts will be installed per module block or approximately 30,000 posts for the up-to-63-MW Facility. Post locations will be determined by the ground coverage ratio (GCR), which is the ratio of the area of the modules to the total area. The GCR for the Facility is currently planned to be approximately 39 percent, meaning that the area occupied by the modules (when fully rotated) will be approximately 39 percent of the area within the array. A ballasted design may be used in portions of the site featuring significant subsurface rock formations, which involves mounting the tracker tables on foundations embedded in concrete blocks (ballasts) that would rest on the surface of the ground rather than on posts driven into the ground.

At the Facility substation, the voltage will again be stepped up to 230 kV for delivery via direct buried cables to the utility-owned, three-breaker ring-bus point of interconnection switching station. Other electrical cables within arrays will be buried to a depth of approximately 3 feet. The collector lines will be directly buried at a depth of approximately 3 feet; however, some portion of the conductors may also be aboveground. Exact collector line routing within the Facility site boundary is still being decided.

H.8 PROPOSED SEISMIC HAZARD MITIGATION

Response: The State of Oregon uses 2012 IBC (International Code Council, 2012), with current amendments by the OSSC and local agencies. Pertinent design codes as they relate to geology, seismicity, and near-surface soil 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 flat terrain and basalt bedrock that underlie the area within the Facility site boundary are not expected to be prone to seismically induced landslides. No structures will be built on steep slopes that could be prone to instability, thus avoiding potential impacts.

H.9 PROPOSED NONSEISMIC HAZARD MITIGATION

Response: Nonseismic geologic hazards and impacts are anticipated to be minimal. Typical mitigation measures for nonseismic hazards include the following:

- 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
- Providing warnings in the event of hazards
- Ensuring that nonseismic geologic events are contemplated under *force majeure* provisions in any relevant Facility contracts

The subsequent sections discuss specific mitigation measures and best management practices (BMPs) for potential nonseismic geologic and soil hazards.

H.9.1 Landslide Mitigation

The solar modules and roads, including the access road and service roads, will be situated on flat-lying areas underlain by sound bedrock. The modules will be situated to avoid steep slopes. A 30-foot-wide slope setback has been designated around the perimeter of the site at the edge of the cliffs to ensure facility structures will not be located near steep slopes.

H.9.2 Volcanic Eruption Mitigation

The USGS has established a Volcano Hazards Program Notification Service that consists of advisories, watches, and warnings (USGS, 2019c; Stovall et al., 2016). The alert-notification system has been standardized and the goals are to accomplish the following:

1. Communicate a volcano's status clearly to nonvolcanologists.
2. Help emergency response organizations determine proper mitigation measures.
3. Prompt people and businesses at risk to seek additional information and take appropriate actions.

In the event of a volcanic eruption that could damage or affect Facility components, the Facility will be shut down until safe operating conditions returned. If an eruption occurred during construction, a temporary shutdown will most likely be required to protect equipment and human safety.

H.9.3 Soil Erosion Mitigation

To reduce the potential for soil erosion, a detailed construction stormwater pollution prevention plan (SWPPP) will be developed for the Facility. The SWPPP will include both structural and nonstructural BMPs. 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.

Because roads, solar modules, and other Facility components will be engineered, they will be subject to the requirements of a National Pollutant Discharge Elimination System (NPDES) stormwater construction permit. The Applicant's application for a NPDES stormwater construction permit is attached to Exhibit I (Attachment I-1) and includes an erosion and sediment control plan.

In addition, Exhibit I contains a comprehensive list of mitigation measures to avoid wind and water erosion and soil impacts.

H.9.4 Collapsing Soils/Freeze-Thaw Mitigation

Because of the thin soil cover, collapsing soils, or freezing and thawing, soils are not anticipated to impact construction or performance. Each tracker table will be bolted to steel posts driven into the ground to serve as the foundation. The post depths will vary depending on soil conditions, which will be confirmed via a detailed geotechnical investigation, but are typically driven to a depth of at least 8 feet below the surface. In addition, a ballasted design may be used in portions of the site featuring significant subsurface rock formations, which involves mounting the tracker tables on foundations embedded in concrete blocks (ballasts) that would rest on the surface of the ground rather than on posts driven into the ground.

H.10 SUMMARY

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 Facility will consist of components such as new and improved roadways, solar module blocks, and an operations and maintenance (O&M) enclosure. None of the facilities will be continually staffed. The probability of a large seismic event occurring while the Facility is occupied is low, which means that the Facility poses minimal risk to human safety during a seismic event. The risk to human safety is slightly higher at the O&M enclosure, which is required to be designed to current seismic standards for Risk Category II in accordance with OSSC for Group U Utility structures.

Further, by adhering to IBC requirements, 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. These IBC 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 followed.

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 nonseismic geologic hazards are considered to be low because the Facility can be designed to avoid or minimize the hazards of landslides, rockfall, soil erosion, and volcanic eruptions. Erosion hazards resulting from soil and wind action will be minimized with the implementation of an engineered erosion control plan.

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). 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.

