3.1 Earth

Earth refers to the soil and geology conditions in a particular area. Soils and geology are resources if the defining characteristics (such as soil structure, composition, or geologic formations) are unique or valuable or support unique habitats. Soils and geology can also influence the potential for geologic hazards, such as landslides, earthquakes, seismic effects (e.g., surface fault ruptures, strong ground shaking, liquefaction, lifting and lowering of the surface, and tsunamis), and volcanic activity. Understanding the types of soils and the underlying geologic conditions is important in determining whether a project would be exposed to increased risks related to these conditions.

This section describes earth resources in the study area, including geology and soils and geologic hazards. It then describes impacts on geology and soils that could result under the no-action alternative or as a result of the construction and routine operation[1] of the proposed action. Finally, this section presents any measures identified to mitigate impacts of the proposed action and any unavoidable and significant adverse impacts.

3.1.1 What is the study area for earth resources and conditions?

The study area for earth resources consists of geology and soils on and near the project site that could be affected by construction and routine operation of the proposed action. The study area also includes geology and soils that could be affected during routine rail transport along the Puget Sound & Pacific Railroad (PS&P)[2] rail line and vessel transport through Grays Harbor out to 3 nautical miles from the mouth of the harbor.

The study area includes the broader geologic conditions that could affect the project site and the rail and vessel transportation systems. These broader conditions include the potential for geologic hazards (e.g., landslides, earthquakes, seismic-related events, and volcanic activity).

3.1.2 What laws and regulations apply to earth resources and conditions?

Laws and regulations for determining potential impacts on earth resources are summarized in Table 3.1-1. More information about these laws and regulations is provided in Appendix B, *Laws and Regulations*.

[1] Chapter 4, *Environmental Health and Safety*, addresses the potential impacts from increased risk of accidents (e.g., storage tank failure, train derailments, vessel collisions) and related consequences (e.g., release of crude oil or other proposed bulk liquids).

[2] The PS&P rail line refers to the rail line between Centralia and the project site.

Table 3.1-1. Laws and Regulations for Earth

Laws and Regulations	Description
Federal	
Clean Water Act, Section 402 (33 U.S.C. 1251 et seq.)	Establishes the NPDES permitting program, under which discharges of pollutants are regulated and mandates that certain types of construction activity comply with the requirements of the EPA NPDES program.
State	
State Building Code (RCW 19.27)	Provides specific design standards, through the adoption of the International Building Code, for occupied structures that should be met to reduce the risk of damage to people and property from geologic hazards.
Facility Oil Handling Standards (WAC 173-180)	Establishes minimum standards for oil facility and transfer operations.
Local	
Adoption of International Building Code (HMC 2.08 and AMC 15.08)	Recognizes that the respective city has adopted the International Building Code, 2012 Edition, as the official building code of the city.
Adoption of International Fire Code (HMC 2.38 and AMC 15.12)	Recognizes that the respective City has adopted the International Fire Code, 2012 Edition, as the official fire code of the City.
Land Development—Erosion and Sediment Control (HMC 10.05.120 and AMC 13.70)	HMC 10.05.120 requires all new industrial development to provide for the control and management of stormwater runoff. AMC 13.70 establishes minimum requirements and procedures to control the adverse impacts associated with increased storm and surface water runoff.
Shoreline Management (HMC 11.04 and AMC 16.20)	Carries out responsibilities imposed by the Shoreline Management Act of 1971.
Critical Areas Ordinance (HMC 11.06 and AMC 14.100)	Sets forth the definitions and process for designating and protecting critical areas within the city limits of Hoquiam and Aberdeen, respectively.

U.S.C. = United States Code; EPA = U.S. Environmental Protection Agency; NPDES = National Pollutant Discharge Elimination System; RCW = Revised Code of Washington; WAC = Washington Administrative Code; HMC = Hoquiam Municipal Code; AMC = Aberdeen Municipal Code

3.1.3 How were impacts on earth resources and conditions evaluated?

This section describes the sources of information and methods used to evaluate impacts.

3.1.3.1 Information Sources

Information on earth resources in the study area was obtained from the following sources. Although past permits and approvals are no longer applicable, information from these sources is relevant to characterizing the affected environment and regulatory context.

- Environmental permitting documents prepared for the proposed action by the applicant, the City of Hoquiam, and Washington State Department of Ecology (Ecology).
  - October 2012 and February 2013 Washington State Environmental Policy Act (SEPA) environmental checklists and associated appendices.
  - February 2013 Shoreline Substantial Development Permit application package.
  - February 2013 Critical Areas Permit Checklist and assessment report.
  - May 2013 Mitigated Determination of Nonsignificance.
  - April 2013Findings of Fact and Conclusions of Law of the Shoreline Administrator.
  - February 2013 Joint Aquatic Resource Permit Application.
  - Geotechnical engineering report and letter (GeoEngineers 2006, 2014).
- U.S. Geological Survey (USGS) National Seismic Hazard Maps and associated report.
- Cascadia Region Earthquake Workgroup report on Cascadia subduction zone earthquakes.
- Grays Harbor County 2011–2016 Hazard Mitigation Plan (2006).
- Federal Emergency Management Agency Risk Report (Draft) for Grays Harbor County including the Cities of Hoquiam, Cosmopolis, Hoquiam, Ocean Shores, Westport, Montesano, McCleary, Elma, and Oakville.
- Geologic mapping of the Hoquiam area by Logan (1987).
- Washington State Department of Natural Resources geologic and hazard mapping.
- An updated assessment of tsunami risks specific to the project site (Appendix C, *Tsunami Impact Modeling and Analysis*).
- Washington State Seismic Safety Committee (2012) Resilient Washington State report.
- Geological literature from professional journals, USGS, and the Washington State Department of Natural Resources as referenced in this section.

Data obtained from these sources were augmented with general observations of site conditions made during a September 10, 2014, site visit and facility tour.

3.1.3.2 Impact Analysis

The impact analysis for geology and soils considers both the potential for the proposed action to affect the geologic environment and for the geologic environment to affect the proposed action. These impacts were evaluated in the context of the regulatory requirements (Section 3.1.2), the geologic and soil conditions at the site, and the broader geologic environment that can affect the project site or its associated transportation corridors (PS&P rail line and Grays Harbor Navigation Channel).

3.1.4 What earth resources and conditions are in the study area?

This section describes the earth resources in the study area that could be affected by construction and routine operation of the proposed action or that could contribute to impacts on the proposed action. This section provides the general context for earth resources in the study area and describes earth resources and geologic hazards on the project site, along the PS&P rail line, and in and along the shoreline of Grays Harbor.

3.1.4.1 Regional Geology

The regional geology of western Washington is related to the eastward movement of the San Juan de Fuca tectonic plate against the North American Plate (Parsons et al. 2005; Washington State Department of Natural Resources 2014a). The San Juan de Fuca plate plunges (or forms a subduction zone) progressively deeper as it move east underneath the North American plate. The movement compresses the rocks above it, producing uplift and down dropping. This plunging zone, the Cascadia Subduction Zone (CSZ), extends from northern California through Oregon and Washington to southern British Columbia. The Juan de Fuca plate also melts at depth and the magma (lava) that is produced rises to the surface forming the Cascade Range volcanic arc.

Hoquiam and Grays Harbor are at the western edge of the Washington Coast Ranges within the Willapa Hills physiographic province (Washington State Department of Natural Resources 2014b). The Willapa Hills are composed of a variety of sedimentary and volcanic rocks and are not intensely deformed compared to the Olympic Mountains to the north. The area is outside the extent of glaciation although glacial-influenced river sedimentation did occur along the Chehalis River during glacial periods. The Chehalis River crosses the Willapa Hills and enters the Pacific Ocean through Grays Harbor. The glacial-age (greater than 10,000 years ago) ancestral Chehalis River flowed through this same valley and the surficial deposits in the valley range from recent alluvium (that is, ongoing sediment transport with associated river channel and floodplain deposition) and older alluvial deposits that are slightly higher in elevation (river terraces). These deposits extend along the Chehalis River to Centralia and beyond. The Chehalis River is at a relatively low elevation along its entire length. It is at about 140 feet mean sea level at Centralia (River Mile 66), about 55 feet mean sea level at Oakville (River Mile 42) about 20 feet mean sea level at Satsop (River Mile 20), and is at sea level at Aberdeen.

