Report

Teanaway Solar Reserve Geology and Soils Hazards Evaluation Kittitas County, Washington

Prepared for

Teanaway Solar Reserve, LLC

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Prepared by

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1.0 Introduction

The proposed project site is located approximately 4 miles northeast of Cle Elum, Washington, in Township 20N, Range 16E, within Sections 22, 23, and 27 (see Figure 1 in Appendix A for site location). The site is located on the eastern slopes of the Cascade Mountains on Cle Elum Ridge, which runs generally from east to west at elevations ranging from approximately 2,200 to 2,600 feet. The Teanaway River is approximately 1 mile to the northeast of Cle Elum Ridge. The site is accessed from Highway 970 by way of county roads such as Red Bridge Road, private roads such as Loping Lane, and Wiehl Road, which is a dedicated public road that is maintained privately and not by the County.

The proposed project area consists of 982 acres. Based on site surveys, the project will utilize approximately 477 acres within the proposed project area. Solar arrays will occupy approximately 399 acres. The remaining acres are currently undeveloped open space, which will be preserved as part of the Wildlife Mitigation Plan (see Attachment H). An open corridor will be maintained to allow for wildlife migration through the site. Figure 2 (see Appendix A) shows the proposed site layout.

Data from the Washington Department of Natural Resources (WDNR), the U. S. Geological Survey, the Web Soil Survey provided by the Natural Resources Conservation Service (NRCS), and aerial photograph base maps were reviewed for information on geology, soil characteristics, and potential geologic hazards in the vicinity of the site. A limited site reconnaissance was conducted to observe general site conditions, presence of geologic hazards, existing erosional features, evidence of slope instability, and collect soil samples to confirm NRCS classification and evaluate soil erodibility potential.

The following section presents an overview of the site geologic setting and soil characteristics, and discusses potential hazards and impacts.

1.1 Geologic Setting and Soil Properties

Surficial geologic units at the site include glacial till that is capped by loess (windblown silt). The till is known as the Swauk Prairie Subdrift of the Kittitas drift (Tabor et al., 1982). This unit is described as "boulder diamicton…capped by as much as 3 m (10 feet) of loess". Based on observations at the site, this unit consists primarily of silty loess containing volcanic ash, with numerous rounded cobbles and boulders scattered across the surface. Some of the boulders observed on the site are up to 5 feet in diameter, which suggests glacial origin. No bedrock outcrops were observed on the site.

The predominant surficial soils present on the site that would underlie project facilities include the Teanaway Loam, 3 to 10 percent slopes, and the Teanaway Loam, 25 to 50 percent slopes (NRCS, 2009). These two soil units have identical characteristics, and are distinguished by slope angles. These soils are formed in loess that overlies glacial till or outwash, with an influence of volcanic ash at the surface. These soils are described as moderately well-drained, moderately low to moderately high permeability, high available water capacity, and no flooding or ponding frequency.

The NRCS provides a large amount of soil data for each soil series. The data include physical properties, engineering properties, and suitability of the soils for certain uses.

These include erosion potential and suitability for roads on forestlands, excavations, etc. However, the NRCS (2009) cautions that "onsite investigations may be needed to validate the interpretations….and to confirm the identity of the soil on a given site." To confirm the NRCS data for the site, eight soil samples were collected. These samples were collected from shallow, hand-dug pits, from depths between approximately 6 and 18 inches. These depths were selected to represent the zone where the most disturbance is anticipated to occur, such as during road construction. These samples were analyzed for soil index properties in a laboratory in order to compare their properties and confirm the NRCS classifications. In addition, because the soil units are based on slope angles (percent), onsite slopes were measured in the field to confirm that the slope angles assigned to the soil classes are accurate.

Figure 3 (see Appendix A) shows the distribution of soils and slopes in the project area, based on NRCS and USGS data.

Table 1 summarizes the physical properties of the predominant soils that underlie the proposed facility, based on NRCS data. Table 2 summarizes the index properties of the onsite soils, based on NRCS data. Table 3 summarizes the index properties of the soil samples collected from the site for comparison to NRCS data.

The laboratory data for the soils collected onsite confirm the NRCS soil data. The soils collected onsite (upper 6 to 18 inches) consist primarily of very low-plasticity to non-plastic sandy silt and have similar laboratory data as presented by the NRCS.

