Section 3.1 Earth

The following sections describe the geology, geologic hazards, soils, topography, unique physical features, and erosion/enlargement of land area at the project site. Existing conditions, potential impacts, and, where appropriate, mitigation measures are discussed below. This section provides additional background detail related to the geology of the site to support section 2.18 that addresses how the project will be protected from earthquakes and volcanic eruptions.

Site-specific measures have been identified to mitigate potential hazards. With standard and site-specific mitigation measures, impacts on the natural earth environment from the construction and operation of the Facility are expected to be minor.

3.1.1 Methodology

The assessment of the geology of the project study area was completed by first reviewing previously completed geotechnical studies on and near the proposed project site, followed by field explorations. Field explorations of subsurface materials and conditions included 25 borings and six cone penetration test probes. An experienced geotechnical engineer from GRI directed the drilling and maintained a detailed log of the materials and conditions disclosed during the course of the work. The results of the review of previously completed studies, field explorations, and mitigation recommendations will be included in the final geotechnical report anticipated to be completed in September 2013.

3.1.2 Geology

The site is situated in the Portland Basin area of the Willamette Lowland geomorphic province. The site is located on the North American continental tectonic plate near a convergent plate boundary with the Juan de Fuca oceanic tectonic plate. The offshore CSZ is the contact area of these two converging plates. The convergent tectonic forces have generated northwest-trending fault zones and crustal blocks (Orr and Orr 1999) resulting in areas of uplifted mountainous terrain and depressed structural basins.

The Portland Basin is a northwest-elongated structural basin bordered to the east by the foothills of the Cascade Mountains, to the west by the Tualatin Mountains, to the south by the Clackamas River, and to the north by the Lewis River (Evarts et al. 2009). The Portland Basin began to form about 20 million years ago with folding and uplift of Tertiary basement marine and volcanic rocks, and was subsequently filled with volcanic and sedimentary rocks. About 15 to 16 million years ago, flood-basalt flows of the Columbia River Basalt Group (CRBG) entered the basin through a broad Columbia River valley transecting the Cascade Range and emptying into the Pacific Ocean (Beeson et al. 1989). The CRBG consists of numerous dark gray to black, dense, crystalline basalt lava flows which cover approximately 63,000 square miles and extend to thicknesses greater than 6,000 feet. By 14 million years ago, the uplift of the Portland Hills diverted the Columbia River northward (Evart et al. 2009).

The Columbia River deposited up to 600 feet of fine-grained river and lake sediments that compose the Sandy River Mudstone into the subsiding Portland Basin (Trimble 1963). Sandy River Mudstone is poorly cemented siltstone, sandstone, and claystone. Overlaying the Sandy River Mudstone is up to 600 feet of consolidated and cemented sandstone and conglomerate of the Troutdale Formation (Tolan and Beeson 1984). The Troutdale Formation resulted from a high-energy braided river system (Evarts et al. 2009) that was eroded during the last ice age by the ancestral Columbia and Willamette rivers and by catastrophic glacial outburst floods (Allen et al. 2009). Glacial outburst floodwaters from Montana washed across eastern Washington and through the Columbia River Gorge to spread out in the Portland Basin and pool to elevations of about 400 feet, depositing boulders, cobbles and gravel sediment grading to thick blankets of micaceous sand. This deposit is subdivided into two facies by Madin (1994) and Phillips (1987): a fine-grained facies (Qff) that consists of primarily coarse sand to silt and coarse-grained facies (Qfc) that consists of pebble to boulder gravel with a coarse sand to silt matrix. The sea level rose by about 300 feet after the last of the glacial outburst floods about 15,000 years ago, forming an estuary environment that extends far upstream in the Columbia River. These low energy environments rapidly filled with Holocene sandy alluvium and broad floodplains developed along the primary Columbia River channel (Peterson et al. 2011) (see Figure 3.1-1).

At the Facility, fill material, consisting primarily of sand and silt, was placed to modify the site for industrial use. Much of this material was derived from suction dredging techniques where Columbia River channel sand was piped on shore for dewatering and grading. This fill material mantles the project site and is common in the historically industrial developed areas in the vicinity.