3.1.4.2 Geology and Soil Conditions

Prior to the late 1970s, the majority of the project site was occupied by a boat slip (Slip 1) that was constructed in the 1920s as part of the Port of Grays Harbor (Port) Marine Terminal No. 1. This slip was used to berth ships for loading and fueling and for the storage of floating logs and log rafts. A 2000-foot by 300-foot pier (Pier 1) once extended along the northern portion of the site, separating Slip 2 from an adjacent boat slip to the southeast (Slip 2). This pier included docks along both sides that provided mooring locations in both slips, two traveling cranes along the Slip 1 dock, and other freight-handling equipment. Other features included multiple rail lines down the center of the pier and a large warehouse adjacent to Slip 2. Between 1983 and 1994, Slip 1 was hydraulically filled by the Port with material dredged from Grays Harbor and was variably capped by fill from a roadway project (GeoEngineers 2006). Additional information on the historical conditions and photographs of the project site are provided in Section 3.11, *Historic and Cultural Preservation*.

The project site is relatively flat (1% maximum slope) with the exception of a dredged material stockpile at its southern end that is approximately 20 feet high. The average elevation of the site is approximately 10 feet above mean sea level. It is partially paved (9.5 acres of the 22.9-acre), with no natural soils or agricultural soils present. Unpaved areas are located in the northern and western portion of the site and include vegetated fill material. These areas are mapped as urdorthents by the

U.S. Department of Agriculture, Natural Resources Conservation Service. Urdorthents are young soils that have developed in dredged materials. The site is underlain at depth by river and floodplain deposits of glacial- and post-glacial-age alluvium (Quaternary-age alluvium from 1.8 million years ago) (Logan 1987; Washington State Department of Natural Resources 2014a: Interactive Geologic Map). Because of this fill, the normal Natural Resources Conservation Service soil mapping and erosion hazard designations are not applicable. If exposed, the underlying dredge materials would have a low erosion hazard (surface, rill, and inter-rill) based on the project site's low gradient. Geotechnical investigations at the project site and the adjacent site for Westway Terminal Company LLC were completed in 2006 and 2013, respectively. According to the investigations completed at the project site, the majority of the site consists of subsurface layers of silt, sandy silt, silty fine sand with occasional gravels (GeoEngineers 2006). These materials are moist to wet and soft to medium stiff to loose. The report estimates that gravel occurred below 150 feet and bedrock at depths of greater than 200 feet below ground surface. Subsurface investigations completed for the Westway project site (Hart Crowser 2013) yielded similar results with subsurface layers consisting of gravel to about 40 feet below the surface underlain by loose to dense sandy gravel to a depth of about 130 feet below the surface. Borings collected at the eastern part of the Westway project site indicate sandier soils.

The area surrounding the project site is also relatively flat with the closest areas of steeper slopes occurring approximately 0.75 mile to the north. The adjacent mountain bedrock uplands begin approximately 0.75 mile to the north with river alluvium, alluvial fans, and talus along the valleys inset within the bedrock (Hoquiam River, Fry Creek, Wishkah River).

PS&P Rail Line

The entire PS&P rail line is built on river sediments of the Chehalis River or its tributaries. Some of these sediments are slightly higher river terraces above the elevation of the floodplain. These sediments are approximately hundreds of feet deep (Logan 1987; Washington State Department of Natural Resources 2014a: Interactive Geologic Map).

Grays Harbor

Overall, the sediments underlying Grays Harbor and the adjacent nonbedrock uplands are varying sequences of shallow marine, longshore coastal bar, estuarine, intertidal, river alluvium, and floodplain deposits. In general, these sediments range from gravel to sands, silts, and clays with the finer grain sizes dominating. Geotechnical investigations at the Port adjacent to the North Channel Reach of the navigation channel have found these types of sediments to depths of greater than 150 feet below ground surface (GeoEngineers 2006; Hart Crowser 2013; Shannon and Wilson 2013).

3.1.4.3 Geologic Hazards

In the study area, the broader geologic conditions that could affect the project site and transportation corridors include landslides and slope instability, earthquake and earthquake-related hazards, and volcanic activity.

Landslides and Slope Instability

Landslides can occur as the result of various factors, but primarily occur on steeper slopes in combination with loose or unstable soils. Landslides most often occur during the rainy season such as during the December 2007 storm, the January 2009 storm, and the January 2015 storms

(Sarikhan and Contreras 2009; Stewart et al. 2013; Washington State Department of Natural Resources 2014b), but can also occur as the result of earthquakes and other earthquake-related hazards. Earthquake-induced landslides also occur primarily during saturated conditions (Washington State Department of Natural Resources 2014b).

Project Site

The soil and slope characteristics of the project site (i.e., gravel, sand, and relatively flat) result in a low potential for landslides or soil instability. Additionally, the risks of mass movement of soil into the adjacent harbor are considered very low because the shoreline adjacent to Terminal 1 is well supported with riprap and armoring for stabilization. No landslide hazard areas are mapped along the Hoquiam shoreline, including the project site (Washington State Department of Natural Resources 2014c: hazard map landslides). The closest landslide hazard area (Slaughter et al. 2013) is approximately 0.75 mile to the north and any landslides at this distance would have no impact on the project site.

PS&P Rail Line

Along the PS&P rail line, there are several areas where landslides could occur because of steeper slopes and looser soils. Beginning on the east side of Aberdeen where it closely parallels US Route 12 (US 12) between highway milepost (MP) 0.0 and MP 2.5, the rail line travels within 60 to 190 feet of a steep hillside for about 2.25 miles before heading south onto the Chehalis River floodplain. It is again close to hillsides from the east side of Central Park, coming within approximately 50 to 100 feet of the base of the slope for about 1.5 miles. In Elma, the rail line comes closer to the hillsides but is still approximately 800 feet away at the closest point. Beginning approximately 3 miles to the southeast of Elma to just east of Oakville, the rail line closely parallels US 12 for about 9.75 miles between MP 24.5 and MP 34.25 and is immediately adjacent to steep hillsides to the east. It is also immediately adjacent to hillsides on its north side for about 5 miles between Oakville and the community of Gate. From Gate to Centralia, the rail line is not adjacent to hillsides except for approximately 0.25 mile where it is next to the hillside at Blakeslee Junction immediately northwest of Centralia.

For the sections of the PS&P rail line that closely parallel US 12, the Washington State Department of Transportation (WSDOT) Unstable Slope Management Program[3] provides some information on the stability of adjacent hillsides (Figure 3.1-1). For the segment between US 12 MP 0.0 and MP 2.5, WSDOT identifies six areas of unstable slopes, including one rock fall, four landslides, and one debris flow that vary between 0.01 and 0.46 mile in length (Trople pers. comm.). The rock fall, debris flow, and one of the landslide areas are located on the north side of the highway (i.e., immediately upslope of the roadway), with the toe of the unstable slope located between 110 and 370 feet away from the edge of the PS&P rail line. WSDOT has installed mitigation measures along the rock fall area in this segment. The remaining three landslide areas occur on the south side of the highway (i.e., immediately upslope of the PS&P rail line), with the toe-of-slope located between about 10 to 20 feet of the rail line.