TABLE 1
Summary of Surficial Soils and their Physical Properties (NRCS Data)

Soil Series	Depth (inches)	USDA Soil Texture	Slopes (percent)	Soil Erodibility Factor (K) [a]	Saturated Hydraulic conductivity (K_{sat}) (um/sec) [b]	Organic Matter (percent)
Teanaway Loam, 3 to 10 percent slopes	3 – 22	Loam, Silt Loam	3 – 10	0.43	4.00 – 14.00	0.5 – 3.0
	22 – 60	Loam, Silt Loam, Clay Loam	3 – 10	0.43	1.40 – 4.00	0.0 – 1.0
Teanaway Loam, 25 to 50 percent slopes	3 – 22	Loam, Silt Loam	25 – 50	0.43	1.4 – 14.00	0.5 – 3.0
	22 – 60	Loam, Silt Loam, Clay Loam	25 – 50	0.43	1.40 – 4.00	0.0 – 1.0

Notes:
[a] Erodibility Factor (K) = susceptibility of a soil to sheet and rill erosion by water
[b] Saturated Hydraulic Conductivity (K_{sat}) = the ease with which pores in a saturated soil transmit water (i.e. the rate at which water moves through soil)

TABLE 2
Soil Index Properties (NRCS Data)

Soil Name	Depth (inches)	USCS Classification	Bulk Density (lbs/ft^3)	Percent Passing Sieve #200 [a]	Liquid Limit [b]	Plasticity Index [b]	Clay Percent
Teanaway Loam, 3 to 10 percent slopes	3 – 22	Sandy Silt (ML)	75 – 97	55 – 75	15 - 25	NP - 5	10 – 13
	22 – 60	Lean Clay (CL)	97 – 106	45 - 75	25 - 40	10 - 20	17 - 30
Teanaway Loam, 25 to 50 percent slopes	3 – 22	Sandy Silt (ML)	75 – 97	55 – 75	15 - 25	NP - 5	10 – 13
	22 – 60	Lean Clay (CL)	97 – 106	45 - 75	25 - 40	10 - 20	17 - 30

Notes:
[a] #200 Sieve is Sand/Silt Boundary
[b] Liquid Limit and Plasticity Index define if the soil will behave plastically based on moisture content
NP = Non-Plastic

TABLE 3
Soil Laboratory Data (Index Properties) – Onsite Soil Samples

Soil Name	Depth (inches)	USCS Classification	Bulk Density (lbs/ft^3)	In Situ Moisture (%)	Percent Passing #200 Sieve [a]	Liquid Limit [b]	Plasticity Index [b]
SS – 1	6 – 18	Silty Sand (SM)		12.7	44	17	NP
SS – 2	6 – 18	Sandy Silt (ML)		13.4	67	21	2
SS – 5	6 – 18	Sandy Silt (ML)	110	15.2	61	16	NP
SS – 6	6 – 18	Sandy Silt (ML)		17.4	57	19	NP
SS – 7	6 – 18	Sandy Silt (ML)		18.4	54	20	NP
SS – 8	6 – 18	Sandy Silt (ML)	100	16.1	36	19	NP

Notes:
[a] #200 Sieve is Sand/Silt Boundary
[b] Liquid Limit and Plasticity Index define if the soil will behave plastically based on moisture content
NP = Non-Plastic

2.0 Potential Soil Impacts and Geologic Hazards

The following section describes the potential soil impacts and geologic hazards based on review of existing literature and geologic mapping, as well as the geologic site reconnaissance. Figure 4 (see Appendix A) shows areas of observed geologic features, slope angles measured on the site, and soil sample locations. The Photo Log in Appendix B shows site photographs of observed features that are described below. Mitigation measures to avoid or minimize the potential impacts and hazards are described in Section 3.0, BMPs and Controls, Mitigation, and Monitoring Measures.

2.1 Soil Limitations

The rate and magnitude of soil erosion by water are controlled by rainfall intensity and runoff, soil erodibility, and vegetation cover. 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 (USLE) and the Revised Universal Soil Loss Equation (RUSLE) 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. The Teanaway Loam soils on the site have an erosion factor K of 0.43, which indicates moderate erosion potential.

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. The volume change is reported as percent change for the soil. The uppermost soils on the site have a linear extensibility (i.e. swelling potential) between 0.0 and 1.5 percent, indicating no to very low swell potential (NRCS, 2009). Therefore, shrinking/swelling soils are not expected on the site, and will not impact project facilities.

Existing two-track roads on the site showed occasional shallow, localized erosion and rills in a few locations. These features were localized and not severe; and in general the on-site roads were in good condition, especially considering these roads are primitive, non-surfaced roads that are typically just a bladed surface of native soils and compacted by vehicular traffic. One area along the existing road near the south side of the western portion of the site showed a small area of erosion in the roadway and sediment transport off the edge of the road.

The onsite soils are rated as “somewhat limited” to “very limited” for local roads and streets (NRCS, 2009). These ratings are based on the soil properties that affect the ease of excavation and grading and the traffic-supporting capacity. A rating of “somewhat limited” indicates the soil has features that are moderately favorable for the specified use, and the limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected. A rating of “very limited” indicates the soil has one or more features that are unfavorable for the specified use. The limitations can be overcome with soil reclamation, and sound design and installation procedures. The Teanaway Loam (25 to 50 percent slopes) is classified as “very limited” ranking for local roads and streets, primarily based on the relatively steep slope angles as shown in the NRCS database (Figure 3).

Figure 3 shows the distribution of slope angles steeper than 33 percent, as requested by Kittitas County Community Development Services in a letter dated December 4, 2009. This slope map is based on a USGS Digital Elevation Model. Based on this data, slopes steeper than 33 percent are primarily present along the edges of the Teanaway River valley, outside the project boundaries. This map shows very small, localized areas with slopes steeper than 33 percent within the site boundaries.