H.11 REFERENCES

Berg, J. W., Jr. and C. D. Baker. 1963. “Oregon Earthquakes, 1841 through 1958.” *Bulletin of the Seismological Society of America*. Vol. 53, No. 1, pp. 95-108. January.

Burns, W. J., K. A. Mickelson, and E. C. Saint-Pierre. 2014. *SLIDO-2: Statewide Landslide Information Database for Oregon, Release 2*. Oregon Department of Geology and Mineral Industries. December 29.

Campbell, K., N. Abrahamson, M. Power, B. Chiou, Y. Bozorgnia, T. Shantz, and C. Roblee. 2009. “Next Generation Attenuation (NGA) Project: Empirical Ground Motion Prediction Equations for Active Tectonic Regions.” Sixth International Conference on Urban Earthquake Engineering, March 3-4, 2009. Tokyo Institute of Technology, Tokyo, Japan. http://peer.berkeley.edu/ngawest/documents/nga_selected_publications/CAMPBELL_6CUEE_NGA_KEYNOTE.pdf.

Cascade Earth Sciences (CES). 2018. *Site-Specific Soil Survey of Property Located along Elk Drive, also known as T10S, R13E, Section 30, Tax Lot 600 (161.47 acres) and Section 31, Tax Lot 100 (317.98 acres), West of Madras in Jefferson County, Oregon*. Prepared for Ecoplexus, Inc. September.

Federal Emergency Management Agency. 2015. *2015 National Earthquake Hazards Reduction Program Seismic Design Provisions*.

Geomatrix Consultants, Inc. (Geomatrix). 1995. *Seismic Design Mapping, State of Oregon*. Technical report to Oregon Department of Transportation, Salem, Oregon, under Contract 11688. Unpaginated, 5 pls., scale 1:1,250,000. January.

International Code Council. 2012. *International Building Code*.

International Code Council and State of Oregon. 2014. *2014 Oregon Structural Specialty Code* Based on the 2012 International Building Code. http://ecodes.biz/ecodes_support/free_resources/Oregon/14_Structural/14_ORStructural_main.html.

Kramer, Steven L. 1996. *Geotechnical Earthquake Engineering*. Prentice-Hall, Inc. Upper Saddle River, New Jersey.

Ma, L., I. P. Madin, K. V. Olson, R. J. Watzig, R. E. Wells, A. R. Niem, and G. R. Priest. 2009. *National Geologic Map Database*. Oregon Department of Geology and Mineral Industries, Digital Data Series OGDC-5, scale 1:100,000. Oregon geologic data compilation, release 5 (statewide). Oregon geologic data compilation [OGDC], release 5 (statewide).

Madin, Ian P., Oregon Department of Geology and Mineral Industries (DOGAMI). 1994. *Earthquake Database for Oregon 1833 – 10/25/93.* Open File Report 0-94-4.

Madin, Ian P., Oregon Department of Geology and Mineral Industries (DOGAMI). 2019. Personal communication (verbal) with Jacobs. November 7.

National Geophysical Data Center/World Data Service (NGDC/WDS). 2019. *Significant Earthquake Database*. National Geophysical Data Center, NOAA. doi:10.7289/V5TD9V7K.

Natural Resources Conservation Service (NRCS). 2019. *Web Soil Survey*. United States Department of Agriculture NRCS, Lincoln, Nebraska. Last modified April 9, 2019. Accessed July 25, 2019. https://websoilsurvey.sc.egov.usda.gov/.

Oregon Department of Geology and Mineral Industries (DOGAMI). 2019. DOGAMI LiDAR Viewer. Accessed July 2019. https://gis.dogami.oregon.gov/maps/lidarviewer/.

Oregon State Board of Geologist Examiners. 2014. *Guideline for Preparing Engineering Geologic Reports*. Second Edition. May 30. Accessed July 2019. https://www.oregon.gov/osbge/Documents/engineeringgeologicreports_5.2014.pdf.

Oregon Water Resources Department (OWRD). 2019. *Well Report Query*. Accessed July 25, 2019. https://apps.wrd.state.or.us/apps/gw/well_log/.

Personius, S. F., compiler. 2002a. "Fault number 851, Warm Springs fault zone." In Quaternary fault and fold database of the United States: U.S. Geological Survey website. Accessed July 8, 2019. https://earthquakes.usgs.gov/hazards/qfaults.

Personius, S. F., compiler. 2002b. "Fault number 853a, Metolius fault zone, Green Ridge section." In Quaternary fault and fold database of the United States: U.S. Geological Survey website. Accessed July 8, 2019. https://earthquakes.usgs.gov/hazards/qfaults.

Personius, S. F., and K. M. Haller, compilers. 2016. "Fault number 852, Sisters fault zone." In Quaternary fault and fold database of the United States: U.S. Geological Survey website. Accessed July 8, 2019. https://earthquakes.usgs.gov/hazards/qfaults.

Smith, G. A., 1986. Stratigraphy, sedimentology, and petrology of Neogene rocks in the Deschutes Basin, central Oregon—A record of continental margin volcanism and its influence on fluvial sedimentation in an arc adjacent basin: Corvallis, Oregon State University, Ph.D. dissertation, 467 pp.

