4.3 Risk Considerations

Impacts of a spill of oil or any hazardous material, should one occur, depend on multiple factors, such as the chemical properties of the spilled material and the environmental conditions at the time of the spill. These factors are described below.

4.3.1 How do the characteristics of spilled materials contribute to potential impacts?

The proposed action would involve the handling, storage, and transport of crude oil. These materials, described in the following subsections, have unique characteristics that contribute to spill risks and impacts.

4.3.1.1 Material Characteristics

Hazardous Materials Classification

The federal hazardous material regulations (49 CFR 171–180) require the proper classification and characterization of a material, which, in turn, determine its transportation requirements. Hazardous materials are categorized by analysis and experience into hazard classes and packing groups based on the risks they present during transportation. Characterization includes identifying the effects a material has on both the reliability and safety of the packaging that contains it. Crude oil's properties and characterization may vary considerably based on time, location, method of extraction, temperature at time of extraction or processing, and the type and extent of processing of the material (Section 4.3.1.2, *Crude Oil Properties*).

Currently, as shipped, crude oil is classified as Class 3 flammable liquid. The U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration (PHMSA) issued a safety alert on January 2, 2014, warning of potential crude oil variability. The alert emphasized conducting proper and sufficient testing to ensure accurate characterization and classification. The safety alert expressed PHMSA's concern that unprocessed crude oil may affect the integrity of packaging or present additional hazards related to corrosiveness, sulfur content, and dissolved gas content. The final rule issued by PHSMA in May 2015 (80 FR 26643) requires accurate classification and enhanced standards for transportation of highly flammable materials, including Bakken crude oil. The specifics of these requirements and the implications for safety in the study area are discussed in Section 4.5, *Environmental Health Risks—Rail Transport.*

Flashpoint

Flashpoint is the temperature at which a fuel will ignite when exposed to an open flame. The flashpoint is used as an index of fire hazard for hazardous materials. A Class 3 flammable liquid has a flashpoint of not more than 140°F (60°C) (49 CFR 173.120). The flashpoints of the crude oils considered under the proposed action—Bakken crude oil and diluted bitumen—are presented in Table 4.3-1 along with other crude oils and petroleum products for comparison purposes.

Table 4.3-1. Flashpoints of Crude Oils and Petroleum Products

Material	Flashpoint[a]
In Situ heavy crude	304°F / 151°C
Bakken crude oil	-73°F or -58°C to 230°F or 110°C
Heavy crude oil (conventional)	-22°F or -30°C to 140°F or 60°C
Light sweet crude	16°F/ -9°C
Diluted bitumen	-31°F/ -35°C
Gasoline	-31°F/ -35°C

[a] Chemical properties of crude oils and petroleum products are high individualized depending upon the source of the crude oil or the petroleum product. Flashpoints derived from other studies will most likely vary from the ones in this table.

Sources: Jokuty 2005 in Tsaprailis 2014; American Fuel & Petrochemical Manufacturers 2014; Polaris 2013.

Persistent and Nonpersistent Oils

Persistence describes how long oil persists in the environment and how the material may behave as it weathers or changes over time. Persistence is one of many factors that determine the impacts of an oil spill and the type and effectiveness of the recovery methods employed. Therefore, along with the amount of oil spilled, the physical characteristics of the area, and the local weather conditions, the persistence of the oil is incorporated into the development of response plans and evaluation criteria used by Washington State, the U.S. Coast Guard (USCG), and the U.S. Environmental Protection Agency (EPA). The definitions of persistent and nonpersistent oils are listed in Table 4.3-2.

Table 4.3-2. Definitions of Oil Persistency for Response Plan Regulations

Nonpersistent oils (Group I)	A petroleum-based oil that consists of hydrocarbon fractions: At least 50% of which, by volume, distills at a temperature of 340°C (645°F) At least 95% of which, by volume, distills at a temperature of 370°C (700°F)
Persistent oils (Group II to Group V)	Group II: specific gravity less than 0.85 Group III: specific gravity equal to or greater than 0.85 and less than 0.95 Group IV: specific gravity equal to or greater than 0.95 and less than 1.0 Group V: specific gravity equal to or greater than 1.0

Source: 40 CFR Part 112, Appendix E to Part 112 - Determination and Evaluation of Required Response Resources for Facility Response Plans, 33 CFR Part 155.1020 Definitions.

Generally, nonpersistent oils (Group I oils) such as diesel, kerosene, and gasoline have lower viscosity and dissipate quickly in the environment. However, rapid dissipation does not diminish the acute toxic effects of such oils on organisms if materials are spilled in higher quantities or on public health if the fumes are confined.

Persistent oils (Groups II through V) are heavier oils with higher viscosity that persist longer in the environment. Crude oil is a persistent oil. Bakken crude oil is a Group II oil and diluted bitumen is a Group III oil when transported and arguably behaves like a Group V oil upon weathering (Section 4.3.1.2, *Crude Oil Properties*).