In order to confirm the onsite slope angles and conditions and verify the USGS and NRCS data, the actual slope angles were measured during the field reconnaissance. Figure 4 (see Appendix A) shows geologic features and slope angles, based on the field measurements and observations. The slope angles measured in the field contrast the slope angles assigned to the soil units by the NRCS, and also the USGS slope data. The soils mapped by the NRCS as "Teanaway Loam, 25 to 50 percent slopes" (see Figure 3) actually overlie slopes between 10 and 20 percent, based on measurements conducted on site. Based on the field measurements, no roads would be constructed on slopes steeper than 33 percent. Therefore, because the true slope angles are not as steep as shown in the NRCS and USGS databases, it is not anticipated that slopes will pose a potential hazard nor interfere with the performance of new roads or structures.

The road design for the Teanaway Solar Reserve (TSR) project includes a 20-foot-wide gravel road designed to carry construction and traffic loads. A final design geotechnical investigation will be conducted to confirm the characteristics of the soil, determine the soil properties related to road building, and design proper roadways to overcome any soil limitations. In addition, future access road design will incorporate drainage facilities and erosion protection on slopes and culverts to pass runoff.

2.2 Stream Erosion/Gullying

No major areas of surficial soil erosion or gullying were observed. One, small drainage on the western side of the site has a small incised gully within the bottom of the drainage, but this was relatively shallow (1 foot deep by 1 to 2 feet wide) and was not continuous (see Figure 4). This is typical of a drainage bottom and did not exhibit large-scale erosion or gullying.

The site was well-vegetated at the time of the site visit in November 2009. Old scrapes and surficial skid furrows from logging activities have revegetated and not eroded further. These logging furrows were typically linear and many were oriented parallel to the fall of the slope and yet did not show signs of catalyzing into larger erosional features.

2.3 Volcanoes

The Pacific Northwest region is home to several active volcanoes along the Cascade Mountain Range. The closest ones to the project area are provided below, with distances from each mountain to the project site:

- Mount St. Helens—90 miles
- Mount Rainier—50 miles
- Mount Adams—80 miles
- Mount Hood—135 miles

Mount St. Helens has experienced the most recent eruption, which occurred in May 1980. Impacts to the project from volcanic activity can be either direct or indirect. Direct impacts include the effects of lava flows, blast, ash fall, and avalanches of volcanic debris. Indirect effects include ash and debris accumulation, flooding, and sedimentation. Depending on the prevailing wind direction at the time of an eruption and the source of the eruption; ash fallout in the region surrounding the project may occur.

2.4 Landslides

No existing landslides have been mapped within the site boundaries on existing geologic maps (Tabor, et al., 1982; WDNR, 2010). These geologic maps show landslides to the north and east side of the site, on steep slopes adjacent to the Teanaway River valley. These landslides formed in oversteepened slopes along the river canyon, and are outside of the site boundaries. No areas of irregular or hummocky slopes indicative of mass movement were observed during the geologic reconnaissance. Given the lack of existing landslides stable slopes based on site observations, and relatively low slope angles; the landslide hazard on the site is low.

Slope angles measured during the site visit ranged from flat (zero percent) up to approximately 20 percent in areas of proposed facilities and roads. A few localized steeper slopes were observed in drainage areas. A few low (<6-foot high) road cuts were observed along existing roads. These cuts are stable with only very minor areas of erosion observed. Onsite slope angle measurements are shown on Figure 4.

2.5 Faults/Seismicity

No potentially seismically active faults have been mapped within the project site boundary. According to the U. S. Geological Survey's Quaternary Fault and Fold database (USGS, 2008a) and the Quaternary Faults map (WDNR, 2010), the closest mapped potentially active fault is the Kittitas Valley Faults, mapped within approximately 10 miles to the southeast of the site. This fault system is inferred to have the latest movement between 3.7 million and 130,000 years ago. This fault is considered a "Class B" Quaternary-age fault with a slip rate estimated to be less than 0.2 millimeters (mm) per year.

The seismic potential for the site is low to moderate, due to the potential for regional earthquakes. For new construction, the facilities' tower foundations will be designed according to the International Building Code and the site will be assigned a seismic site class based on soil properties in the upper 100 feet of the subsurface. Seismic design issues will be fully addressed in a geotechnical report prepared for final design.

3.0 BMPs and Controls, Mitigation, and Monitoring Measures

Proper Best Management Practices (BMPs) will be implemented to minimize or eliminate the potential for increased erosion and protect the project facilities. BMPs are listed throughout the SEPA checklist, including BMPs for reducing dust generation and stormwater runoff. However, due to potential soil constraints such as slopes and potentially erodible soils, the following mitigation measures should also be employed, based on final design and site layout. Complete erosion and sediment control guidelines and BMPs are outlined in Washington State Department of Transportation (WSDOT) Highway Runoff Manual M 31-16 (WSDOT, 2008).