Smith, G. A. 1987. *Geologic Map of the Madras West and Madras East Quadrangles*. Jefferson Counties: Oregon Department of Geology and Mineral Industries, Geological Map Series 45, scale 1:24,000.

Stovall, W. K., A. M. Wilkins, C. W. Mandeville, and C. L. Driedger. 2016. *U.S. Geological Survey Volcano Hazards Program—Assess, forecast, prepare, engage*. U.S. Geological Survey Fact Sheet 2016–3040, 4 p. http://dx.doi.org/10.3133/fs20163040.

U.S. Geological Survey (USGS). 2005. "The Orphan Tsunami of 1700: Japanese Clues to a Parent Earthquake in North America." Professional Paper 1707. Published by the USGS and University of Washington Press. pp. 144.

U.S. Geological Survey (USGS). 2014. *National Seismic Hazards Mapping*.

U.S. Geological Survey (USGS). 2019a. Earthquake Hazards Program, National Seismic Hazard Mapping Project. Golden, Colorado. Accessed July 2019. http://earthquake.usgs.gov/.

U.S. Geological Survey (USGS). 2019b. Earthquake Hazards Program, Earthquake Search Databases. Golden, Colorado. Accessed July 2019. http://earthquake.usgs.gov/earthquakes/search/.

U.S. Geological Survey (USGS). 2019c. USGS Volcano Hazards Program Notification Service. Accessed July 2019. https://volcanoes.usgs.gov/vhp/updates.html, CVO tab.

Wald, D. J., V. Quitoriano, T. H. Heaton, and H. Kanamori. 1999. "Relationships Between Peak Ground Acceleration, Peak Ground Velocity, and Modified Mercalli Intensity in California." *Earthquake Spectra*. Vol. 15, No. 3, pp. 557-564. August.

Walder, J. S., C. A. Gardner, R. M. Conrey, B. J. Fisher, and S. P. Schilling. 1999. Digital Data for Volcano hazards in the Mount Jefferson region, Oregon: U.S. Geological Survey, Open-File Report 99-24.

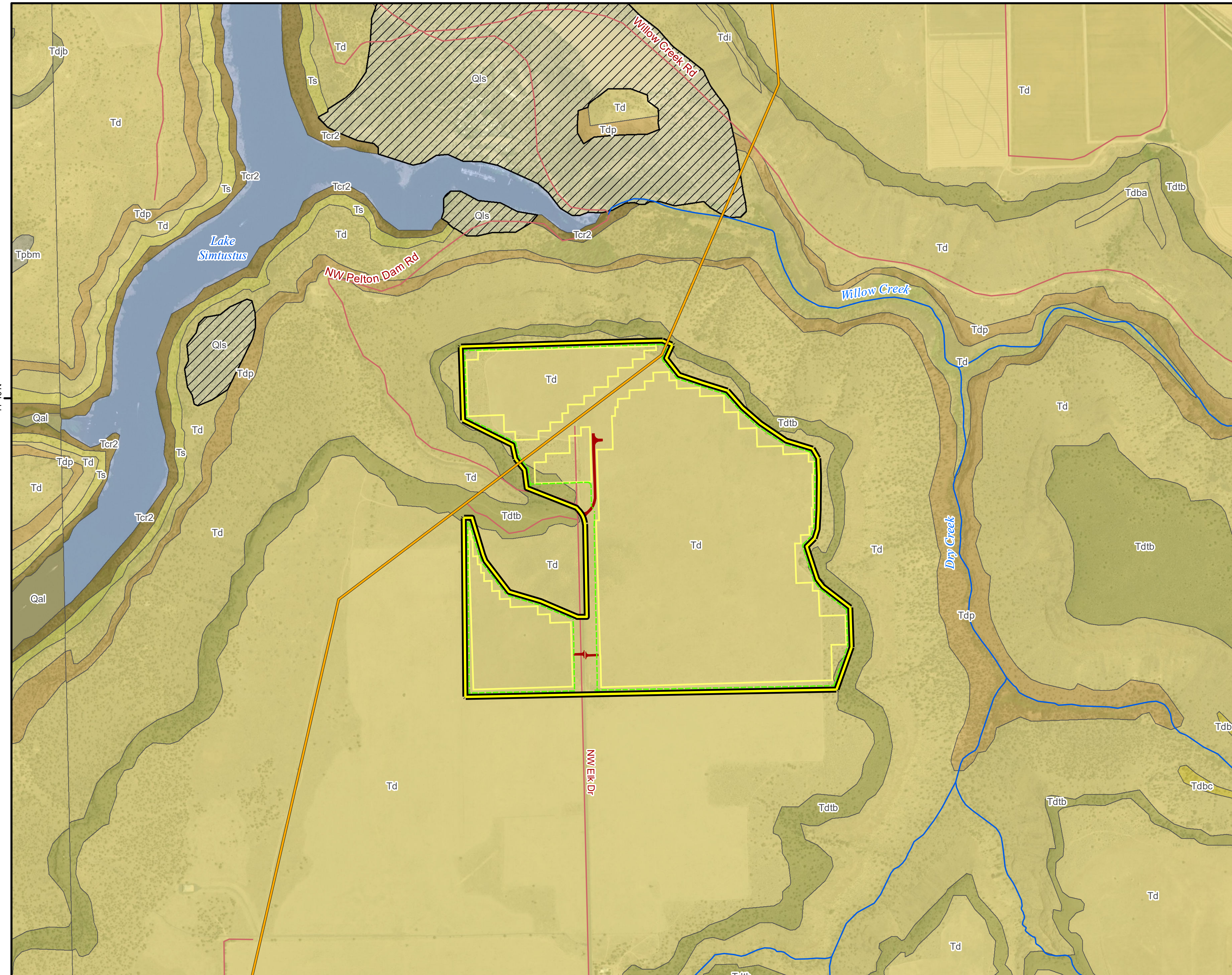
Wang, Y., Oregon Department of Geology and Mineral Industries (DOGAMI). 2019. Personal communication (written and verbal) with Jacobs. July and August.