4.3.1.2 Crude Oil Properties

Bakken Crude Oil

Bakken crude oil is considered an "unconventional" crude oil due to the unconventional method in which it is mined. Bakken crude is produced by hydraulic fracturing (fracking). Because of the way it is mined, Bakken crude is referred to as a shale oil. Large known shale oil reserves include the Bakken formation straddling North Dakota and Montana and parts of Saskatchewan and Manitoba (Canada) (Lee et al. 2015: 69).

As discussed in Chapter 3, Section 3.14, *Hazardous Materials*, Bakken crude oil is typically characterized as a light crude oil; it contains more volatile components and flows more easily (is less viscous) than heavier types of crude oil. Under response plan regulations (Table 4.3-2), Bakken crude oil is considered a Group II Persistent Oil. From a cleanup perspective, Bakken crude oil is easier to remove from the environment than heavier oils (Lee et al. 2015: 226). However, the volatility and flammability of Bakken oil could pose a concern for responders.

Diluted Bitumen

The bitumen imported into the United States is produced from Canadian oil sands. Bitumen is a highly viscous, nearly solid type of petroleum that occurs in natural deposits along with clay, sand, and water. Like Bakken, bitumen is also mined using unconventional methods. For transport, bitumen is diluted with diluents such as natural gas condensates, naphtha, or other light oils and called diluted bitumen (also known as *dilbit*). (Lee et al. 2015: 36, 73; National Research Council 2013: 34–35 and 47). Although dilbit is classified as a crude oil, the added diluent means that, when spilled into the environment, dilbit will behave differently than other heavy oils (National Oceanic and Atmospheric Administration 2015). As noted, dilbit is a Group III persistent oil when transported. Group III oils have a specific gravity equal to or more than 0.85 and less than 0.95. The specific gravity of fresh water is 1, which means that dilbit is less dense than fresh water and, if spilled in the environment, would initially float in fresh water and salt water. However, if spilled dilbit were to remain in the marine environment, the lighter components would evaporate and, as experienced during the 2010 Enbridge spill in the Kalamazoo River, Michigan, the leftover residue becomes denser than what was spilled initially.[1] The responders for the Enbridge spill found that after the oil remained in the environment for a few hours or days, it sank because its composition changed (weathered).[2]

Weathering Behavior

Oil weathering (how the physical and chemical characteristics of the spilled oil change over time) can affect the persistence of oil in the environment. The processes involved in weathering include the potential for spreading, evaporation, dispersion, emulsification, sinking, and biodegradation. Factors influencing the weathering behavior of Bakken oil and dilbit are summarized below and

[1] The 2010 Marshall Spill (Kalamazoo River in Kalamazoo, Michigan) from the Enbridge Pipeline occurred after a 30-inch pipeline ruptured on Monday, July 26, 2010, near Marshall, Michigan. The release was estimated at 843,000 gallons of diluted bitumen.

[2] During a study conducted in Gainford, Alberta in 2013 over a 10-day period, spilled dilbit crude oil did not submerge or sink under simulated weather conditions (Witt O'Brien's et al. 2013: 61). However, the study authors note that after weathering (particularly in a fresh water environment) and with the addition of sediment dilbit could become submerged (Witt O'Brien's et al. 2013: 41 and 60).

discussed in Appendix N, *Oil Spill Modeling*. Weathering behavior, or how spilled oil changes over time and persists in the environment, greatly influences how best to respond to an oil spill and the potential for environmental impacts.

Although crude oils generally contain the same classes of compounds, the amounts of the different compounds in each type of crude oil vary, producing different effects when the oil weathers in the environment. Table 4.3-3 shows a comparison of important crude oil properties, like viscosity, among different crude oils before a spill and after additional weathering.

Table 4.3-3. Comparison of Important Crude Oil Properties Prior to Release

Type of Crude Oil	Adhesion (g/m^2)	Density (g/cm^3)	Viscosity (mPa-s)	Flashpoint (°C/°F)
Light crude[a]	0	0.77	1	-30/-22
Weathered light crude[b]	9	0.84	5	95/203
Medium crude[c]	12	0.85	8	-10/14
Weathered medium crude	33	0.90	112	>110/>230
Heavy crude[d]	75	0.94	820	-3/26.6
Weathered heavy crude	600	0.98	475,000	>95/>203
Diluted bitumen[e]	98	0.92	270	-35/-31
Weathered diluted bitumen	1,580	1.002	50,000	>70/>158

Source: National Academies of Sciences, Engineering, and Medicine 2016.
[a] Scotia Light.
[b] After additional weathering.
[c] West Texas Intermediate.
[d] Sockeye Sour.
[e] Cold Lake Blend.
g/m^2 = gram per square meter; g/cm^3 = gram per cubic meter; mPa-s = millipascal-second