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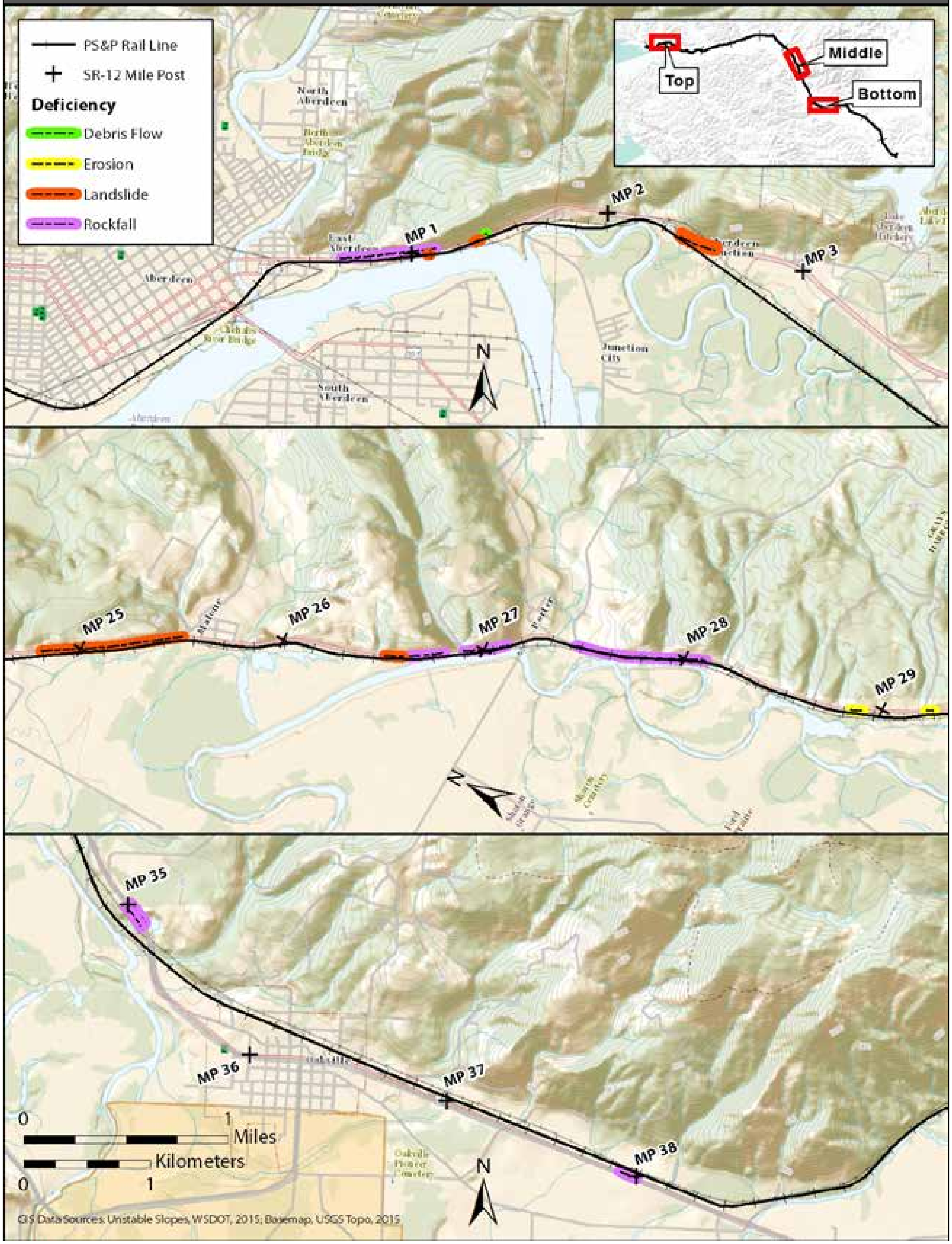
[3] The Unstable Slope Management Program was developed by WSDOT to inventory, rate, and describe unstable slopes within the WSDOT highway system and to develop conceptual slope mitigation designs and cost estimates for these areas. It includes the Unstable Slope Management System, which is a computer program used to evaluate known unstable slopes by balancing hazard and risk in prioritizing funding for proactive stabilization efforts (Washington State Department of Transportation 2010).

For the segment the PS&P rail line that parallels US 12 between MP 24.5 and MP 34.25, WSDOT identifies seven unstable slopes including three areas with rock falls, two areas with landslides, and two areas with slope erosion issues (Trople pers. comm.). These areas vary between 0.04 to 0.7 mile in length, with the unstable slopes occurring on the east side of the highway (i.e., immediately upslope of the roadway). Distance between the rail line and toe-of-slope in these areas typically varies between 60 to 280 feet. WSDOT has installed mitigation measures for one of the rock fall areas in this segment.

Grays Harbor

Some moderately steep slopes are directly adjacent to the Grays Harbor shoreline along the northern edge of the Bowerman Basin near Grays Harbor City, approximately 4 miles west of the project site. This area is susceptible to shallow landsliding (Slaughter et al. 2013). Submarine (underwater) landslides do occur in deep water approximately 40 miles west of the entrance to Grays Harbor. However, these landslides would not cause any instability within Grays Harbor.

Figure 3.1-1. Unstable Slopes near the PS&P Rail Line



Earthquakes

Western Washington is subject to substantial earthquake activity (Washington State Department of Natural Resources 2014b). Earthquakes are most often the result of sudden movement within the Earth's crust or from volcanic activity. The magnitude of an earthquake is most commonly measured by the moment magnitude scale (1.0 to 10.0), which is a 10-base logarithmic scale. This means that an earthquake of magnitude 5.0 would be 10 times stronger than an earthquake of magnitude 4.0, and so on.

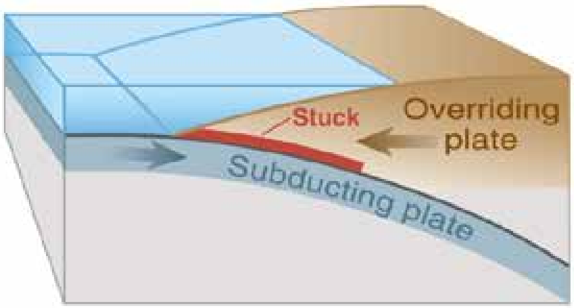
The Modified Mercalli intensity scale[4] correlates the measured magnitude of an earthquake with the perceived intensity and likelihood of damage. For example, according to the Mercalli scale, earthquakes of 6.0 to 6.9 magnitude are considered strong with slight to moderate damage to ordinary, well-built structures. Historic moderate to large earthquakes in the region include the magnitude 7.1 Olympia earthquake (April 13, 1949), the magnitude 6.5 Seattle-Tacoma earthquake (April 29, 1965), and the magnitude 6.8 Nisqually earthquake (February 28, 2001) (Noson et al. 1988; Pacific Northwest Seismic Network 2014). Earthquakes of these magnitudes can cause substantial damage in the immediate vicinity of their occurrence. The amount of shaking and associated damage declines with distance from the earthquake source.

The largest magnitude earthquakes (9.0 magnitude and higher) that could affect the region would likely occur as the result of movement along the CSZ, which extends from northern California through Oregon and Washington to southern British Columbia. A subduction zone is the area created when one tectonic plate moves over another plate within the Earth's crust. The CSZ is created as the San Juan de Fuca tectonic plate plunges (or forms a subduction zone) progressively deeper as it move east underneath the North American plate. The overriding plate is compressed, producing stress (Figure 3.1-2, Panels A and B). The CSZ earthquake is the result of the release of that stress by the unlocking of, and movement between, the two plates.

A rupture along the CSZ would affect the entire coastline from northern California to southern British Columbia. Damage would occur in communities facing the Pacific Ocean (e.g., Cosmopolis, Hoquiam, and Aberdeen, Washington) and in the major urban areas of Portland, Oregon; Puget Sound, Washington; California and Vancouver, British Columbia (Cascadia Region Earthquake Workgroup 2013).

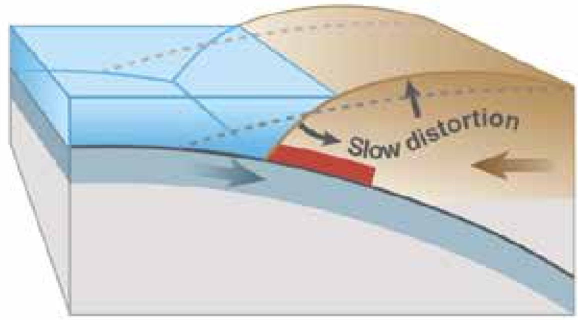
[4] The Modified Mercalli intensity uses a series of 10 intensity levels (Levels I through X) to provide a more meaningful measure of earthquake severity to the nonscientist than the magnitude scale because it describes the actual effects that might be experienced during an earthquake of a certain magnitude (U.S. Geological Survey 2015). According to the Modified Mercalli scale, earthquakes with magnitudes of 6.0 to 6.9 are characterized as Level VI to VII events causing strong to very strong shaking that is felt by all, with slight to moderate damage to ordinary, well-built structures. Earthquakes of magnitudes of 7.0 to 7.9 are characterized as Level VII to VIII that cause very strong to severe shaking, with moderate to substantial damage to ordinary, well-built structures. Earthquakes with magnitudes of 8.0 or higher are characterized as Level VIII to X events with severe to extreme shaking resulting in substantial structural damage to total structure destruction. Historic moderate to large earthquakes in the region have been Level VI to VII events.

Figure 3.1-2. Subduction Zone Earthquake



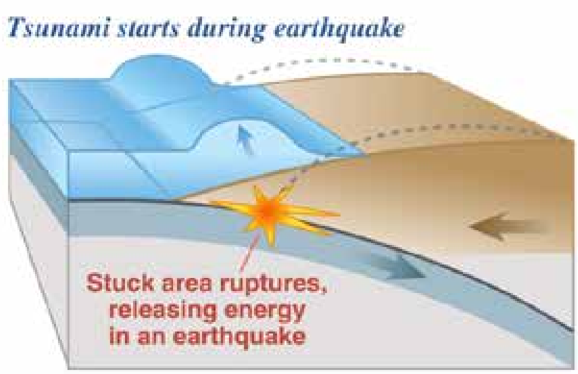
A. Vertical Slice Through a Subduction Zone

One of the many tectonic plates that make up Earth's outer shell descends, or "subducts," under an adjacent plate. This kind of boundary between plates is called a "subduction zone." When the plates move suddenly in an area where they are usually stuck, an earthquake happens.