Weldon, R. J., D. K. Fletcher, E. M. Weldon, K. M. Scharer, and P. A. McCrory. 2003. An update of Quaternary faults of central and eastern Oregon: U.S. Geological Survey, Open-File Report OF-2002-301, scale 1:100,000.

Wells, Donald L. and Kevin J. Coppersmith. 1994. "New Empirical Relationships among Magnitude, Rupture Length, Rupture Width, Rupture Area, and Surface Displacement." *Bulletin of the Seismological Society of America*. Vol. 84, No. 4. pp. 974-1002. August.

Figures

VICINITY MAP



LEGEND

- Madras Solar Energy Facility Site Boundary
- Existing Pelton Dam to Round Butte 230-kV Transmission Line
- Fence
- Access Road
- Solar Array Outline
- Road
- Stream
- Landslide

Geology Map Unit Formation

- Qal: Quaternary alluvium
- Qls: Landslide debris
- Tcr2: Columbia River Basalt Group, Prineville chemical type
- Td: Deschutes Formation
- Tdbc: Big Canyon basalt member
- Tdjb: Jackson Butte ignimbrite member
- Tdp: Pelton basalt member
- Tdtb: Tetherow Butte member, Agency Plains basalt flow
- Tpbm: Basalts of Metolius Bench
- Ts: Simtustus Formation
- No Data/Water

Coordinate System: NAD 1983 UTM Zone 10N

Data Sources: Geology and Landslides: Oregon Department of Geology and Mineral Industries; Site Boundary: Ecoplexus; City Limits: Jefferson County; Imagery: DigitalGlobe 2016 via ESRI ArcGIS online; Waterbody: BLM; Watercourse: NHD; Warm Springs Reservation: USGS 2009

