

# **EXHIBIT E – ENVIRONMENTAL REPORT**

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## **SUBPART E.6 GEOLOGY AND SOILS**

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### **SUBPART E.6 GEOLOGICAL AND SOIL RESOURCES**

#### **E.6.1 INTRODUCTION**

Section E.6.2 describes the regional geological setting, project geology and active mining operations. Soil resources are described in Section E.6.3, and geologic hazards are discussed in Section E.6.4. Direct and indirect project-related impacts on these resources are evaluated in Section E.6.5, and preservation, mitigation and enhancement measures are proposed in Section E.6.6. Some of this information was synthesized from reports and information available for this area. Additional information was gathered from surveys and studies conducted in consultation with applicable state and federal agencies in accordance with Title 18, Part 4, Section 41 of the Code of Federal Regulations (18 CFR 4.41): Application for Major Modified Project-Existing Dam.

#### **E.6.2 GEOLOGY**

##### **REGIONAL SETTING**

The complex structure and lithology along the Similkameen River above and below the Enloe impoundment reflect its position at the boundary of several distinct physiographic and lithological regions. The impoundment is located within the Cordilleran fold and thrust belt (Bayer 1983) of northwestern North America. In this region successive episodes of accretion, volcanic-arc mountain building, and back-arc deposition have created a complex physiography.

The Enloe impoundment is situated on the Similkameen River near the boundary of the Cascade Range and Columbia Mountains physiographic provinces where they converge around the 49th parallel, separating the Canadian Interior Plateaus from the Lava Plateaus of eastern Washington and Oregon, western Idaho, and northern California (Haugerud 2004).

The Similkameen River originates in Canada in the Kelowna Upland (Figure E.6-1). It connects below Palmer lake with drainage from Sinlahekin Creek on the northeast edge of the North Cascades, and cuts east through a narrow valley to the Okanogan River, which forms the western border of the Okanogan Highland (Haugerud 2004). The Kelowna Upland lies at the southern end of a wedge-shaped region of Tertiary Neogene volcanic and Triassic-Jurassic intrusive rocks (Reed et al. 2005). The Canadian Coast Mountains and the Cascade Range to the west of Similkameen are formed of Jurassic-

Cretaceous intrusive rocks, as are the Columbian Mountains and the Canadian Rockies to the east. Bedrock in the vicinity of the impoundment is a mosaic of the lithologies of the adjacent regions, mantled in many places by Quaternary glacial drift and colluvium (Stoffel 1990, Villalobos 1982).

### **E.6.3 PROJECT AND GEOLOGY**

Along the narrow valley section of the Similkameen River downstream of Palmer Lake and upstream of the Enloe impoundment, the uplands are composed primarily of Triassic-Permian metasedimentary and metavolcanic rocks of the Kobau Formation, interspersed with Jurassic metavolcanic, intrusive, and sedimentary rocks, Eocene conglomerate and Eocene intrusive dacite (Figure E.6-2). Much of the valley and sideslopes are mantled in Quaternary glacial drift. The complicated structure is the result of Late Triassic or Early Jurassic accretion of Paleozoic and Mesozoic volcanic archipelagos accompanied by regional metamorphism and plutonism, subsequent overlayering of Late Cretaceous and early Tertiary volcanic and sedimentary rocks, and Quaternary erosion and deposition resulting from continental glaciation (Stoffel 1990).

In the immediate vicinity of the impoundment, highly deformed Triassic/Permian metamorphic rocks of the Kobau and Spectacle Formations are unconformably overlain by Jurassic/Cretaceous metaconglomerate and metavolcanic rocks of the Ellemeham Formation. These are in turn are unconformably overlain by Eocene sandstone and conglomerate, and the latter are again unconformably overlain by Quaternary glacial drift, colluvium, and alluvial deposits (Villalobos 1982).