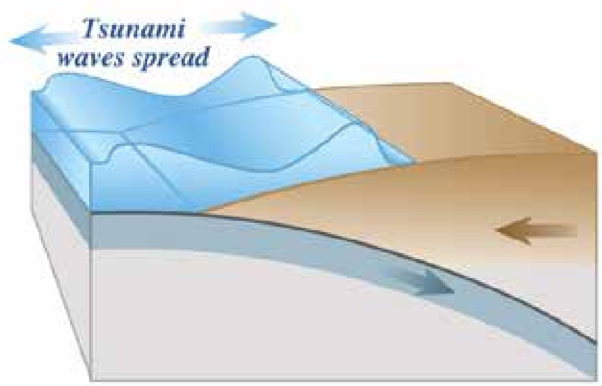
B. Between Earthquakes

Stuck to the subducting plate, the overriding plate gets squeezed. Its leading edge is dragged down, while an area behind bulges upward. This movement goes on for decades or centuries, slowly building up stress.



C. During an Earthquake

An earthquake along a subduction zone happens when the leading edge of the overriding plate breaks free and springs seaward, raising the sea floor and the water above it. This uplift starts a tsunami. Meanwhile, the bulge behind the leading edge collapses, thinning the plate and lowering coastal areas.



D. Minutes Later

Part of the tsunami races toward nearby land, growing taller as it comes in to shore. Another part heads across the ocean toward distant shores.

Source: Atwater et al. 2005

Although no CSZ earthquakes have occurred during the period of written records, there is evidence that they have occurred in recent geologic history. The most recent CSZ earthquake was the 1700 event (Atwater et al. 1995; Jacoby et al. 1997). Its date is known quite precisely (January 26, 1700), because it caused a substantial tsunami in Japan (Atwater et al. 2005).

The probabilities of earthquakes of magnitude 6.0 to 9.0 and greater affecting the study area are shown in Table 3.1-2. In general, the likelihood of an earthquake decreases as the magnitude of the event increases. At the project site, a magnitude 6.0 earthquake has a 30 to 40% likelihood of occurring once in 50 years (i.e., this does not mean that a 6.0 earthquake is expected to occur after 50 years; rather, the likelihood that it could occur during a 50-year window would be 30 to 40% and would be the same likelihood of occurring in any one of those years). An earthquake of magnitude 9.0 or greater has a lower likelihood of occurring, 6 to 8% chance within a 50-year window.

Along the PS&P rail line, which extends 59 miles from Hoquiam to Centralia, the likelihood of an earthquake of a given magnitude varies over that distance, reflecting the change in distance from a given earthquake source. The likelihood of earthquakes of magnitudes of 7.0, 8.0, and 9.0 declines from west to east relative to the distance from the CSZ, the dominant source of these larger earthquakes. The likelihood of an earthquake of magnitude 6.0 initially increases then decreases moving west to east away from the CSZ and into and away from the complex of interrelated faults of the Puget Sound region, the more likely source of earthquakes of this magnitude.

Table 3.1-2. Probability of Stronger Earthquakes in the Study Area

Earthquake Magnitude (Moment Magnitude Scale)	Probability of Occurrence at the Project Site (% within 50-year period and within 31 miles)	Probability of Occurrence Along the PS&P Rail Line (% within 50-year Period and within 31 miles)
6.0 or greater	30–40	30–50
7.0 or greater	12–15	3–15
8.0 or greater	10–12	2–12
9.0 or greater	6–8	1–8

Source: U.S. Geological Survey 2009 generates maps based on zip code, earthquake magnitude, and time span. Note that the source distance of these earthquakes is only 31 miles (50 kilometers) so that it does not fully capture more distant earthquakes such as at the western part of the Cascadia Subduction Zone. Additionally, this website calculator has not been updated for 2014 (Petersen et al. 2014). However, this data still provides a useful comparison of expected earthquake magnitudes by location across the study area. Note that the maps produced for Hoquiam and Elma (approximately halfway between Hoquiam and Centralia) are the same. Consequently, data from the maps generated for Hoquiam are used in the table.

Seismic-Related Effects

CSZ earthquakes are known to cause surface rupture, ground shaking, liquefaction, coseismic uplift and subsidence[5], and tsunamis. These seismic effects are described below.

Surface Fault Rupture

Earthquakes caused by movement within the earth's crust can cause surface fault rupture. Surface fault rupture occurs when the ground moves in two different directions above a fault line that intersects the surface. This movement can damage infrastructure, such as roads or buildings that sit

[5] Coseismic subsidence refers to the lifting and lowering of coastal areas that occurs simultaneous to the earthquake.

atop a fault line. There are no recognized surface-exposed faults that are active or potentially active in the study area (Lidke et al. 2003). The Grays Harbor Fault Zone, located on the sea floor, is the closest fault to the study area. It begins approximately 1 mile offshore to the west of Ocean Shores and runs east-west for approximately 13 miles. This fault has an estimated most recent event of less than 1,500 years ago (Lidke et al. 2003). The seaward edge of the CSZ is about 120 miles to the west of Hoquiam. Because there are no active surface faults located in the study area, the potential for impacts related to surface fault rupture are not discussed further.

Strong Ground Shaking

Large earthquakes can also cause damage through strong ground shaking. Ground shaking is most commonly measured in terms of peak ground acceleration (PGA). PGA is a measure of the earth's acceleration compared to earth's gravity (g) as recorded by seismic instruments. Earth's gravity is 1.0 g. To provide context for the intensity of the movement in terms of how such events feel and what the extent of the damage may be, the Mercalli intensity scale can be used to describe general relationships between PGA and perceived shaking and the potential damage that could occur. According to this scale, PGA in the range of 0.34 to 0.65 g is perceived as severe shaking and could cause moderate to heavy damage, depending on the duration of the event and the structural integrity of affected buildings. PGA in the range of 0.65 to 0.8 g is perceived as violent shaking and would likely cause heavy damage (Petersen et al. 2014).

To characterize the potential risks within an area, USGS develops National Seismic Hazard Maps that show the degree of ground shaking that could occur at various probability levels. These USGS maps inform the design requirements in building codes and other professional standards that apply to the proposed action (Section 3.1.2).

The USGS maps show the expected peak ground movement that could occur as the result of all possible earthquake events within a specific area. The 2014 USGS map shows that, for the study area, there is a 2% probability of an earthquake exceeding a PGA of 0.7 g in a 50-year period. As a generalization, this means that in any 50-year period, there is a 2% chance that an earthquake could occur that would result in severe shaking and moderate to heavy structural damage.

Ground shaking would be strongest in areas underlain by soft soils or unconsolidated deposits such as sand and silt and least in areas underlain by solid rock. The Site Class Map of Grays Harbor County, Washington characterizes the project site as Site Class E, which is the highest level of expected increase of ground shaking due to the type of underlying materials (Palmer et al. 2004). Similar areas of soft soils also occur along the PS&P rail line and would be susceptible to ground shaking in the event of a magnitude 6.0 earthquake or higher.

Liquefaction

Liquefaction occurs when water-saturated, loose sand layers that occur below the ground surface liquefy during strong ground shaking. These liquefied layers can flow like a liquid or lose their strength and consistency such that they cannot support the ground above them. The flowing sediment may erupt to the surface, producing sand boils or sand volcanoes. The liquefied soil layers may also flow laterally and enter waterways. The loss of support for overlying layers may result in these overlying layers subsiding or moving laterally (lateral spreading). Liquefaction also contributes to the loss of bearing capacity for shallow foundations. Subsidence or lateral spreading can damage building foundations or lead to building collapse.

The Hoquiam-Aberdeen area is underlain by sandy gravel, which is susceptible to liquefaction. The Hoquiam-Aberdeen shoreline, including the project site, is mapped as having a high liquefaction hazard (Slaughter et al. 2013); consequently, these areas are susceptible to liquefaction during a strong (6.0 magnitude or greater) earthquake. This high hazard zone extends up to 0.5 mile inland from the shoreline of the harbor.