- TSR will obtain a Washington State Department of Ecology Individual National Pollutant Discharge Elimination System (NPDES) Permit prior to construction. TSR will develop a Stormwater Pollution Prevention Plan (SWPPP) that meets the requirements of the Permit.

- As part of the SWPPP, TSR will prepare a temporary erosion and sediment control (TESC) plan. The TESC plan will address excavation, grading, and erosion control measures, both during construction and restoration of temporarily disturbed areas. On completion of the construction activities, all work areas, except any permanent access roads will be regraded so that all surfaces drain naturally, blend with the natural terrain, and are left in a condition that will facilitate natural revegetation, provide for proper drainage, and prevent erosion. Revegetation will be implemented for all areas temporarily disturbed by the construction of the facility in accordance with the terms of the Vegetation Plan (see Attachment G).
- Construction zones and areas to be disturbed will be well-defined, limited in extent, and managed by onsite inspectors and construction managers.
- Periodic inspection will be made of erosion control measures, and as required after precipitation events. Erosion control measures will be repaired or replaced as necessary.
- Berms and other water-channeling measures will be used to direct stormwater runoff to appropriate detention ponds, where necessary.
- Barriers and other measures including hay bales, silt fences, and straw mulches will be used to minimize and control soil erosion.
- Cut slope design for roads will not exceed the soil strength limits. Potentially unstable areas will be identified in the design process and avoided during construction. Site grading will be implemented to achieve stable, non-erosive slopes.
- The seismic site class according to the International Building Code will be determined during subsequent geotechnical investigations. Structures and tower foundations will be designed to withstand anticipated seismic loads.
- For the final design phase, a detailed geotechnical investigation and testing program will be conducted to evaluate the engineering properties of the soil.
- In the event of a volcanic eruption that could damage or impact project facilities, the project facilities would be shut down until safe operating conditions return. If an eruption occurred during construction, a temporary shutdown would likely be required to protect equipment and human health.

Geotechnical Investigation for Final Design

The subsurface conditions and engineering properties of the soils across the site can influence the engineering design and construction. Each of the components of the facility requires specific design calculations, drawings, and final engineering design for successful construction and future operation. Therefore, during final design of the facility a detailed geotechnical investigation and testing program will be conducted to evaluate the engineering properties of the soils. The information from the geotechnical investigation will be used to design the foundations securing the solar modules, inverter pads, and substation;

and design proper roadway sections to carry the anticipated traffic loads, as well as applicable portions of the Kittitas County Code.

The geotechnical investigation will consist of a combination of soil borings and test pits. Shallow sampling (upper 5 feet of soil) is typically targeted for access roads. Soil samples at the anticipated bearing layers of the solar modules (between 5 and 10 feet deep) will be collected to evaluate foundation conditions and soil strength. Samples collected during the investigation will be tested for engineering properties including compressive strength, Atterberg limits, grain size, moisture content, and compaction. Based on the soil properties, geotechnical analyses will be used to calculate bearing capacity for proper foundation and access road design.

The foundations and structures will be designed to withstand high winds, snow loads, and earthquake shaking. The site may have multiple foundation types to match the ground conditions and type of mounting structure used. The embedment will be to a depth of approximately 8 feet. The foundation design will depend on the engineering soil properties as determined by the geotechnical engineering analysis.

4.0 Conclusions

Based on the information presented in this document, the project can be designed, constructed, and operated safely to minimize or avoid adverse geologic and soil impacts to the environment. The potential for soil erosion during project construction and operation is low and will be further minimized by adherence to an erosion control plan, BMPs, and the mitigation measures described above. Areas of vegetation removal due to construction activities will be reclaimed through reseeding of appropriate vegetation to protect against loss of soil to wind and water erosion. Site grading, roads, and stable cut slopes will be incorporated into final design to minimize or avoid potential impacts that could endanger the project. No direct impacts from geologic hazards such as landslides are anticipated from design, construction, and operation of the project.

5.0 References

Tabor, R.W., R.B. Waitt Jr., V.A. Frizzell Jr., D.A. Swanson, G.R. Byerly, and R.D. Bentley. 1982. Geologic Map of the Wenatchee 1:100,000 Quadrangle, Central Washington. U.S. Geological Survey Map I-1311.

U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS), Soil Survey Staff. 2009. Web Soil Survey. Available online at *http://websoilsurvey.nrcs.usda.gov/*. Accessed December 2009.

U. S. Geological Survey (USGS). 2008. *Quaternary Fault and Fold Database*, *http://earthquake.usgs.gov/regional/qfaults/*. Accessed December 2009.