Within the impoundment itself, from Shanker's Bend downstream to approximately 1600 feet above the dam, the Similkameen River lies at the boundary of the Kobau and Ellemeham Formations; between 1600 feet above and 1000 feet below the dam the river flows over Eocene sandstone and conglomerate. Enloe Dam is located above the Similkameen Falls on resistant Eocene granitic-clast conglomerate. Downstream of the dam and falls the river again flows over Triassic/Permian metamorphic rocks of the Kobau and Spectacle Formations (Villalobos 1982).

[ Figure E.6-1 ]

[ Figure E.6-2 ]

Table E.6-1 lists the rock units within or adjacent to the FERC boundary and in the surrounding upland area. Rock units listed in **bold** type are located within or adjacent to the FERC boundary; descriptions of these lithologies are provided in Table E.6-1. Other rock units listed in the table have surface expression within the map area of Figure E.6-1, but not within or adjacent to the FERC boundary; only the formation names, if available, are provided for those rock units.

**Table E.6-1: Lithological Units in the Vicinity of the Enloe Impoundment**

<b>Map Symbol</b>	<b>Age/Lithology</b>	<b>Formation name and/or description</b>
<b>Qgd</b>	<b>Pleistocene continental drift, Fraser-age</b>	Unconsolidated glacial debris, including till, glaciofluvial sand and gravel, and glaciolacustrine silt and clay; fills valleys and mantles uplands throughout the map area; includes some colluvium on slopes and alluvium along valley-floors and floodplains.
<b>Ecg</b>	<b>Eocene continental sedimentary deposits or rocks, conglomerate</b>	Conglomerate, feldspathic sandstone, and siltstone, and shale that form the basal unit of Eocene strata in the map area. The thickest section of these sedimentary rocks is located northwest of Oroville. The sedimentary rocks unconformably overlie metasedimentary, metamorphic, and igneous rocks, and are conformably overlain by and locally grade into volcanoclastic rocks and tuff. Typical conglomerate consists of subrounded to rounded metamorphic clasts in a poorly-sorted sandy matrix. Most clasts are 1-2 cm in diameter, but boulders up to 1 m diameter are present.
Eida	Eocene intrusive dacite	--
KJii(s)	Cretaceous-Jurassic intermediate intrusive rocks	Silver Nail Lake pluton
Jcg(e)	Jurassic continental sedimentary deposits or rocks, conglomerate	--
Jik(sb)	Jurassic alkalic intrusive rocks	alkalic complex of Shanker's Bend
<b>Jmv(e)</b>	<b>Jurassic metavolcanic rocks</b>	Ellemeham Formation; interbedded metavolcanic massive greenstone and thinly laminated metasilstone. Primary minerals and textures are only locally preserved in the aphanitic greenstone. Vesicles, amygdules, and crude pillow structures indicate that some of the greenstone represents lava flows, but remnant clastic textures and bedding suggest that some was originally tuff. Weak schistosity is locally developed in the greenstone.
TRPMib	Triassic-Permian basic intrusive rocks	--
<b>TRPMmt(k)</b>	<b>Triassic-Permian metasedimentary and metavolcanic rocks</b>	Kobau Formation; layered sequence of phyllite, greenstone, and quartzite (metachert); Magnesitic metadolomite and serpentinite form discontinuous lenses along the Similkameen River.
PMmm(s)	Permian marine metasedimentary rocks	Spectacle Formation, Anarchist Group

Data Source: Stoffel 1990.

## ACTIVE MINING OPERATIONS

According to the Directory of Washington Mines (2001), the only active mine or quarry is located approximately 3.5 miles southeast of the southernmost portion of the FERC boundary. The Oroville mine/quarry is operated by North Central Construction and recovers sand and gravel.

Additionally, small-scale gold dredging operations are conducted in the Similkameen River in the study area as documented by recreational surveys (see Exhibit E.7) and Ecology (2005). Hobby dredging has been traditionally allowed under mineral prospecting leases from the WDNR. Although there is no accurate count of these dredging operations, Ecology's Central Regional Office has observed as many as 20 dredges on the river at once (Ecology, 2005). Dredging operations are not continuously operated, though several may be in operation simultaneously. Though there are no restrictions placed on where dredging may be done in the river, the dredging season is limited to July 1 through September 30.