From Grays Harbor to Centralia, the liquefaction hazard of the majority of the Chehalis River Valley is classified as moderate to high with smaller areas of low and very low risk (Washington State Department of Natural Resources 2014c:natural hazards map). Consequently, earthquakes of magnitude 6.5 to 7.0 or higher could cause liquefaction of the ground surface along much of the PS&P rail line. Earthquakes of magnitude 6.5 to 7.0 would cause localized areas of liquefaction while larger magnitude earthquakes would cause more extensive areas of liquefaction. Liquefaction could also destabilize bridges or other foundations where railroad tracks cross streams. The PS&P rail line has more than 30 stream crossings between Grays Harbor and Centralia. Larger named stream crossings include Van Winkle Creek, Higgins Slough, Wynoochee River, Camp Creek, Satsop River, Newman Creek, Vance Creek, Cloquallum Creek, Mox Chehalis Creek, Porter Creek, Gibson Creek, Cedar Creek, Harris Creek, Roundtree Creek, Black River, Scatter Creek, Prairie Creek, and Skookumchuck River. Although the PS&P rail line parallels and is near the Chehalis River at many locations, it does not actually cross the river.

Coseismic Subsidence

Subduction zone earthquakes are also known to result in extensive coseismic uplift and subsidence, where parallel strips of coastline are lifted or lowered, respectively (Cascadia Region Earthquake Workgroup 2013). In the study area, these motions would occur because of the pre- and post-earthquake interaction between the subducting San Juan de Fuca plate and the overlying North American plate. During a CSZ earthquake, coseismic subsidence would occur almost instantaneously and the land in the study area would drop 5 feet or more. Substantial geologic evidence exists of these events in the Grays Harbor vicinity and in Grays Harbor specifically (Atwater 1992; Shennan et al. 1996; Atwater and Hemphill-Haley 1997; Wang et al. 2013).

As noted above, the most recent CSZ earthquake and associated coseismic subsidence occurred January 26, 1700 (Atwater et al. 1995; Jacoby et al. 1997; Atwater et al. 2005). Wang et al. (2013) review CSZ earthquake subsidence analyses from a wide variety of CSZ sites from northern California to British Columbia. Based on two sites in the Grays Harbor area that they consider to provide the best basis for determining the amount of local coseismic subsidence from the event, Wang et al. (2013) approximate coseismic subsidence of approximately 2 to 5 feet. This subsidence would affect all of Grays Harbor, Hoquiam, Aberdeen, and the lower part of the Chehalis River. Subsidence on this order would increase the depth of the navigation channel and Grays Harbor in general by approximately 5 feet.

Tsunamis

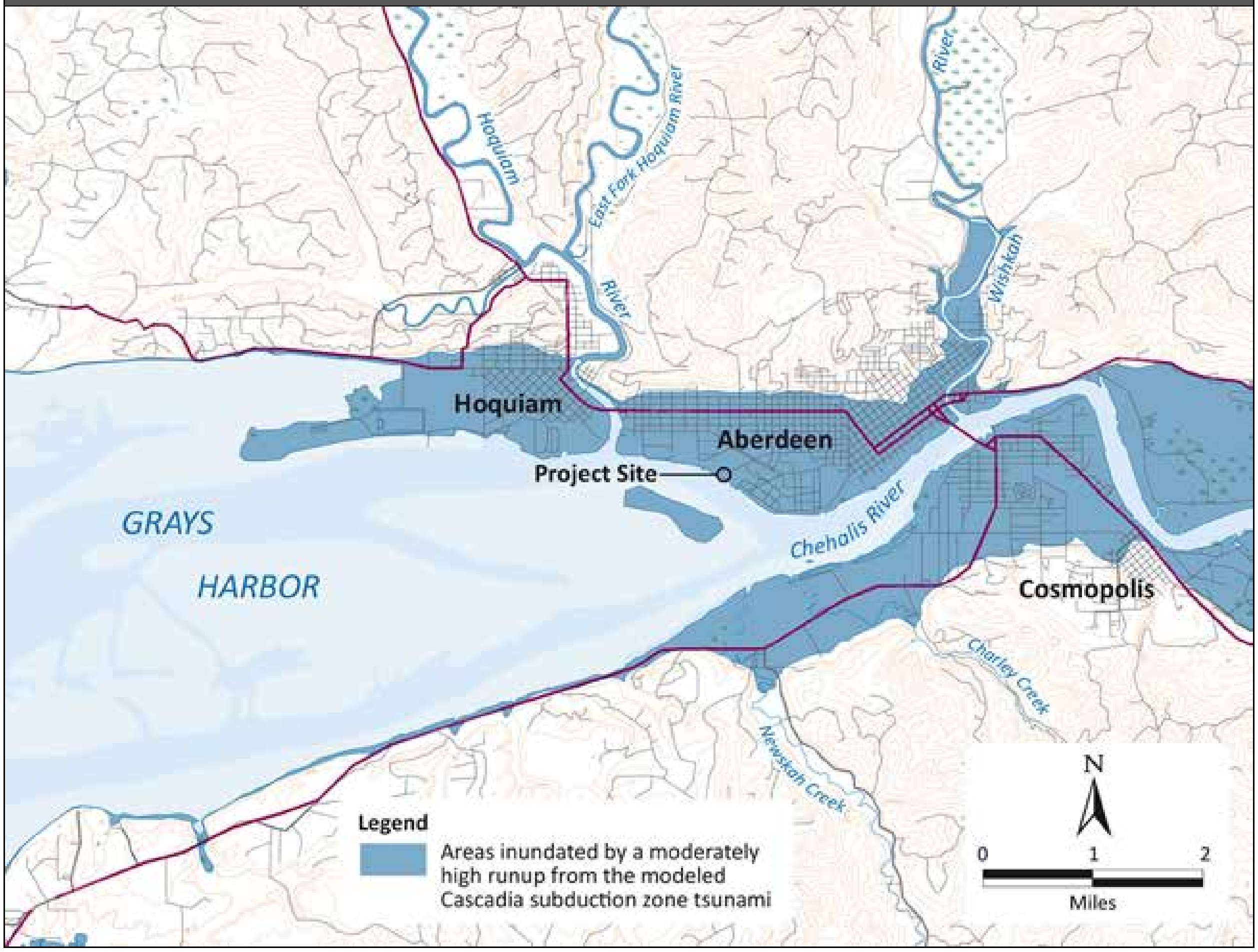
Tsunamis are a train of waves that can be generated during an earthquake by the rapid movement of the sea floor or a lakebed (Figure 3.1-2, Panel D) and even by larger landslides. As mentioned above, there are some areas susceptible to shallow landsliding around the harbor (Slaughter et al. 2013); however, these areas occur near shallow water, resulting in a very low potential for larger waves to occur.

Tsunamis generated by seismic activity in the open ocean have small wave heights at the point of origin but gain height as they enter shallow coastal zones. When reaching the land surface, the tsunami surge wave may travel inland until it loses its momentum. At that point, the water will flow back toward the ocean. A large tsunami may have many waves that reach the shore over a period of hours, and the first wave is generally not the largest wave. Tsunamis are highly destructive because of the weight and velocity of the water combined with the items that are pushed along by the wave (e.g., boats, cars, refrigerators, propane tanks, debris from destroyed buildings). The destruction occurs from both directions as the wave moves inland and then flows back to the ocean.

Tsunamis may reach the Washington coast from several locations; however, the largest potential tsunamis are associated with a CSZ event. Tsunami modeling by Walsh et al. (2000) was used to develop hazard mapping for Washington State to characterize tsunami risks for planning purposes. The modeling was completed for a moderate CSZ earthquake consistent with a 500-year event.[6] The modeling was informed by the best available data at the time of analysis and showed that most of the Grays Harbor communities (including Westport, Ocean Shores, Hoquiam, Aberdeen, and Cosmopolis) would be inundated by a moderately high run-up CSZ tsunami (Figure 3.1-3). Based on the model used to develop the mapping, the first tsunami wave would reach Hoquiam in 1 hour, with a wave elevation above the ground surface of about 2 feet and a maximum height of subsequent waves of about 3.5 feet (Walsh et al. 2000). In contrast, the modeled wave heights at Westport and Ocean Shores on the south and north spits, respectively, at the west end of Grays Harbor, would be over 11 feet and 13 feet, respectively.

[6] A 500-year event means the probability that a moderately powerful CSZ earthquake will occur in any given year is 0.2%.