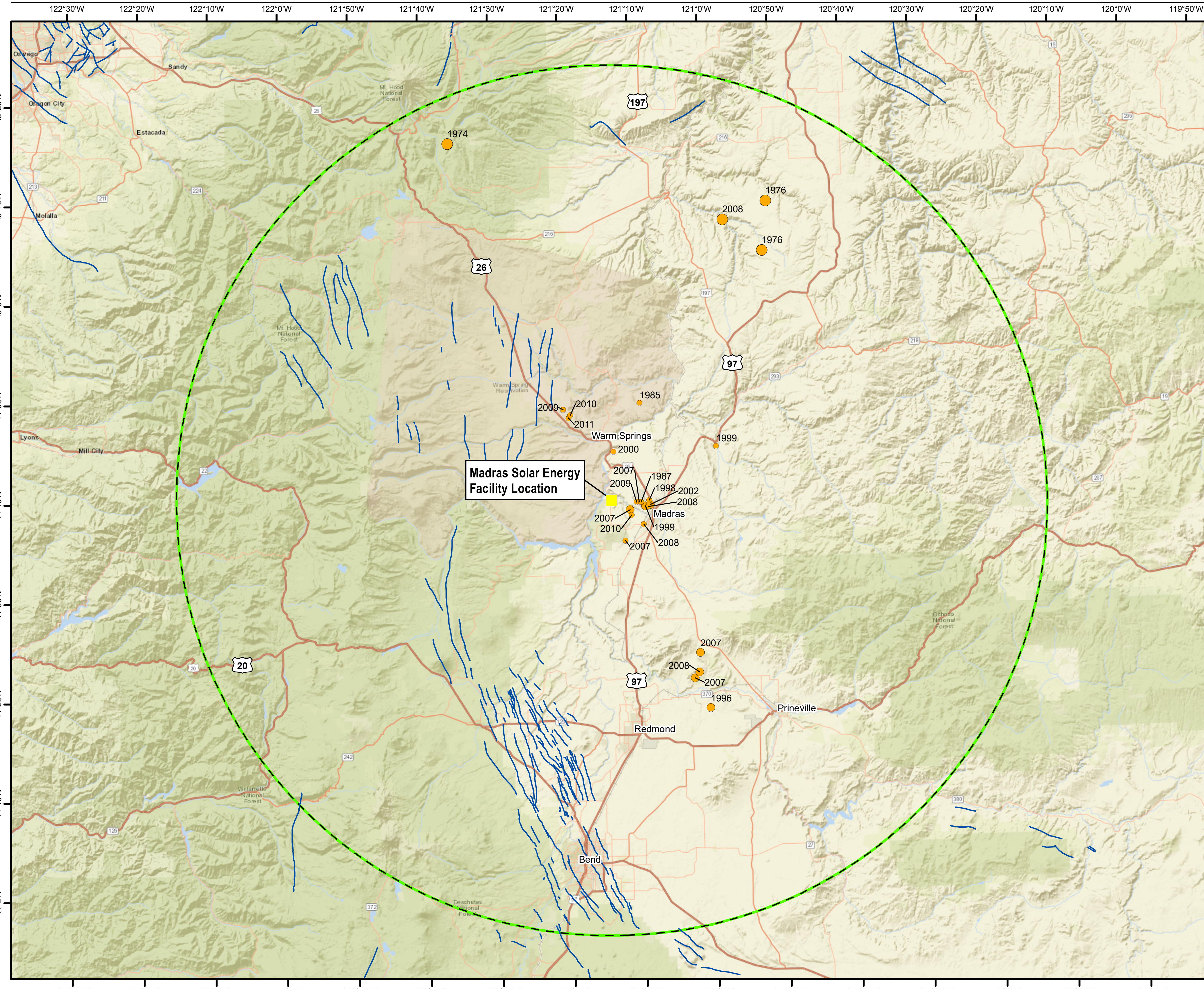
N

0 250 500 1,000 1,500 2,000
Feet

1 inch equals 1,100 feet

Figure H-1
Geology Map
Application for Site Certificate
Madras Solar Energy Facility
Jefferson County, OR

JACOBS



VICINITY MAP

LEGEND

- Madras Solar Energy Facility Location
- 50-mile Radius
- Fault

Historical Earthquakes - Magnitude

- 2.5 - 2.9
- 3.0 - 3.9
- 4.0 - 4.6

N

Coordinate System: NAD 1983 UTM Zone 10N

0 5 10 20 Miles

1 inch equals 11.3 miles

Figure H-2
Historical Seismicity and Quaternary Faults
Application for Site Certificate
Madras Solar Energy Facility
Jefferson County, OR

JACOBS

\\BROOKSIDEFILES\GIS_SHARE\ENBG\00_PROJ\E\ECOPLEXUS\MADRASSOLARPROJECT\MAPS\REPORT\2019\SITECERTIFICATEAPP\H-2_190801.MXD KGRANT1 9/26/2019 5:20:30 PM