3.1.2.1 Impacts

The primary impacts of the project on geologic conditions and materials at the site are on the foundation construction, excavation, grading, trenching, backfill, ~~and~~ compaction and subsurface soil improvements associated with site development. The impacts generally will be limited to shallow soil at the site as the proposed excavations, utilities, and structures generally will not exceed 20 feet in depth. However, the results of preliminary geotechnical investigation conducted at the site have determined that site improvements will be required to mitigate static and seismic settlement and lateral deformations as addressed in Appendix L, Geotechnical Investigation.

3.1.2.2 Mitigation

The project will have no adverse impacts on geologic conditions at the site and mitigation is not considered necessary for impacts to geology. While the project will not adversely impact geologic conditions at the Facility, the project has been designed to meet all applicable requirements and codes based on the seismic and soil conditions of the site as described in further detail in sections 3.1.3 and 3.1.4 below.

3.1.3 Seismicity

As previously discussed in section 2.18 of this application, the project is located in a regional tectonic regime that is capable of producing earthquakes of magnitude (M) 9 or greater (Atwater 2005). The convergence of the Juan de Fuca and the North American tectonic plates results in folding and faulting of rocks where sudden movement along faults generate strong ground motions. The general lack of surface expressions of faults, faults buried under hundreds of feet of recent alluvial deposits, and the limited 150-year recorded history of earthquakes in the area make it difficult to estimate the occurrence, magnitude, and frequency of earthquakes. However, an estimate of the maximum plausible earthquake magnitude can be made based on several seismicity studies (Bott and Wong 1993; Mabey, Black, Madin et al. 1997; Mabey, Madin, and Palmer 1994; Mabey, Madin, Youd et al. 1993; Atwater and Hemphill-Haley 1997; Wong et al. 2000; Pratt et al. 2001; Palmer et al. 2004).

Table 3.1-1.Possible Earthquake Sources

Earthquake Source	USGS Fault No.	Distance from Project Site (km)[a,c]	Magnitude Max (M)[a]	Length (km)[a]	Dip Angle [a,b,c]	Slip Rate (mm/yr)	Most Recent Deformation (years ago) [b,c]
Cascadia Subduction	781	100-200	9.0	1,100	9°-11°E	>5	300 yr
Intraplate	--	40-60	7.5	~1,000	>9°E	>5	>150 yr
Portland Hills Fault	877	6	6.6-7.1	49	70°SW	<0.2	<1.6 m.yr
East Bank Fault	876	4	6.8-7.1	29	70°NE	<0.2	<15 k.yr
Lacamas Lake Fault	880	11	6.5-6.9	24	>75° SW	<0.2	<750 k.yr

a Wong et al., 2000.
b Gregor et al., 2002.
c Personius et al., 2003, information is approximate.
km = kilometer
mm = millimeter
yr = year
m.yr = million years
k.yr = thousand years

3.1.3.4 Volcanic Eruptions

As stated above in section 2.18.3, volcanoes in the region pose a variety of eruptive hazards. Volcanoes of the Cascade Mountains are found from northern California to British Columbia. Mount St. Helens and Mount Hood are located within 50 miles of the project, located to the northeast and southeast of the project site, respectively. Mount St. Helens is capable of producing eruptions of ash, lava flows, pyroclastic flows, and lahars (Wolfe and Pierson 1995). However, the site is upstream of drainages that extend from the flank of Mount St. Helens and would not be subject to pyroclastic flows or lahars.