Figure 3.1-3. Modeled Tsunami Inundation from a Cascadia Subduction Zone Earthquake



Source: Walsh et al. 2000

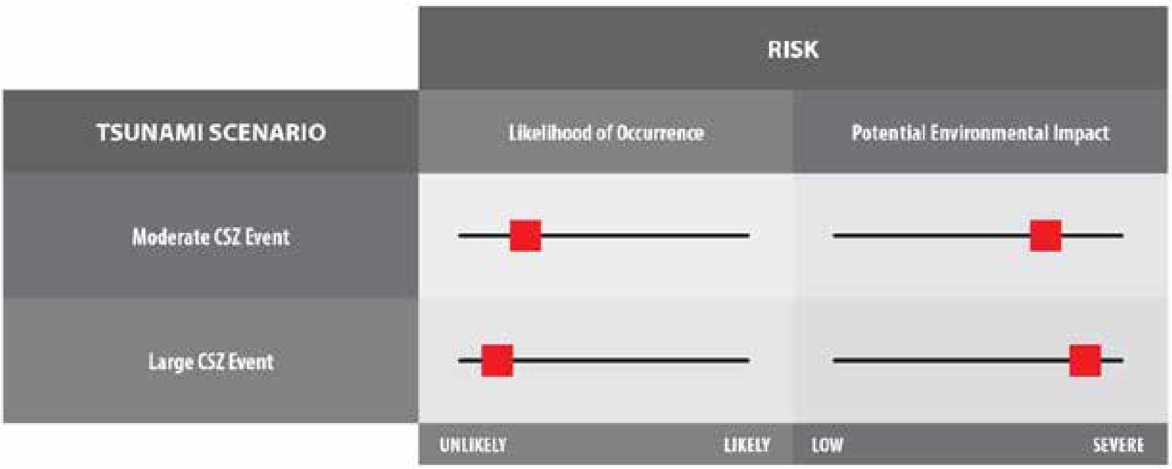
Since the publication of the state's hazard mapping in 2000, recent tsunami events and advancements in the understanding and methods applied to tsunami modeling have provided for refinement of these estimates. To further inform the risk of tsunamis in the study area, an updated tsunami model was completed (Appendix C, *Tsunami Impact Modeling and Analysis*). The model used in this updated analysis focuses specifically on the study area and extends approximately 200 miles offshore from the project site. Consistent with current practices, the updated model considers a more conservative tsunami event (i.e., a 3,333-year event[7]) than past efforts used to characterize risk, including the state's current hazard mapping. In other words, current practices evaluate the potential for a much larger seismic event (which corresponds with a lower likelihood of occurrence) and incorporate an additional factor of safety[8]. The relative comparison of the likelihood of these two CSZ scenarios and the potential for environmental impacts is shown graphically in Figure 3.1-4. The analysis concluded that the extent of the inundation (i.e., how far inland the tsunami waves

[7] A 3,333-year event means the likelihood that a powerful CSZ earthquake will occur in any given year is 0.03%, or very low. Another way to state this is that a tsunami of this size could occur once every 3,333 years.

[8] With respect to this analysis, application of a factor of safety means the results of the model (i.e., predicted height and forces of the tsunami waves) were subsequently increased (in this case by 1.3 times) to provide an additional "factor of safety." Incorporation of a factor of safety of 1.3 was used to reflect federal requirements since no state or local requirements are available.

reached) would be similar to that shown in the state's hazard mapping but that the larger seismic event could cause a tsunami with wave heights of 23 to 33 feet (North American Vertical Datum of 1988) near the project site. This means that in the event of a large-scale CSZ earthquake, there is a potential tsunami waves (water and debris) reaching the proposed facilities at the project site could be 21 to 26 feet above the ground surface. As noted, the likelihood of an event that would result in waves of this size occurring in any given year is extremely low, or approximately 0.03%. In other words, the chance that a tsunami of this size would not occur would be 97.7% in any given year. For additional information about this analysis, refer to Appendix C*, Tsunami Impact Modeling and Analysis*.

Figure 3.1-4. Risks of Tsunami in the Study Area



Existing tsunami modeling does not extend up the Chehalis River Valley (Walsh et al. 2000; Coast and Harbors Engineering 2014). However, based on the low-elevation topography, there is some tsunami risk for approximately 5 miles up the valley to the vicinity of Montesano. Tsunami wave height and intensity would dissipate rapidly as waves move up the river valley and the risk would decrease commensurately. For example, Walsh et al. (2000) modeled tsunami crests at more than 10 feet at the entrance to Grays Harbor but only 3 feet at Aberdeen. The wave heights east of Aberdeen would be less.

Tsunamis can also be generated by large submarine landslides. These landslides disturb the overlying water and waves radiate out from that location. With sufficiently large landslides, these waves can generate tsunamis when the waves reach shallow water. Although submarine landslides are known to originate from offshore Washington, much of their activity has been correlated with CSZ earthquakes. No non-CSZ earthquake-related tsunamis are known to have been generated from submarine landslides on the outer Washington coast. Submarine landslide-generated tsunamis are not discussed further.

Volcanic Activity

Two active volcanoes are present in the Cascade Range approximately 100 miles to the east of Hoquiam and about 50 miles to the east and southeast of Centralia. Volcanic hazards at these distances would be from the air fall of volcanic ash and from volcanic mudflows that would flow down volcano slopes into, and then down, adjacent rivers. The project site is outside the lowest probability level of the accumulation of 4 or more inches of volcanic ash from a Cascade volcano eruption (Wolfe and Pierson 1995). The eastern parts of the Chehalis River Valley have an even lower risk of experiencing substantial ash fall (0.01 and 0.02%) (Wolfe and Pierson 1995) and volcanic activity would not be likely to affect rail operations in the area.

Volcanic mudflows from the 1980 Mount St. Helens volcanic eruption flowed from the volcano into the Toutle River and downstream into the Cowlitz River as far as the Columbia River (Haini 1983). However, no mudflows reached the Chehalis River. Based on past evaluations, it is unlikely mudflows from Mount Rainier would reach the Chehalis River (Cakir and Walsh 2012) and are not likely to reach the PS&P rail line.

Based on the above information, volcanic hazards would not affect the project site, the PS&P rail line, or navigation in the navigation channel or offshore. Volcanic hazards are not discussed further.

3.1.5 What are the potential impacts related to earth resources and conditions?

This section describes the impacts related to earth resources and conditions that could occur in the study area. Potential impacts of the no-action alternative are described first, followed by potential impacts of the proposed action.

3.1.5.1 No-Action Alternative

Under the no-action alternative, impacts related to earth resources from the construction of the proposed action would not occur. The applicant would continue to operate its existing facility as described in Chapter 2, Section 2.1.2.2, *Existing Operations*. Although the proposed action would not occur, it is assumed that growth in the region would continue under the no-action alternative, which could lead to development of another industrial use at the project site within the 20-year analysis period (2017 to 2037). Such development could result in in impacts similar to those described for the proposed action.

As described in Section 3.1.4.3, *Geologic Hazards*, there is a potential for larger magnitude earthquakes and earthquake-related hazards to occur in the study area. Under the no-action alternative, because no new facilities or operational changes would occur, there would be no increased exposure to risk of damage related to these events compared with existing conditions.

Under the no-action alternative, geologic events, including landslides, earthquakes, ground shaking, liquefaction, coseismic subsidence, and tsunamis would continue to have the potential to disrupt existing rail service and cause incidents and derailments if the events were strong enough. Specifically, ground shaking associated with a magnitude 6.5 earthquake or higher could destabilize the tracks (because of liquefaction) or cause incidents, including possible derailments. This would be most likely to occur in areas where the PS&P rail line is located on looser soils. As discussed above, this occurs primarily closest to the project site and in areas where the PS&P rail line comes closer to the Chehalis River floodplain in areas closer to Centralia. Much larger events (CSZ event of magnitude 9.0 or greater) could also result in coseismic subsidence that could affect portions of the PS&P rail line in Hoquiam and Aberdeen and the lower part of the Chehalis River. These same areas could also be affected by tsunami waves that could be large and powerful enough to destabilize the tracks and cause train derailments.

Under the no-action alternative, large magnitude CSZ events could affect existing vessel traffic in the harbor. If large enough, tsunami waves could move vessels located in the harbor and cause incidents as vessels came into contact with one another or with debris. As discussed in Section 3.1.4.3, *Geologic Hazards,* depending on the magnitude of the event, tsunami waves between 3 to 26 feet in height could reach the project site.

3.1.5.2 Proposed Action

This section describes the impacts that could occur in the study area as a result of construction and routine operation of the proposed action. This section also addresses potential impacts of broader geologic conditions on the proposed action and the transportation systems that would support it. First, this section describes impacts from construction of the proposed action. It then describes impacts of routine operation at the project site and of routine rail and vessel transport to and from the project site.

Construction

Construction of the proposed action could increase erosion and soil instability from earthwork (e.g., excavation, filling, site grading). The proposed action would develop an additional 10.9 acres at the site. Approximately 314,000 square feet (7.2 acres) would be graded. Approximately 77,000 cubic yards of material would be removed and 23,000 cubic yards filled.