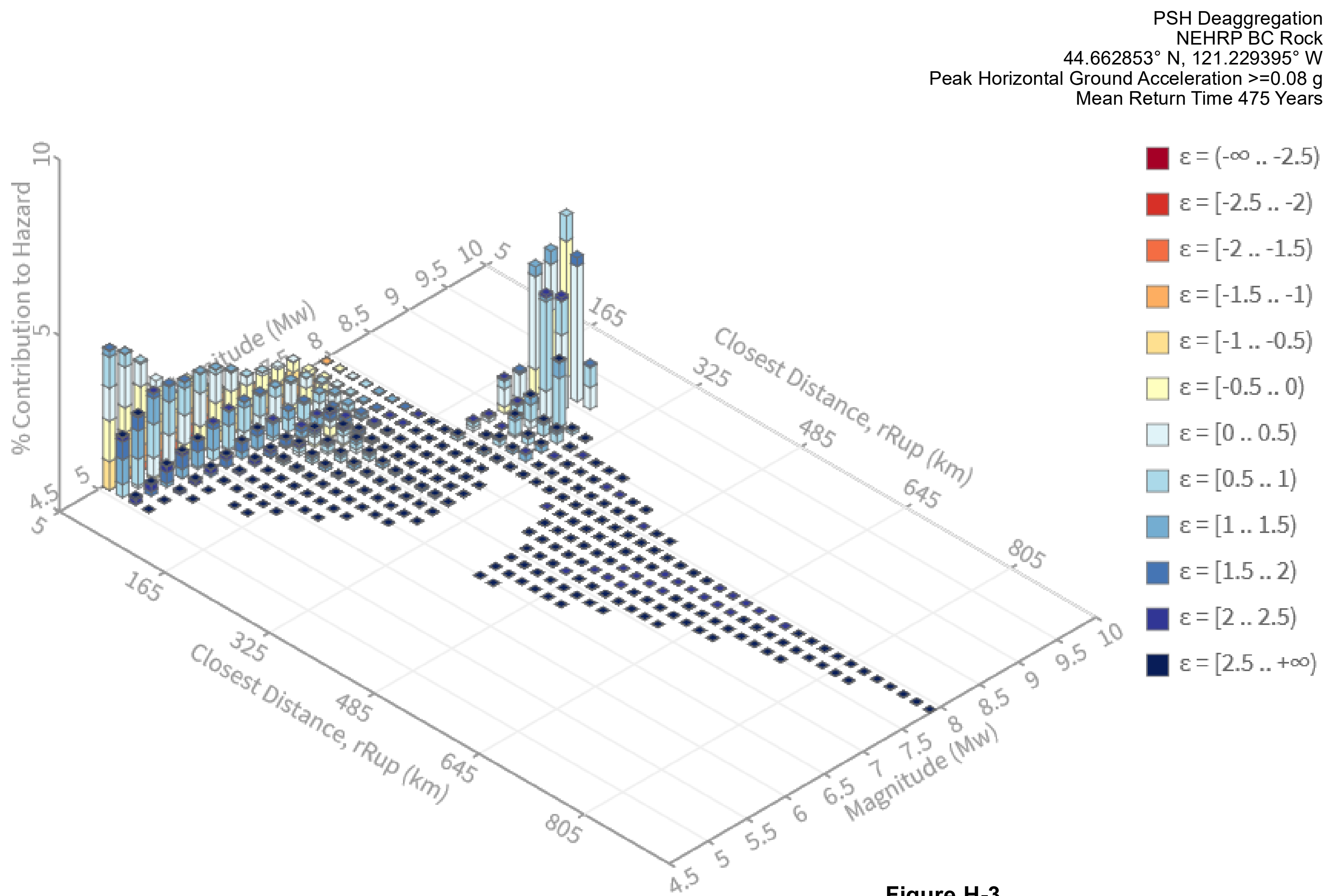


Figure H-3

Probabilistic Seismic Hazard Deaggregation for the Maximum Probable Earthquake Event

Application for Site Certificate

Madras Solar Energy Facility

Jefferson County, OR

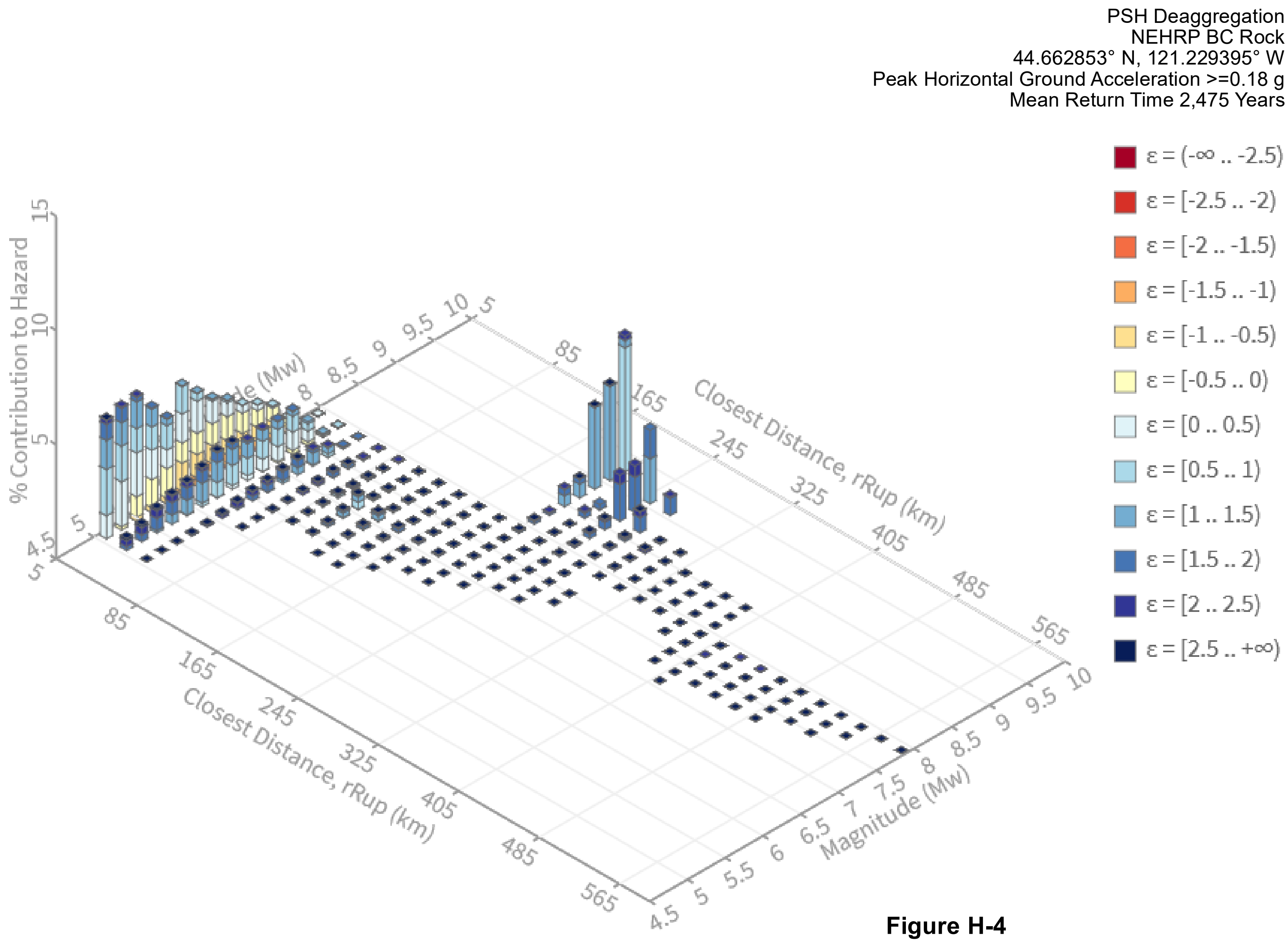


Figure H-4

Probabilistic Seismic Hazard Deaggregation for the Maximum Considered Earthquake Event