3.1.3.5 Impacts

The potential impacts of earthquakes and seismicity include fault rupture, ground motion, soil liquefaction, lateral spreading, and volcanic eruptions. Active faults have not been identified at the project site (see Figure 3.1-3). Surface fault rupture is not considered a potential impact. The potential ground motion during an earthquake event is generally represented by horizontal PGA estimated to range from 0.2 g (9.81m/s^2 [g-force]) to approximately 0.42 g in the vicinity of the project site (Figure 3.1-4). Ground motion can also cause soil to lose strength as the seismic waves allow the collapse of soil pore space. As pore space is decreased, pore water pressure increases and the liquefiable soil layers behave more like a viscous fluid during ground shaking. As a result, there is an increased risk of settlement and the loss of some bearing capacity for both shallow and deep foundations when soil liquefaction occurs. Structures can be adversely affected by liquefaction-induced settlement and reduced bearing capacity. Lateral spreading can occur during ground shaking as blocks of soil move horizontally toward unsupported banks such as the Columbia River. The site is located in a high liquefaction-susceptible soil area (Palmer et al. 2004) (Figure 3.1-5).

As illustrated in Figure 3.1-6, the USGS estimates that there is between a 0.01 and 0.02 percent annual probability that ~~there would~~ 4 inches or more of ash ~~will~~ would be deposited at the site from eruptions throughout the Cascade Range, with the highest probability resulting from~~. Most Cascade Range contribution in the analysis is from~~ Mount St. Helens (Wolfe and Pierson 1995). However, based on the distance and activity level of nearby volcanoes to the project site, there is a low potential for damaging volcanic processes to reach the project, and these events would be considered extremely rare.