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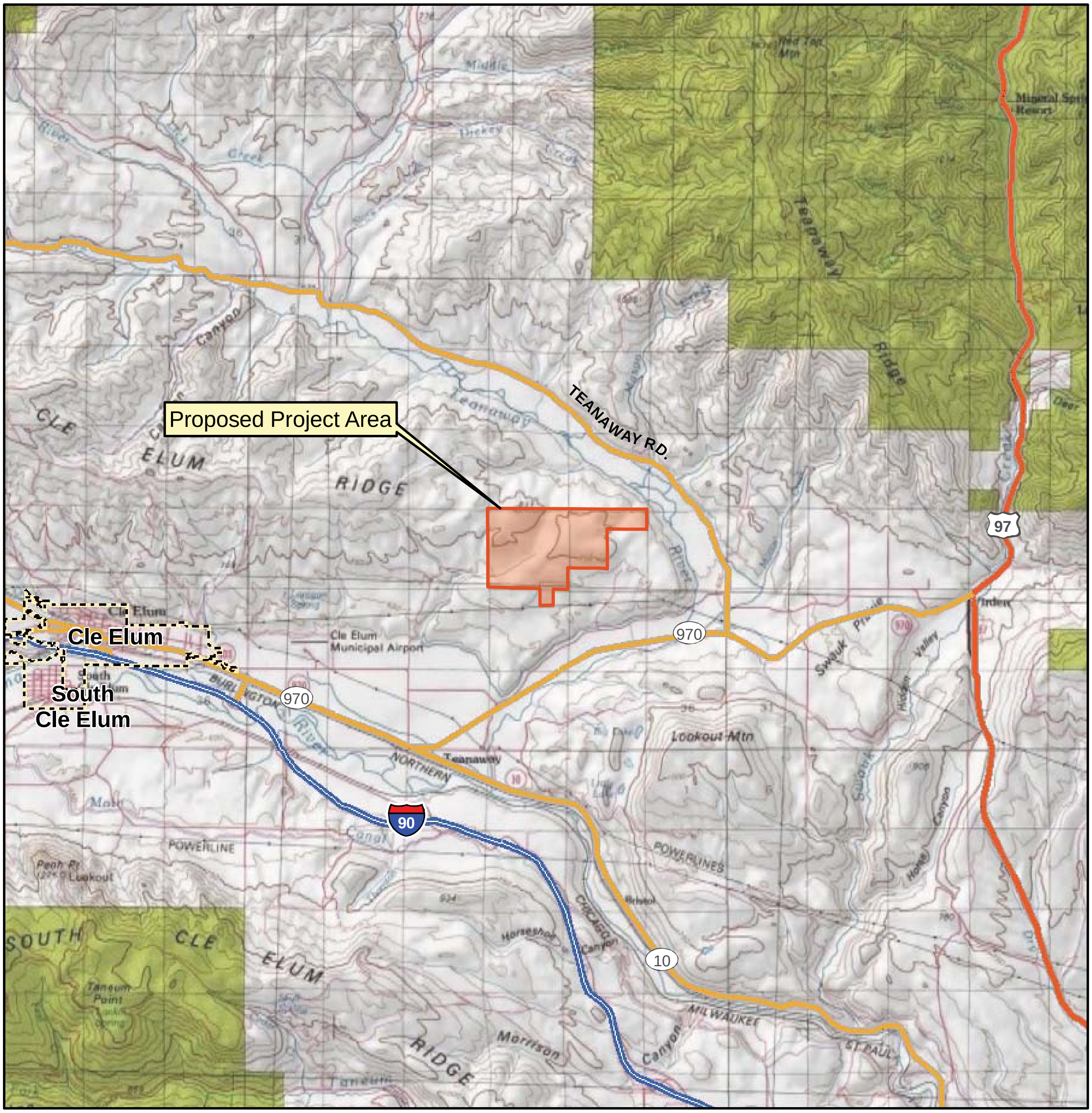
APPENDIX A
Figures

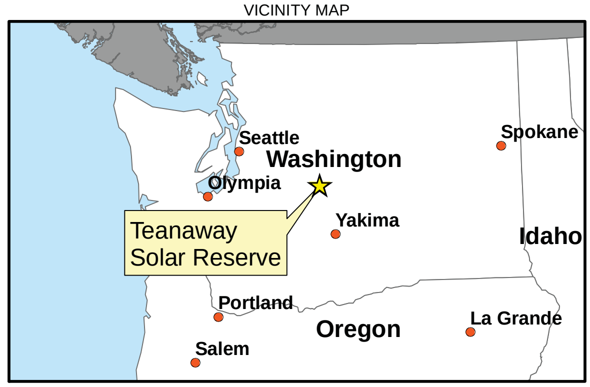


LEGEND

- Proposed Project Area
- City Boundary
- Interstate
- Highway
- Major Road

Note:
1. USGS 100K Quadrangle: Wenatchee.