Crude oil exhibiting lower adhesion is easier to remove from the environment. Density is one indicator of whether the crude oil is likely to sink. Crude oils with a density approaching or greater than 1 gram per cubic meter are more likely to sink, particularly if they come in contact with even small amounts of sand, clay, or suspended sediment (National Academies of Sciences, Engineering, and Medicine 2016: 29). Viscosity is a measure of a flow resistance and influences how rapidly spilled oil spreads and how easy it may be to collect with traditional collection equipment. The flashpoint influences the extent to which the crude oil may be likely to ignite. A liquid with a flashpoint of less than 140°F (60°C) is considered to be flammable (U.S. Department of Transportation 2016).

Table 4.3-3 shows that Bakken crude (a light crude) exhibits relatively lower adhesion, density, viscosity, and flashpoint when compared to other types of heavier crude oils, with the exception of dilbit's flashpoint. In addition to the characteristics of the spilled oil, the effects of crude oil on the environment depend a great deal on how the oil is spilled and into what type of environment it is spilled.

Table 4.3-4 provides a qualitative comparison of the physical properties between weathered Bakken crude oil and other light crude oils if spilled in the environment and the comparative effects on cleanup. Light crude oils, such as Bakken, are slightly less viscous than medium crude oils and significantly less viscous than heavy crudes and will spread rapidly on the water's surface if spilled in a marine environment without a source of ignition. If ignited, however, Bakken crude oil will

burn. Firefighters and incident responders will determine the best methods to fight the fire. This could include applying firefighting foam, cooling tank cars with water, or monitoring the fire (U.S. Department of Transportation 2016). In the absence of an ignition source, the evaporation rate of a light crude oil like Bakken can be substantial (between 30 and 50% of the amount spilled) (Lee et al. 2015: 78). The oil remaining in the environment is less altered than weathered dilbit and more easily cleaned using traditional recovery methods (skimmers and sorbent materials).

Table 4.3-4. Comparative Discussion of Behavior of Bakken Crude Oil versus Other Light Crude Oils for Response and Cleanup Considerations

Property	Bakken Compared to Other Light Crude Oils	Cleanup Considerations
Viscosity	Similar to other light crudes.	Bakken crude oil will quickly spread and evaporate when spilled on water.
Density	Similar to other light crudes.	Oil will float on water's surface and can be recovered using conventional forms of spill response.
Flashpoint	Lower flashpoint than most other crudes in the U.S.	Is a flammable liquid. Should keep away from ignition sources.
Adhesion	No data	Adhesion is not a property of concern for light crude oils due to high rate of evaporation.

Sources: Washington State Department of Ecology 2015; Commonwealth of Massachusetts Department of Environmental Protection 2016.

Table 4.3-3 shows that dilbit tends to be more adhesive, dense, and viscous than other crude oils; however, the diluents that are added to bitumen to facilitate transport are volatile. Prior to a spill in the environment, dilbit is most likely to be classified as a flammable liquid for transport by rail or vessel, although weathered dilbit is not flammable. When dilbit spills and weathers, the diluent evaporates and the residual oil will increasingly adhere to surfaces (National Academies of Sciences, Engineering, and Medicine 2016). The density of dilbit prior to a spill is comparable to that of other oils classified as Group III or IV oils (Table 4.3-3). However, weathered dilbit rapidly approaches the density of a Group V oil, becoming greater than 1 and therefore more likely to sink in water. This property of dilbit may result in more spilled oil persisting in the environment if it is not recovered rapidly (using a vacuum, skimming, or manually) compared to other crude oils. This affects how rapidly on-water collection equipment would be required at the scene of a spill. As the diluent evaporates, the remaining dilbit residue becomes extremely viscous; more so than the weathered residue of other commonly transported crude oils (light and medium crudes), making it harder to collect with the required on-water containment and skimming equipment.

Weathered dilbit is best compared to the behavior of heavier crudes in the environment (rather than light and medium crudes), but there are important differences even between dilbit and heavy crude oils. Table 4.3-5 provides a qualitative comparison of the physical properties between weathered dilbit and heavy crude oils if spilled in the environment and the comparative effects on cleanup. Chapter 4, *Spill Response Planning and Implementation*, of the 2016 National Academies of Sciences, Engineering, and Medicine (2016) study contains additional information about the properties of dilbit and heavy crude and their implications for spill response.