Additional information regarding historical mining operations and impacts on the Similkameen River can be found in Ecology's Total Maximum Daily Load (TMDL) evaluation for arsenic (Johnson 2002) and Draft Implementation Plan (Water Cleanup Plan) (Peterschmidt 2005).

### E.6.4 SOILS

Most of the soils present within or adjacent to the FERC boundary are classified as Nighthawk loam or Nighthawk extremely stony loam. Ewall loamy fine sand and Lithic Xerochrepts – Nighthawk complex soils and riverwash and rock outcrop areas are also present within or adjacent to the FERC boundary in the study area.

Nighthawk loam soils are formed in glacial till deposited over shale and are present just upstream of the dam and upstream of Shanker's Bend. These soils are deep and well-drained. Nighthawk loam soils with 3 to 8 percent slopes (map symbol 131) are characterized by slow runoff and present a slight erosion hazard. Nighthawk loam soils with 8 to 15 percent slopes (132) are characterized by medium runoff and present a moderate erosion hazard.

Nighthawk extremely stony loam soils are generally formed in glacial till and are located adjacent to the dam and powerhouse and a portion of Shanker's Bend. These soils are deep and well-drained. Nighthawk extremely stony loam soils with 8 to 25 percent slopes (134) are characterized by medium runoff and present a high to very high erosion hazard. When slopes reach 25 to 65 percent (135) these soils are characterized by rapid to very rapid runoff and present a high to very high erosion hazard.

Ewall loamy fine sand soils are formed in glacial outwash sand and are located in a small area immediately downstream of Shanker's Bend. These soils are deep and excessively drained. Ewall loamy fine sand soils with 0 to 15 percent slopes (53) are characterized by slow runoff, and present a slight erosion hazard and a high soil-blowing hazard.

Lithic Xerochrepts soils are generally shallow and well-drained and are located downstream of the dam in the study area. Lithic Xerochrepts-Nighthawk complex soils with 15 to 45 percent slopes (93) are characterized by medium runoff and present a moderate erosion hazard.

Areas classified as riverwash and rock outcrops are also present within or adjacent to the FERC boundary. Riverwash (161) consists of coarse sand and gravelly alluvium. Rock outcrop areas (162) contain little or no shallow soil material.

Table E.6-2 lists the soils within or adjacent to the FERC boundary and in the surrounding area. Soils listed in **bold** type are those that are present within or adjacent to the FERC boundary in the study area. All other soils are present in the upland or surrounding areas (Figure E.6-3). The code numbers in Table E.6-2 and on Figure E.6-3 refer to Natural Resource Conservation Service (NRCS) designations and are taken from the Soil Survey of Okanogan County Area, Washington (NRCS 2007). Detailed soil characteristics including selected physical properties, chemical properties, and soil features are presented in Appendix E.6.1.