VICINITY MAP

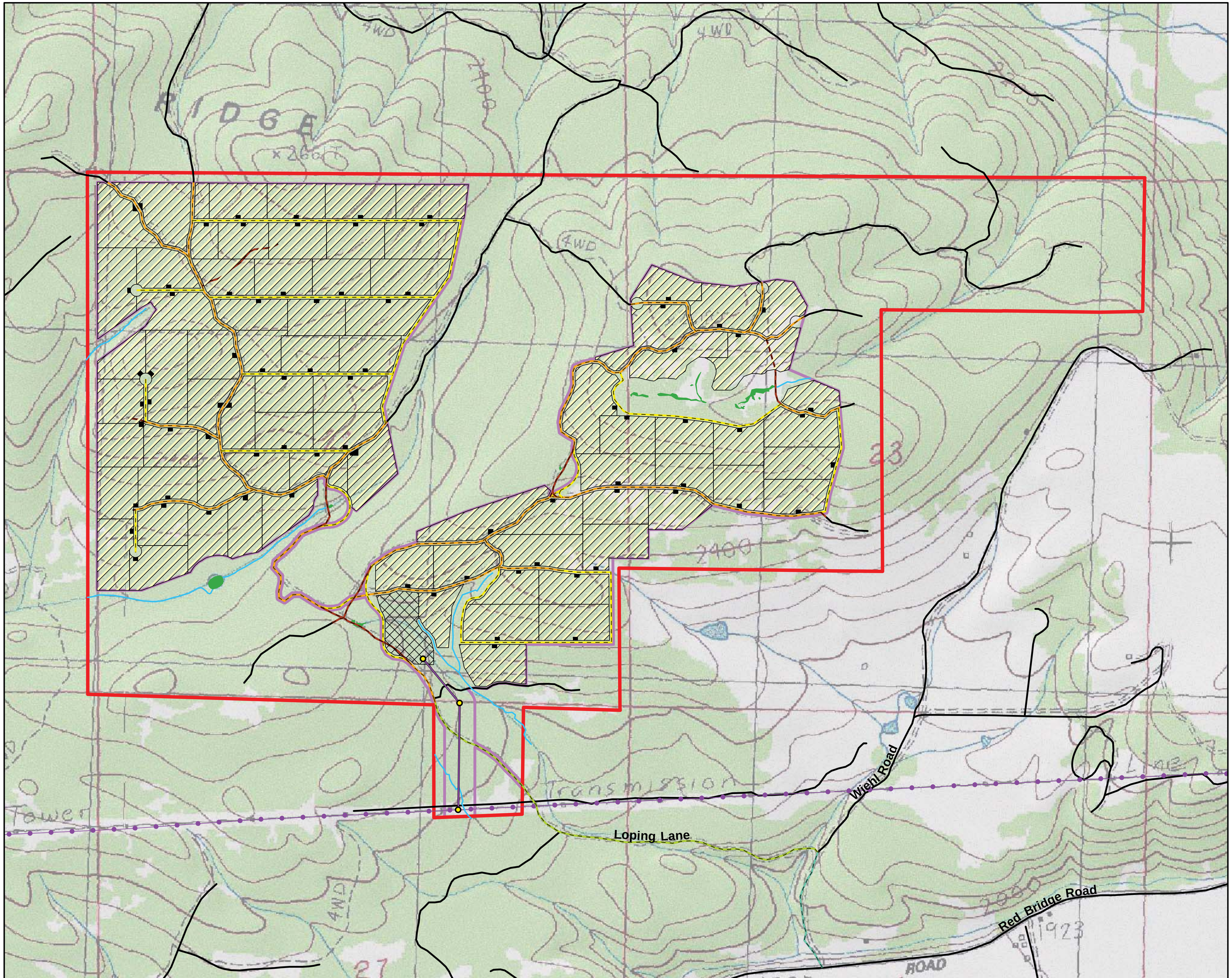


0 1 2
Miles

N

FIGURE 1
Vicinity Map
Geo Hazard Report
Teanaway Solar Reserve
Kittitas County, Washington

VICINITY MAP



LEGEND

Proposed Project Features

- Proposed Project Area (982 Acres)
- Proposed Project Site (477 acres)
- Proposed PV Array Block
- Proposed Field Inverter and Field Transformer
- Proposed Substation/O&M Facility
- Proposed Transmission Line
- Proposed Transmission Structure
- Proposed Maintenance Road
- Proposed Improved Maintenance Road
- Existing Maintenance Road (Planned Decommissioning)
- Proposed Improved County Access Road
- Proposed Improved Private Access Road

Existing Features

- Existing BPA Transmission Line and ROW
- Existing Road
- Stream
- Wetland

Note:
1. USGS 24K Quadrangle: Teanaway.