Table 4.3-5. Comparative Behavior of Dilbit versus Other Heavy Crude Oils for Response and Cleanup Considerations

Property[a]	Dilbit Compared to Other Heavy Crude Oils	Cleanup Considerations
Viscosity	Slightly less viscous prior to release than a heavy crude oil. Rapidly approaches same level of viscosity to a heavy crude after initial weathering.	Although less viscous than a heavy crude spilled dilbit will leave more residue in the environment than the heavy crude as the diluents evaporate.
Density	Densities of weathered dilbit can approach and possibly exceed that of heavier crude oils.	The longer dilbit remains in the environment the more likely it will submerge unlike most other crude oils.
Flashpoint	Due to diluents, flashpoint prior to release is similar to light crude (lower than heavy crude). After a release, flashpoint increases as diluents evaporate.	Rapid containment of spilled dilbit is complicated due to flammability and volatile vapors unlike heavier crudes.
Adhesion[b]	More adhesive than heavy crude. Adhesiveness increases with additional weathering.	Adhesion of dilbit to the surfaces of rocks, manmade structures, and vegetation can impede cleanup.

Source: National Academies of Sciences, Engineering, and Medicine 2016.

[a] The properties as presented in this column are interrelated and affected by the ambient temperature and other environmental conditions.

[b] Adhesion is not a property that is measured during industry-standard analyses of crude oils but it is an important variable for spill cleanup.

4.3.2 What environmental factors contribute to potential impacts from an incident?

Factors such as the amount of oil spilled, product characteristics and persistence, physical characteristics of the area, local weather conditions, and water flow conditions can influence the outcome of a spill. These factors are important to consider for planning and responding to spills. This section provides information for these factors and describes how they influence the spill consequences.

4.3.2.1 Air Dispersion

Volatile vapors released from a spill may create flammable atmospheres or inhalation hazards. Air monitoring should be implemented as soon as possible by first responders. Responders should wear appropriate respiratory protection based on air monitoring results, such as air-purifying respirators or self-contained breathing apparatus to avoid potential exposure when responding. Climatic patterns that may affect the dispersion of vapors in the study area are presented in Appendix D, *Air Data.*

4.3.2.2 Weather Conditions

Weather conditions can influence the movement and spread of oil in the environment. Weather in the study area is typically windy and rainy in winter and relatively cool in summer, with some periods of fog in summer and, to a lesser degree, in the fall. Wind and fog conditions are often local to Grays Harbor. Winds recorded at Bowerman Airport (in Grays Harbor) are generally from the east or northeast during the winter and the west or southwest or directly from the south (less

frequently) during the summer. The strongest winds, more frequent during winter storms from October through March, reach gale force (34 to 40 knots) 3 to 6% of the time. Average wind speeds year round are generally 9 to 10 miles per hour. Storms are less frequent in the spring and summer.

In the winter, rain falls on about 15 to 25 days per month. Rainfall diminishes to 8 to 15 days per month in the spring and 5 to 10 days per month in the summer. Average temperatures range from 35 to 50°F in midwinter to a high of 68 to 69°F in the hottest summer months (July to August).

Weather near the lower Chehalis River is similar to weather in Grays Harbor. Further inland along the river toward Centralia, the weather is similarly mild. The interior of western Washington has slightly less measurable rainfall on record than along the coast (150 days each year versus 190 days along the coast) and temperatures are generally 10 degrees warmer in the summer months.

4.3.2.3 Water Flow

In addition to fog and swells caused by high winds, water flow conditions in the Bar Channel Reach of the Grays Harbor Navigation Channel (at the entrance of the harbor) vary depending on ebb or flood tidal currents, speed of the Chehalis River runoff, wind, and ocean swells just outside the entrance. Average current velocity is about 1.9 knots on the flood and 2.8 knots on the ebb but velocities have been known to reach 5 knots. The direction of the current near the bar can be erratic, running north close inshore and south offshore. In the harbor, current velocities in the navigation channels seldom exceed 3 knots. The tidal cycle in Grays Harbor is mixed semidiurnal (two high tides and two low tides in a 24-hour period with varied heights), which means that tidal height relative to mean low water ranges from less than 1 foot to almost 9 feet twice a day.

The discharge rate (flow) in the Chehalis River Basin is characterized by seasonal variation, with sharp rises of relatively short duration from October to March corresponding to the period of heaviest rainfall (U.S. Army Corps of Engineers 2003). A low flow of 731 cubic feet per second is based on the period of record (1952 to 2013) for the U.S. Geological Survey stream gauge at Porter, Washington. Higher flow events range from a 2-year flood (31,000 cubic feet per second) to a 100-year flood (83,000 cubic feet per second). Flow velocities for these flow events in the lower Chehalis River average 1.3 cubic feet per second for the low flow case, 4.0 cubic feet per second for the 2-year flow case, and 4.8 cubic feet per second for the 100-year flow case. These average velocities are influenced by the shallow gradient of the river and the backwater effect of the tidally influenced portion of the river. While these velocities can vary based on the tides, they are typical for a river with similar topography and hydrologic characteristics.