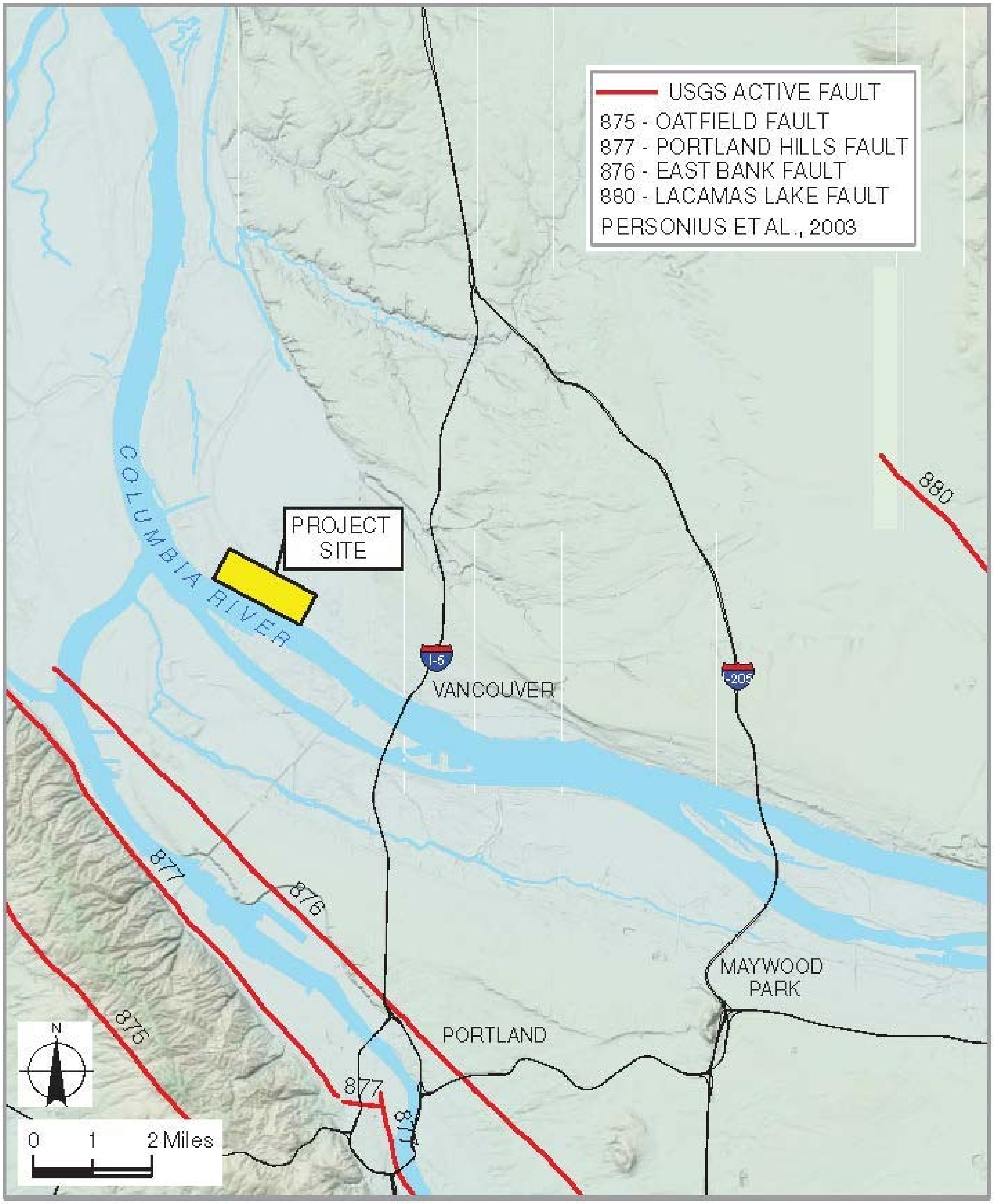

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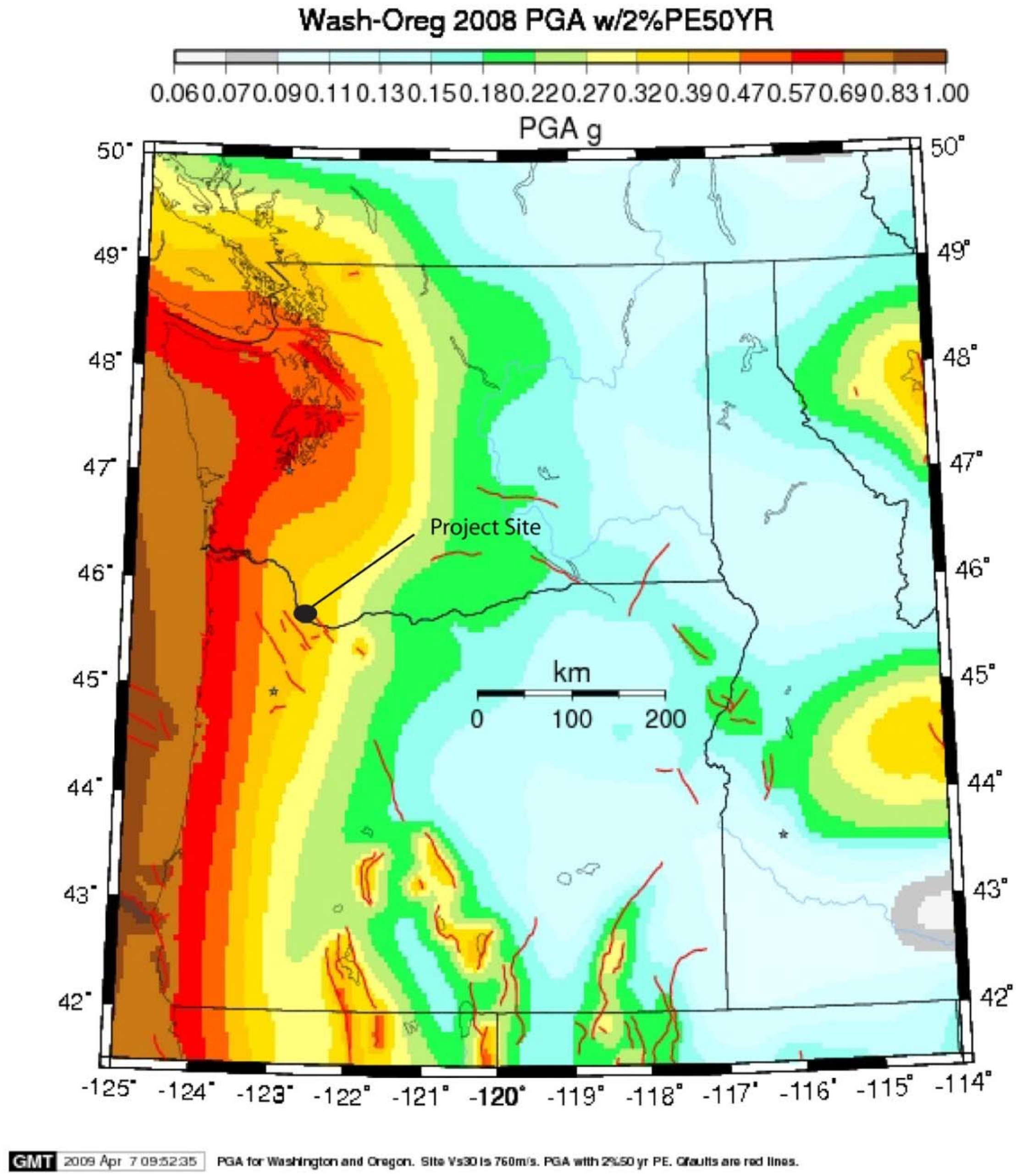
Figure 3.1-3. Local Fault Map (Revised)