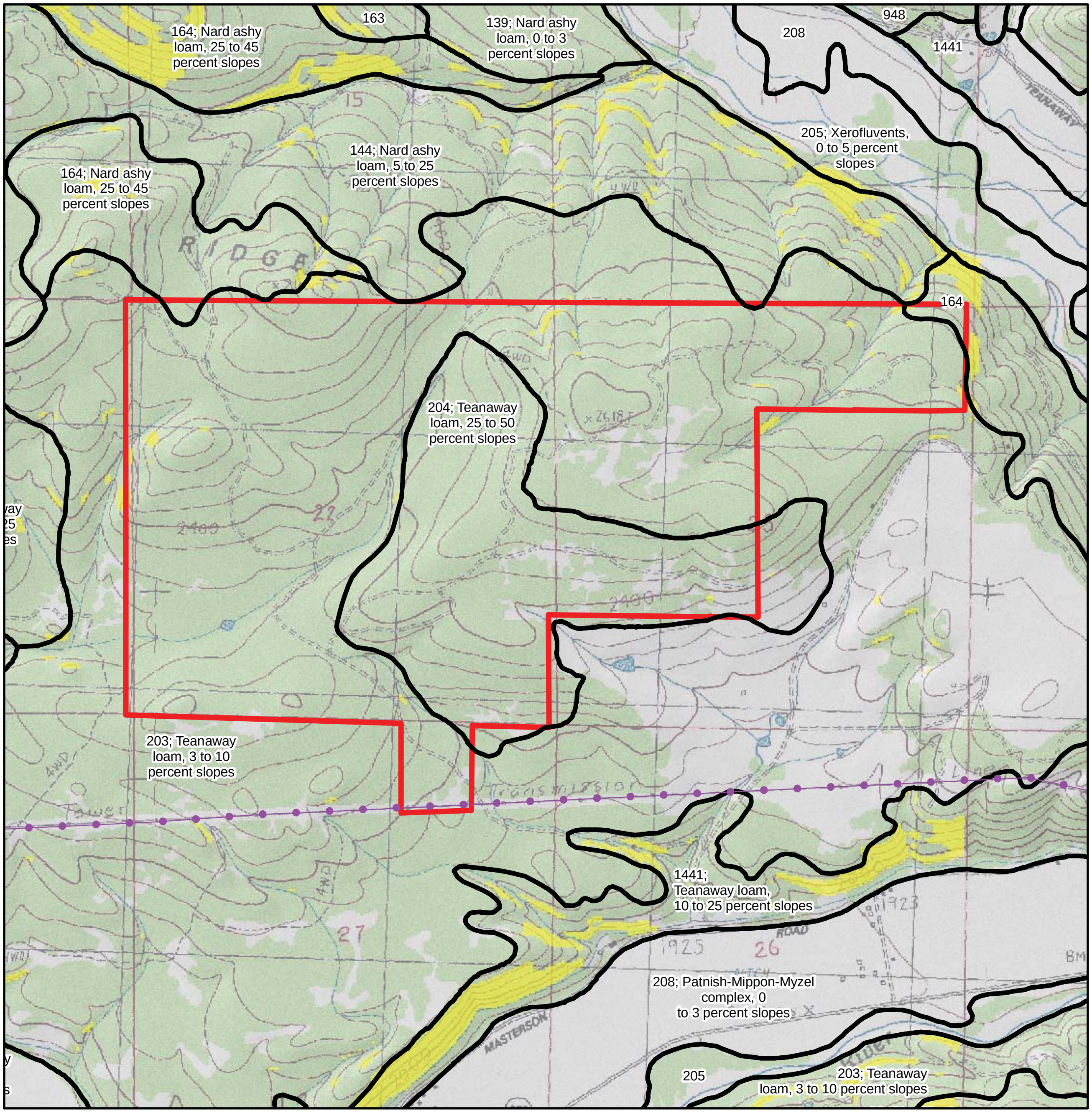
N

0 1,000
Feet

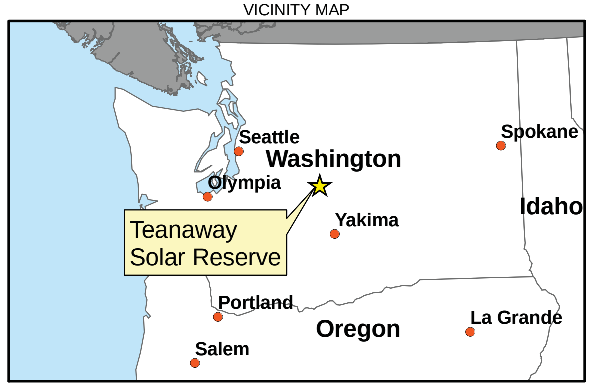
1 inch = 1,000 feet

FIGURE 2
Proposed Site Layout

Geo Hazard Report
Teanaway Solar Reserve
Kittitas County, Washington



VICINITY MAP



LEGEND

Proposed Project Area (982 Acres)