**Table E.6-2: Soil Units in the Vicinity of the Enloe Impoundment**

<b>Map Symbol</b>	<b>Soil Type/Map Unit Name</b>	<b>Map Symbol</b>	<b>Soil Type/Map Unit Name</b>
4	Badland	134	<b>Nighthawk extremely stony loam, 8 to 25 percent slopes</b>
26	Concully gravelly sandy loam, 8 to 25 percent slopes	135	<b>Nighthawk extremely stony loam, 25 to 65 percent slopes</b>
53	<b>Ewall loamy fine sand, 0 to 15 percent slopes</b>	136	Nighthawk extremely stony loam, 25 to 65 percent slopes
93	<b>Lithic Xerochrepts-Nighthawk complex, 15 to 45 percent slopes</b>	145	Pogue fine sandy loam, 0 to 3 percent slopes
95	Lithic Xerochrepts-Vallan complex, 15 to 45 percent slopes	151	Pogue extremely stony fine sandy loam, 0 to 25 percent slopes
122	Newbon loam, 3 to 8 percent slopes	152	Pogue extremely stony fine sandy loam, 25 to 65 percent slopes
124	Newbon loam, 15 to 25 percent slopes	161	<b>Riverwash</b>
125	Newbon gravelly loam, 0 to 8 percent slopes	162	<b>Rock outcrop</b>
130	Newbon extremely stony loam, 0 to 45 percent slopes	173	Tonasket silt loam, 0 to 3 percent slopes
131	<b>Nighthawk loam, 3 to 8 percent slopes</b>	174	Tonasket silt loam, 3 to 8 percent slopes
132	<b>Nighthawk loam, 8 to 15 percent slopes</b>	175	Tonasket silt loam, 8 to 15 percent slopes
133	Nighthawk loam, 15 to 25 percent slopes	177	Tonasket silt loam, 25 to 45 percent slopes

Data Sources: NRCS SSURGO database; SCS 1980.

[ Figure E.6-3 ]

### **E.6.5 GEOLOGIC HAZARDS**

The Enloe impoundment is located in an area of historically low seismicity. Peak ground acceleration with a 2 percent probability of occurrence in 50 years is approximately 0.16 g, and peak ground acceleration with a 10 percent probability of occurrence in 50 years is approximately 0.07 g (USGS 2002). Localized faults have been mapped in upland areas adjacent to the Similkameen valley (Stoffel 1990). An inactive fault is presenting the conglomerate bedrock approximately 100 feet downstream of the proposed tailrace outlet (Villalobos 1982). The fault does not displace overlying glacial drift, which indicates that it has not been active in over 10,000 years.

No significant historical earthquakes (magnitude 5.5 or intensity VI or larger) have been recorded within 50 miles of the dam site since 1568. (USGS-NEIC 2007a,b). The impoundment area was designated “Zone 2 – Moderate Damage” under the Uniform Building Code, and a less conservative designation of “Zone 1 – Minor Damage” has been given to the project site on the basis of regional intensity records (Rasmussen, 1967).

There are no karst-forming limestone deposits in the vicinity of the Project Area, so the presence of solution cavities is highly unlikely, and there is minimal likelihood of subsidence. Although joints are common in the Permian/Triassic metamorphic rocks that underlie the middle section of the impoundment, they are not common in the Tertiary conglomerate upon which the dam and proposed power-generation facilities are located (Villalobos 1982). During geological field mapping conducted in December of 2006, some seepage was detected along joints and bedding planes in the conglomerate and sandstone that forms the east abutment of the dam (Christensen Associates 2007). These areas would be grouted and stabilized during the construction of proposed facilities.

There is potential for landsliding and soil erosion both from the uplands and along the banks of the Similkameen River. Based on field survey and review comparing aerial photographs from 1953 and 2000, 14 separate upland sediment sources in the study area were identified. These sources include badlands, gullies, streambeds (wet or dry), and minor landslides. These features are shown in Figures 1A – 1D of the Bank Erosion Assessment Technical Report (Appendix E.6.2).

Some of the soils present adjacent to the Similkameen River present high to very high erosion potential. Nighthawk extremely stony loam soils that occur on slopes in excess of 8 percent (134 and 135) have a high to very high erosion hazard. Badland areas (4) also have a very high erosion hazard. Nighthawk extremely stony loam soils are present upstream of Shanker’s Bend, adjacent to portions of Shanker’s Bend, and on either side of the river adjacent to the dam, and proposed intake location. Landslide or mass wasting hazards are most likely to occur in these areas, however no signs of recent

instability were noted during December 2006 geological field investigations (Christensen Associates 2007).

### **E.6.6 PROJECT-RELATED IMPACTS**

Facilities proposed in this license application include new crest gates on Enloe Dam, a new east-bank approach channel, intake structure, intake canal, penstock intake, twin penstocks, powerhouse, tailrace channel, and a short section of new road. Construction and operation of the proposed facilities is expected to have minor impacts on geology and soils in the Project Area.