Construction activities would expose bare soil during ground disturbance and could result in the need to temporarily stockpile soil. This would increase the potential for erosion from wind or surface-water runoff and for loose soils to enter waterways, resulting in water quality concerns. Potential water quality impacts associated with sedimentation are discussed in Section 3.3, *Water*.

As mentioned previously, the potential for increased erosion on the project site is low because the site is relatively flat, and because sandy, gravely soils have a low erosion potential. Additionally, the proposed action would be required to obtain a General Permit for Stormwater Discharges Associated with Construction Activities (National Pollutant Discharge Elimination System Construction Stormwater General Permit) and to develop and implement a stormwater pollution prevention plan. Implementation of best management practices consistent with the Stormwater Management Manual for Western Washington (Washington State Department of Ecology 2012) would reduce the potential for erosion and sedimentation during construction. No geologic or soil conditions at the project site suggest that such erosion control and best management practices would not be effective in reducing environmental impacts.

Although there would be small, temporary areas where soils would be stockpiled and some cut slopes, no large areas of steep slopes would be created. Therefore, construction of the proposed action would not result in the potential for increased soil instability such as landslides that could occur because of steeper slopes. Additionally, once contoured, the site would be paved, which would limit the potential for further soil movement.

Operations

This section describes impacts that would occur as a result of routine operations at the project site, rail transport along the PS&P rail line, and vessel transport through Grays Harbor.

Onsite

Landslides and Slope Instability

There is no potential for natural landslide instability to affect the project site during operations.

Earthquakes and Related Hazards

As discussed in Section 3.1.4.2, *Geology and Soil Conditions*, the project site is located in an area that has the potential for moderate to severe earthquakes to occur. The extent of the damage would depend on the magnitude of the event, but should a CSZ earthquake of magnitude 9.0 or higher occur, the following hazards would also occur: intense ground shaking (PGA) in the range of 0.7 g, liquefaction and ground settling of 6 to 12 inches, coseismic subsidence on the order of 2 to 5 feet, and tsunamis that could affect the project site. Although the potential for these events to occur would remain the same compared to the no-action alternative, there could be increased risk of damage to the newly proposed occupied office buildings, storage tanks, and related infrastructure if the appropriate design standards were not met.

Prior to construction, the applicant would be required to obtain the appropriate building permits and approvals from the Cities of Hoquiam and Aberdeen. This would require final design of the proposed action to be consistent with the building codes and standards described in Section 3.1.2. Compliance with those regulations would ensure that the proposed office structures and storage tanks meet the design standards required to reduce the risk of property and personal damage to acceptable levels.

In addition to meeting the general minimum standards, these regulations require site-specific assessments to be completed and any additional mitigation measures to be implemented to ensure risks related to geologic hazards are adequately reduced. As mentioned previously, a site-specific evaluation was completed in 2006 by GeoEngineers. The analysis considered PGA and ground settling factors for the project site and applied the International Building Code (2003) and American Society of Civil Engineers 7-02, as the basis of making additional design recommendations. Note that since the preparation of the GeoEngineers (2006) report, the International Building Code has been updated (2009, 2012) and the American Society of Civil Engineers 7-02 has been changed to 7-05 (which incorporates International Building Code 2009). These measures would be required to adequately reduce the risks at the construction phase for future operations of the proposed office buildings and storage tanks.

The consideration and implementation of geotechnical engineering and structural design for a project is an iterative and ongoing process, during which varying levels of investigation and analysis are performed to identify and address the potential impacts associated with a project commensurate with its stage in development. Therefore, prior to receiving the final building permits, the applicant would need to ensure the geotechnical evaluation considered the most current applicable information and standards. Implementation of measures identified during investigations specific to the proposed action and any others identified during subsequent investigations would be required to adequately reduce the risks of the proposed action.

As discussed in Section 3.1.4.2, *Geology and Soil Conditions*, the project site is located in an area that has the potential to be inundated by tsunami waves. The extent of damage would vary with the magnitude of the seismic event, the tidal level at the time for the earthquake, the current state of sea-level rise, and the amount of debris (from ships or buildings) that may be traveling with the wave. Although the risk of tsunami is unchanged with or without the proposed action, construction of new facilities associated with the proposed action would expose additional structures and workers to potential harm. However, if a tsunami were to occur, current analyses indicate there would be approximately 1 hour for onsite personnel to evacuate. Therefore, the development and implementation of the emergency evacuation plan described in Section 3.1.7.2, *Applicant Mitigation*, would help to reduce this impact.

Depending on the magnitude of the event, the new storage tanks could also become damaged and contribute to the tsunami debris, or rupture and result in a leak of bulk liquids into the environment. Although the proposed action is expected to be designed and constructed to the currently required minimum design standards, these standards (as defined by the International Building Code, adopted through State Building Code [RCW 19.27] and City Building Codes [HMC 2.08 and AMC 15.08]) do not require consideration of site-specific tsunami risks. To address this, the mitigation discussed in Section 3.1.7.2, *Applicant Mitigation*, identifies the specific forces that should be considered during the design of the proposed facilities to reduce potential impacts related to a tsunami event.[9]

Rail

Although the proposed action would not result in any modifications to the PS&P rail line that would directly affect soils or geological resources, geological events could affect increased rail traffic and safety under the proposed action. Potential events that could affect the PS&P rail line include landslides, earthquakes, and other seismically related events, such as liquefaction, coseismic subsidence, and tsunamis. The potential impacts associated with incidents along the rail line are addressed in Chapter 4, *Environmental Health and Safety*.

Landslides and Slope Instability

As discussed in Section 3.1.4.3, *Geologic Hazards*, approximately 19 miles of the 59-mile (about 32%) PS&P rail line are located within 10 to 280 feet of moderate to steep slopes and hillsides. In these locations, the rail line is susceptible to damage from landslides. Although the risk of a landslide occurring in this portion of Washington is moderate because of the presence of steep slopes, unstable soils, high regional rainfall, and a relatively long rainy season, the potential for such events to derail a passing train is low. For approximately 12 of the 19 miles (about 63%) that the rail line is adjacent to steep or unstable slopes, it is separated from the adjacent hillslope by US 12, a two-lane highway that is between 40 to 70 feet wide and often divided by a concrete barrier, as well as a vegetated median of varying width. Based on data obtained from WSDOT's Unstable Slopes Management Program, debris flows from the majority of the known unstable slopes upslope of the highway are not expected to impede more than half of the roadway width (Fish pers. comm.). Consequently, it is unlikely that landslide debris from these locations could reach the PS&P rail line. In the two locations where potential debris flows from unstable slopes are expected to impede the entire width of the roadway, the PS&P rail line is an additional 25 to 50 feet away from the edge of the road. Although debris flows from landslides in these locations could reach the rail line, the likelihood that such events could hit and derail a train is low, as these areas only account for approximately 0.1 mile (about 0.2%) of the 59-mile PS&P rail line in the study area.

[9] As discussed in Section 3.1.4.3, *Geologic Hazards*, the updated analysis of tsunami risks specific to the project site considers a risk scenario consistent with a more conservative 3,333-year event and an additional 1.3 factor of safety. Although not currently required by state or local regulations, these assumptions would be applied following guidance presented in Appendix M of the International Building Code, which documents voluntary standards.

In the three locations along the rail segment between Aberdeen and MP 2.5 of US 12, WSDOT identified unstable slopes between the highway and PS&P rail line (Trople pers. comm.). Debris flows from landslides in these locations could reach the rail line, as it is located close (approximately 10 feet) to the toe-of-slope in some locations. The potential for this to occur is relatively low, as these areas occur along only 0.23 mile (about 0.4%) of the 59-mile PS&P rail line in the study area.

Because there would be an increase in the number of trains traveling within this corridor under the proposed action, these risks would be similar to, but slightly greater than under the no-action alternative. Specifically, operation of the proposed action at maximum throughput would result in approximately two unit train trips per day, on average, along the PS&P rail line, compared to an average of three train trips per day under the no-action alternative. The increased frequency of travel could result in a slight increase in the exposure of people and property to harm from derailment incidents caused by landslides. The increased risks of exposure of the environment to crude oil or other proposed bulk liquids (e.g., oil spills or explosions from train accidents) directly attributable to the proposed action are discussed in Chapter 4, *Environmental Health and Safety*.