Existing BPA Transmission Line

Soil Unit

Slope

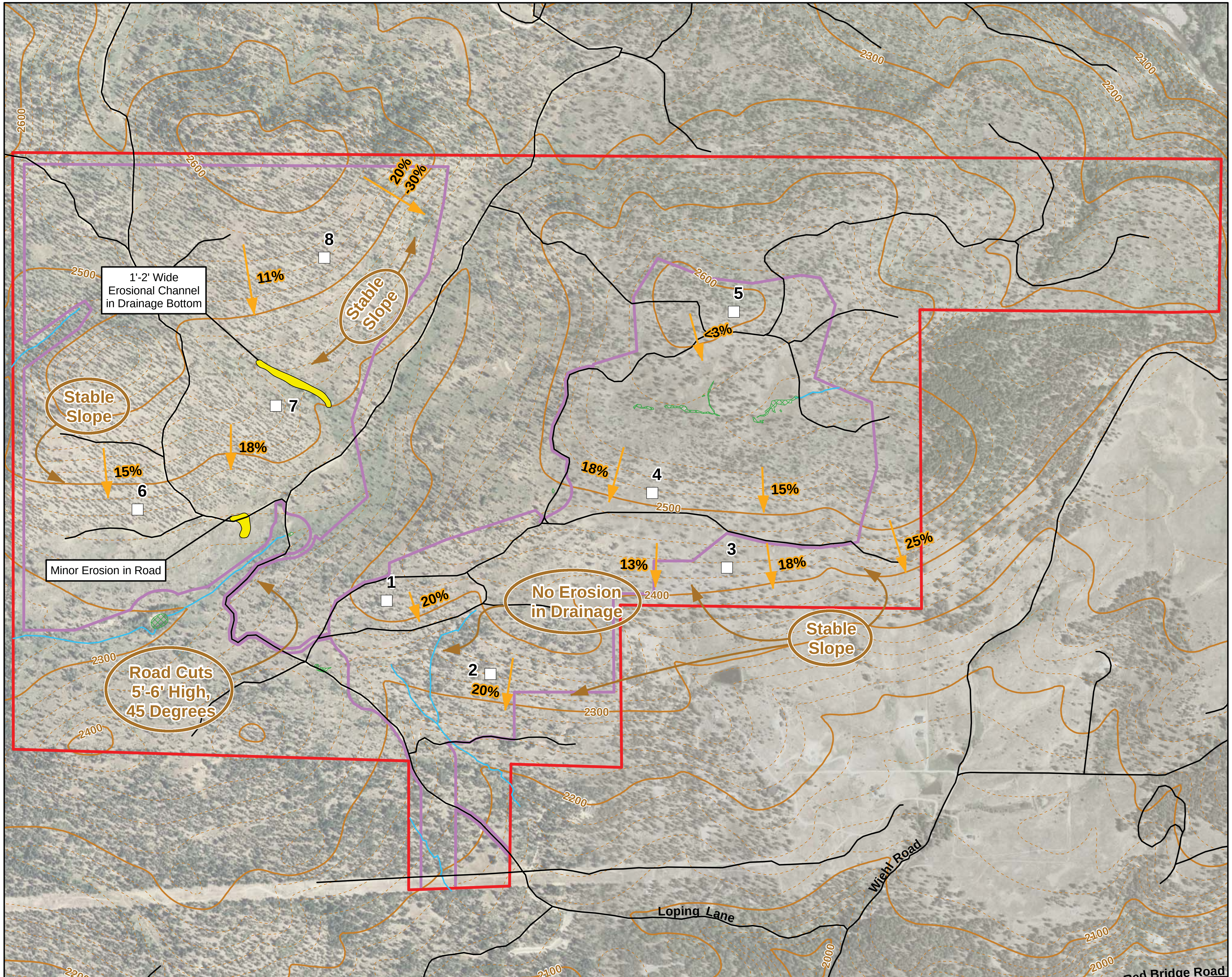
0 - 33% (not symbolized)

33%+

Notes:
1. USGS 24K Quadrangle: Teanaway.
2. Soils Data: Soil Survey Geographic (SSURGO) Database. MUSYM; MUNAME labeled.
3. Slope Date Derived from USGS 10m Digital Elevation Model

0 1,000 2,000
Feet
N

FIGURE 3
Soils & Slopes Map
Geo Hazard Report
Teanaway Solar Reserve
Kittitas County, Washington



VICINITY MAP

LEGEND

- Soil Sample Location
- Slope Angle Measured in Field
- Erosion Areas
- Stream
- Wetland
- Existing Road
- 20 Feet
- 100 Feet
- Proposed Project Area (982 Acres)
- Proposed Project Site (477 acres)

N

0 875
Feet
1 inch = 875 feet

FIGURE 4
Observed Geologic Features and Soil Sample Locations
Geo Hazard Report
Teanaway Solar Reserve
Kittitas County, Washington

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APPENDIX B

Photo Log

Photo 1: Stable slope and terrain, east side of proposed project facility location.

Photo 2: Minor rill erosion on existing unimproved road, east side of proposed project facility location.

Photo 3: Stable slopes and terrain, east side of proposed project facility location.

Photo 4: Stable slopes and terrain, east side of proposed project facility location.

Photo 5: Stable slopes and unimproved road on east side of proposed project facility location.

Photo 6: Drainage bottom, east of proposed project facility location. Note lack of erosion in drainage bottom.

Photo 7: Road cut between east and west portions of proposed project facility location. Note lack of erosion and stable cut slope.

Photo 8: Stable slopes and terrain, west side of proposed project facility location.

Photo 9: Stable slopes and terrain, west side of proposed project facility location.

Photo 10: Stable slopes and terrain, west side of proposed project facility location.

Photo 11: Minor rill erosion in existing unimproved road, west side of proposed project facility location.

Photo 12: Sediment transport at low road crossing on unimproved road.

Photo 13: Minor, inactive stream erosional channel, west side of proposed project facility location. Culverts will be placed where access roads cross drainages.