Where new facilities are to be constructed, soils will be permanently displaced, and there may be a temporary increase in soil erosion during construction. The greatest impact will result from the construction of the new intake channel and penstocks; bedrock and soils will be permanently displaced from the location of those structures. All of the proposed facilities are located within the area of Nighthawk extremely stony loam soil overlying horizontally-bedded Triassic conglomerate bedrock. Facility-specific impacts are discussed below:

- Crest gates – The crest gates will be retrofitted to the existing dam structure; no impacts to geology or soils are expected.
- Approach-channel, intake structure, intake canal, and penstock intake – Soils and bedrock will be permanently displaced from the location of these facilities. The volume of excavation is expected to be around 11,000 cubic yards. Nighthawk extremely stony loam has a high to very high erosion hazard rating, so erosion potential during construction is a concern; mitigation measures may include the installation of silt-fences, check-dams, and/or geotextile surface protection. A detailed Erosion and Sediment Control plan will be prepared as part of final design. Excavated materials will be disposed of in accord with permit requirements, and the District will comply with all regulatory requirements applicable to sediment removed by project construction and operations.
- Penstocks – The steel penstocks will be located above-ground, but there will be minor excavation of soils and bedrock where concrete saddles and anchor-blocks are located.
- Powerhouse – Construction of the powerhouse will require the excavation of approximately 2300 cubic yards of rock and soil.
- Tailrace channel – After the surface layer of soil is removed, the tailrace will be excavated in bedrock using controlled blasting techniques. Approximately 5300 cubic yards of rock and soil will be excavated.

- Road improvement and rehabilitation – of the OTID Ditch Road, together with associated culverts, as described in Exhibit A will require minor amounts of cut and fill. In total, approximately 110,000 square feet of soil would be permanently covered by the new section of road.

Proposed operation of the Enloe Hydroelectric Project will extend the period during which the reservoir inundates land to the ordinary high water mark. Although saturating the toe of slopes this could create minor bank instabilities around the impoundment, banks erosion has already occurred and a stony surface armor has developed along much of the shoreline (HDR 1991). The proposed water-surface elevation increase is within the historical range of variability in April, May and June (which created impoundment elevation increases of 0.5, 2.7 and 3.0 feet, respectively, above the median flow condition). Any slopes that could not withstand saturation are likely to have already failed.

Evidence of relatively large slips caused by toe-slope undercutting has been noted downstream of the dam (HDR 1991). The proposed run-of-the-river operation will not affect the timing or volume of flows downstream of the dam, and so is expected to have no influence on slope- or bank-stability in downstream reaches. Construction and operation of the proposed project is not expected to affect the likelihood of earthquakes, landslides, subsidence, or other geological hazards.

### **E.6.7 PROTECTION, MITIGATION & ENHANCEMENT MEASURES**

A summary of Project PM&Es is provided in Appendix D.1.

#### **ISSUE: EROSION MAY OCCUR DURING CONSTRUCTION**

##### **Potential Impact**

Soils may be eroded where vegetation is removed and heavy construction equipment operates.

##### **Proposed PM&Es WQ 06 – Erosion and Sediment Control Plan and WQ 08 – Construction Sediment Management Program**

Please refer to Exhibit E.2, Section E.2.8 and Appendix E.6.4 for discussion and costs of the PM&Es related to erosion control.

##### **Expected Outcome**

Implementation of erosion BMPs will avoid discharges of sediment-laden water during Project construction that would violate criteria.

### **E.6.8 CONSULTATION SUMMARY**

Consultation conducted for geological and soils resources focused on sediment trapped behind Enloe Dam, and was largely concerned with potential contaminants deposited in the sediments and the potential for mobilization of such contaminants during Project construction and operations. Inasmuch as this focus shared common ground with water quality issues and was of concern to the same agencies and tribes, consultation for the two issues was conducted together, and is summarized in Exhibit E.2, Section E.2.7.