Earthquakes and Related Hazards

As discussed in Section 3.1.4.3, *Geologic Hazards,* the PS&P rail line is located in an area that has the potential for moderate to severe earthquakes to occur. The extent of the damage would depend on the magnitude of the event, but should a CSZ earthquake of magnitude 9.0 or higher occur, the following hazards would also occur: intense ground shaking (PGA) in the range of 0.7 g, liquefaction, coseismic subsidence near Hoquiam and Aberdeen, and exposure to tsunami waves that could affect portions of the rail line closest to Hoquiam and Aberdeen. Events of this magnitude would have the potential to cause damage the rail line and trains to derail.

Because there would be an increase in the number of trains traveling within this corridor under the proposed action as described above, these risks would be similar to, but slightly greater, than under the no-action alternative. The increased frequency of travel could result in a slight increase in the exposure of people and property to harm from derailment incidents caused by earthquakes and earthquake-related hazards, such as those described above. The increased risks of exposure of the environment to crude oil or other proposed bulk liquids (e.g., oil spills or explosions from train accidents) that would be directly attributable to the proposed action are discussed in Chapter 4, *Environmental Health and Safety*.

Vessel

Although the proposed action would not result in modifications to the harbor that would directly affect soils or geological resources, vessel operations could result in the slight increased potential for shoreline erosion associated with vessel wake. Additionally, potential geological events, specifically earthquake-related hazards of coseismic subsidence and tsunamis, could affect increased vessel traffic and safety under the proposed action.

Landslides and Slope Instability

Increased vessel traffic related to the proposed action could result in a slight increase in erosion within the navigation channel and along the shoreline as the result of propeller wash or vessel wake. A ship's propeller generates a continuous stream of fast-moving water known as a propeller-induced jet (AMOG Consulting 2010:5). When a propeller-induced jet impinges directly on a seabed or channel bottom, it can resuspend soft bottom sediments, cause the erosion of channel banks and cut-lines, and physically damage aquatic vegetation and benthic communities. This is referred to as *propeller wash* and its effects are determined by a number of parameters including the depth of the waterbody; number, type, and diameter of propellers; distance between propellers and the seabed or channel bottom; size of the vessel; engine power; and maneuvering speed, among other factors. Potential effects of propeller wash on water quality and critical saltwater habitat are described in Section 3.3, *Water*, and Section 3.4, *Plants*, respectively.

Large tankers would be more likely to create turbulence that can erode bottom sediments than tugs or because the large propellers on these vessels are closer to the channel bottoms. The potential for increased erosion could be reduced if vessels were to call during higher tides (as discussed in Section 3.17, *Vessel Traffic*) because increased channel depth would increase the distance between the vessel's propeller and the channel bottom. Additionally, vessels associated with the proposed action are likely to be escorted into the harbor and maneuvered around the Terminal 1 dock and the turning basin by tugs, which have smaller propellers that operate nearer the surface, reducing the potential for propeller wash to impinge on the channel bottom and sides. However, as tugs maneuver a large vessel, they may create wakes perpendicular to the vessel and the navigation channel.

Vessel wake or waves caused by vessels transiting the harbor could increase shoreline erosion if large enough waves were to reach the shoreline with increased frequency and sufficient intensity to accelerate erosion. The location and extent of vessel wake effects would depend on a variety of factors, including climatic conditions, tidal conditions, vessel type, vessel location, and vessel speeds.

Operation of the proposed action at maximum throughput would add 400[10] tank vessel trips[11] through the harbor per year to the 436 large commercial vessel[12] trips under the no-action alternative (Section 3.17, *Vessel Traffic*). These additional trips would result in a small, incremental increase in the potential for impacts associated with wake compared to the no-action alternative. The implications of increased vessel wake are addressed in Section 3.3. *Water*, Section 3.4, *Plants*, and Section 3.5, *Animals*.

Additionally, and as discussed in Section 3.1.4.2, *Geology and Soil Conditions*, there is the potential for localized landslides around the harbor; however, these areas are located away from Terminal 1 and would not be large enough to affect vessel traffic within the harbor.

Earthquakes and Related Hazards

As discussed in Section 3.1.4.2, *Geology and Soil Conditions*, Grays Harbor and the area where vessels would travel out to 3 nautical miles from the mouth of the harbor is located in an area that has a potential for moderate to severe earthquakes. Although unlikely, these events could affect vessel traffic and waterway safety if the event was large enough to result in large waves, including tsunamis that could cause vessels to collide with one another or even to run aground in shallower areas.

Operation of the proposed action at maximum throughput would add one tank vessel trip per day on average to the one large commercial vessel trip per day under the no-action alternative (Section

[10] Proposed vessel trips are total for the facility so are not in addition to trips attributable to the applicant under the no-action alternative (approximately 14 per year).

[11] A trip represents one-way travel; in other words, an inbound trip and an outbound trip are counted as two trips.

[12] The term *large commercial vessels* refers collectively to tank and cargo vessels.

3.17, *Vessel Traffic*). Because there would be an increase in the number of vessels traveling in this corridor under the proposed action, these risks would be similar to, but slightly greater, than under the no-action alternative. The increased frequency of travel could result in a slight increase in the exposure of people and property to harm from earthquakes and earthquake-related hazards, such as those described above. The increased risks of exposure of the environment to crude oil or the other proposed bulk liquids (e.g., oil spills related to vessel accidents) that would be directly attributable to the proposed action are discussed in Chapter 4, *Environmental Health and Safety*.

3.1.6 What required permits apply to earth resources and conditions?

The following permit conditions and required plans are expected to reduce impacts related to earth resources and conditions.

- City of Hoquiam and City of Aberdeen Critical Areas Reviews for fish and wildlife habitat and geologically hazardous areas
  - Critical area review report
  - Buffer establishment and protection requirements
  - Buffer mitigation and monitoring requirements
  - Buffer activity limits and restrictions
- City of Hoquiam and City of Aberdeen Building Permits
  - Requirement for compliance with American Society of Civil Engineers 7 and American Petroleum Institute 650 design and construction standards, including climatic and geologic loading requirements
  - Erosion control plan
  - Geotechnical report
  - Shoreline substantial development permit
  - Critical areas review
- City of Hoquiam and City of Aberdeen Grade and Fill Permits

3.1.7 What mitigation measures would reduce impacts related to earth resources and conditions?

This section describes the applicant mitigation that would reduce impacts related to earth resources from construction and routine operation of the proposed action

3.1.7.1 Applicant Mitigation

The applicant will implement the following mitigation.

- To minimize the potential for impacts at the project site related to unstable soils, the applicant will review and update the construction mitigation measures identified in GeoEngineers (2006) and discussed in GeoEngineers (2014). These measures for site preparation and construction will be implemented during construction.

- Over-excavate the existing soil and compact the exposed soil to a uniformly firm and unyielding condition prior to placement of fill.
- Based on existing site grades and proposed development, standard erosion control measures are considered adequate; however, if construction and grading are staged, slopes may be created that require additional erosion control measures.
- For railroad spurs on site, support, over-excavate, and recompact materials so that there is a minimum of 2 feet of compacted fill.

- To minimize the potential for damage to the storage tanks related to geologic risks and unstable soils, the applicant will install pile-supported foundations that extend up to 75 feet deep for storage tanks to avoid excessive settlement from potentially liquefiable materials.
- To minimize the potential for damage to the storage tanks related to geologic risks and unstable soils, the applicant will develop final design specifications for proposed structures based on evaluation of the following more current standards/information (some of which were identified in GeoEngineers 2014).
  - U.S. Geological Survey ground-shaking report and maps released in July 2014 (Petersen et al. 2014).
  - American Petroleum Institute Standard 650 (2012).
  - International Building Code 2012.
- The applicant will ensure that a tsunami evacuation and emergency management plan is prepared prior to beginning project operations. This plan will consider evacuation planning, identification of safe havens, and identification of evacuation routes to natural high ground and will be developed in coordination with emergency management officials (City of Hoquiam, Grays Harbor County, Washington State, U.S. Coast Guard, ship captains, and pilots).

To reduce the potential for environmental damage related to a tsunami event, the applicant will conduct a study to assess the technical feasibility and cost of implementing measures to construct the proposed facilities to withstand a CSZ L1 tsunami wave based on the Scenario 2 inputs listed in Table 4 of the Tsunami Impact Modeling and Analysis (Appendix C). Agreed upon measures will be implemented prior to project design and construction in coordination with the co-lead agencies.

3.1.8 Would the proposed action have unavoidable and significant adverse impacts on earth resources and conditions?

Although the likelihood of a large-scale tsunami event is low, such an event would likely cause unavoidable and significant adverse environmental effects at or near the site if it occurred and the facility was not constructed to withstand it. The potential impacts in the event of a large scale tsunami would include oil spills, fires, or explosions which are discussed in Chapter 4, *Environmental Health and Safety*.