Application for Site Certificate

Madras Solar Energy Facility

Jefferson County, OR

JACOBS

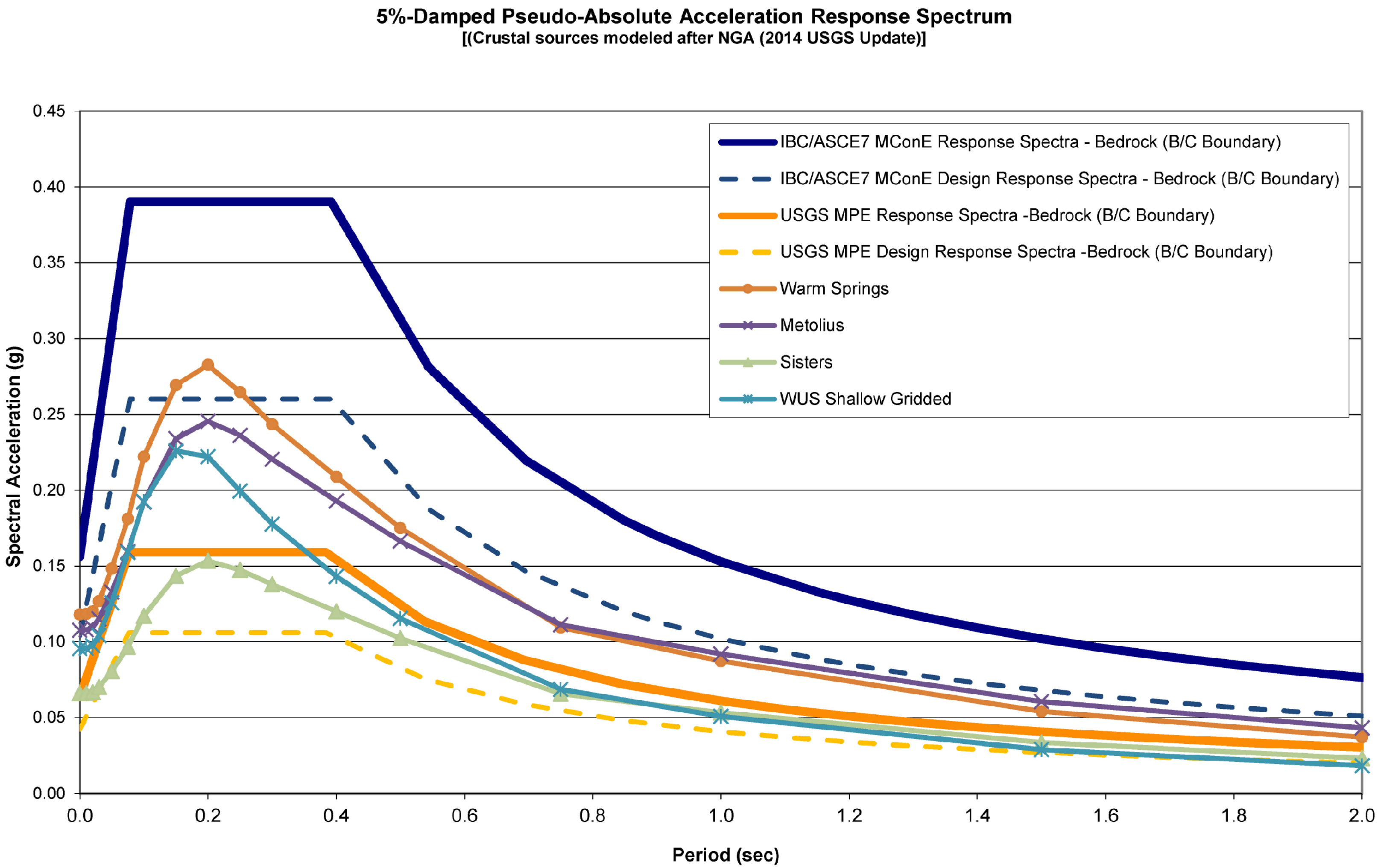


Figure H-5
Median Ground Response Spectra Plots
Application for Site Certificate
Madras Solar Energy Facility
Jefferson County, OR

JACOBS

Attachment H-1
DOGAMI Consultation Records

JACOBS

Meeting Minutes

999 W. Main St., Ste. 1200
Boise, ID 83702
208.850.9819
www.jacobs.com

Subject	**DOGAMI Consultation**		
Project	Madras Solar Energy Project		
Project No.	709202CH.E2.05	**File**	DOGAMI Consultation - Telephone Record
Prepared by	Josh Butler/Jacobs	**Phone No.**	208.345.5310
Location	Conference Call	**Date/Time**	August 20, 2019
Participants	Yumei Wang/DOGAMI Chase McVeigh-Walker/ODOE		
Copies to	Paul Seilo/Jacobs		