DATA FROM 2008 U.S. Geological Survey
National Seismic Hazard Maps

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3.1.6 Unique Physical Features

The project site is relatively flat, and was the location of historical industrial activities, and nearly all of the surface area of the site has been modified significantly. Therefore, unique physical features are not present at the site.

3.1.6.1 Impacts

Because there are no unique physical features, at the site, there will be no impacts to unique physical features.

3.1.6.2 Mitigation

No mitigation efforts are anticipated.

3.1.7 Erosion/Enlargement of Land Area (Accretion)

Erosion is the breakdown and transport of soils and bedrock by chemical and mechanical processes. The susceptibility of a soil to erosion is based on its properties, the ground slope; and the effects of rainfall, surface water, wind, and vegetation cover. These features are identified by NRCS and used in the determination of potential soil erosion susceptibility. As noted in section 3.1.4 above, the on-site soils have a low to slight erosion hazard, except in cases where flooding may occur. Erosion can occur along unprotected portions of the riverbank of the Columbia River, particularly during periods of elevated river levels. The riverbank slope at the docks is currently protected with riprap.

Enlargement of land area or accretion includes the deposition, or change of land surface, shoreline, beach, or submarine area due to project-related activities. The project does not include plans for increased land area. Excess soils may be generated due to removal of unsuitable soils during unloading trench excavation and piping trenches and placement of base coarse or structural fill. These soils may be disposed of off site at a suitable facility or reused at other locations on site where appropriate. Structural fill may also be necessary to level the ground surface in various areas of the site. In addition, material will be required for construction of the containment berm for the tank farm.

3.1.7.1 Impacts

Project activities, including excavation, grading and fill placement, and temporary stockpiling of excess soils for construction, may disturb soils resulting in a localized increase in soil erosion susceptibility. Proposed modifications of the marine terminal area will include in-water and over-water construction activities~~ for the installation of mooring dolphins, dock platforms, walkways, and steel piles~~. In-water work may result in the disturbance of riverbed soils that could suspend soils within the water column and lead to increased turbidity. Other work activities proposed for Area 400 will occur above the OHWM and include the construction of the MVCU, control room, maintenance parking area, and transfer pipeline. Construction in these areas may disturb soils and could lead to potential soil erosion. The project will not significantly impact the potential for erosion along the riverbank.

3.1.7.2 Mitigation

The potential erosion impacts will be minimized through the use of erosion and sedimentation control measures outlined in the preliminary SWPPP (Appendix C) and as described in section 2.11 of this application, which states that construction activities will be sequenced and controlled to limit erosion. Clearing, excavation, and grading will be limited to the areas necessary to construct the Facility. Interim surface protection measures, including dust control, straw matting, and erosion control blankets, will be required to prevent erosion. Final surface restoration will be completed within 14 days of an area’s final disturbance. All construction practices will emphasize erosion control over sediment control. Temporary cutoff swales and ditches will be installed to route stormwater to the appropriate sediment trap and discharge location. As identified above in section 3.1.4, soils found on the site are classified as having little to no erosion hazard.