Notes		**Action**
1	Latest review process may be more systematic than I'm familiar with. Yumei requested that this consultation follow along with the DOGAMI Scope of Review document for EFSC. Josh has reviewed this document and has it open for guidance during this call.	Need to share this summary document of our meeting with Yumei and Chase, and invite her/his review.
2	I provided a brief overview of the project to Yumei and Chase, described the site setting, my background and history preparing Exhibit H for Applications, and discussed some of the potential geologic hazards at this site based on my personal site visit.	
3	Use the Oregon State Board of Examiners guideline for reports. Using current Oregon Specialty Structural Codes (OSSC, 2014)…anticipate adopting the OSSC 2019 later this year. Yumei anticipates it will be adopted in October 2019.	Yumei suggests considering the 2019 OSSC as our reference spec since our Application may fall under the timeframe after which the State of Oregon has already adopted the 2019 version.
4	A site-specific study is also recommended prior to commencing any work. Describe what has already been done, or, what will be done to inform design (drilling, lab testing, Probabilistic Seismic Hazard Assessment, LiDAR, and other site-specific work).	Provide detailed and specific description of what has been done, what will be done, and when.
5	Site description – be sure to mention in Exhibit H whether the site is in a floodplain (100-year floodplain) or not; whether there is liquefaction hazard, landslides potential, etc. Just be specific in description of all potential hazards, and how we have addressed or considered them.	Be overt in description of floodplain, liquefaction, any other geologic hazards.

Notes		Action
6	Faults and seismic sources: we discussed our draft Figure H-2. There are other fault sources in the area that have been mapped by DOGAMI. Jason McClaughry in DOGAMI's Baker City office or Ian Madin are good sources for this information. Yumei commented that there may some faults that both Ian and Jason have mapped, which are NOT included in USGS's database. Josh: will perform a deterministic analysis and provide response spectra for crustal sources and others that are potentially detrimental to this site. Josh also mentioned that we have looked at the Slido database for LiDAR-based landslide mapping.	Contact Jason: 541.523.3133 Contact Ian: 971.673.1542
7	Are there specific types of bracing or resistance for solar panels? DOGAMI is aware of lateral shaking that has damaged some solar facilities. Old facilities utilized friction slips/platforms, which DOGAMI deems insufficient, as communication would get disrupted after a seismic event due to damage. Just something to consider. Josh explained his role as providing accurate geotechnical design information for duration and magnitude of shaking to inform the correct structural design. Just something to consider because of disaster resilience, and trying to keep energy facilities up and running with as little down time as possible. DOGAMI indicated that following a natural disaster, prolonged down time poses a public health and safety concern.	Josh to discuss this with our structural engineers to see what has been done. We discussed that contemporary design typically includes a single foundation (pier) for single panels; the load is small, not high off the ground.
8	Chase: to issue Project Order in next couple weeks. Following this, he anticipates the pASC being wrapped up at the end of September/first of October. This is based on his conversations with EcoPlexus and also with Paul Seilo/Jacobs.	

JACOBS

Meeting Minutes

999 W. Main St., Ste. 1200
Boise, ID 83702
208.850.9819
www.jacobs.com

Subject	**DOGAMI Consultation**		
Project	Madras Solar Energy Project		
Project No.	709202CH.E2.05	**File**	DOGAMI Consultation - Telephone Record
Prepared by	Greg Warren/Jacobs	**Phone No.**	208.850.9819
Location	Conference Call	**Date/Time**	November 7, 2019
Participants	Ian Madin/DOGAMI		
Copies to	Paul Seilo/Jacobs		

Notes		**Action**
1	Ian said that new faults (fault scarps) have been identified, based on QC of recently available LiDAR coverage. Many of these were described at the Geological Society of America (GSA) in a presentation. However, we can't say what we know about the faults. i.e., magnitude/recurrence interval.	In general, there's no published information about these faults outside the GSA paper. We [DOGAMI] can't send out or use this unpublished [fault] information. We can share images because the LiDAR is public information.
2	Ian suggested that we as consultants look closely at the sites we are studying – there's lots of unmapped faults. Every time new LiDAR becomes available for central Oregon, new potentially active faults are identified. Particularly look at those areas within our area of concern. Unfortunately, there's holes in LiDAR coverage. Ian suggested take a close look at Google Earth imagery if no LiDAR coverage is available.	One issue in the Madras vicinity is the Warm Springs Reservation – they have LiDAR but have not allowed any geologists onsite to ground-truth potential faults for decades. However, they recently allowed Dave Sherrod (volcanologist with USGS) to see LiDAR imagery and conduct geologic mapping. He could be a resource and he may be allowed to discuss potential faults.
3	The GSA presentation concluded: Cursory review of the large, high-quality LiDAR dataset collected by the Oregon LiDAR consortium has identified dozens of previously unrecognized young faults. None have been studied in significant detail.	