CHAPTER 2: GEOLOGY, SOILS, AND HAZARDOUS MATERIALS

2.1 Introduction

In this section, the regional and local geologic setting is described for the study area, including an overview of the geologic hazards that could be encountered. In addition, environmental databases were reviewed to evaluate the study area for sites that currently store hazardous materials or have had a documented release to the subsurface.

Changes from the DEIS

Chapter 2 includes analysis of the newly developed Preferred Alternative, which was not included in the DEIS. No other substantive revisions were made to this chapter, relative to the DEIS.

The following data sources were reviewed:

- Various past geotechnical investigations for multiple sites in the study area;
- King County Hazard Vulnerability Analysis (King County, 2009);
- Hazardous Materials Discipline Report for the study area (Environmental Data Resources [EDR], 2015); and
- Seattle Department of Planning and Development geographic information system (GIS) (City of Seattle, 2015).

2.2 Affected Environment

2.2.1 Regional Setting

The study area is located in the central portion of the Puget Sound basin. This is an elongated, north-south trending depression in western Washington, between the Olympic Mountain Range to the west and the Cascade Mountain Range to the east. The regional topography is characterized by a series of north-south trending ridges separated by deep troughs that are now Puget Sound, Elliott Bay, Lake Washington, and Lake Sammamish.

The regional topography was formed by the movement of glaciers over thousands of years. The glaciers were up to several thousand feet thick, and soils that were present beneath them are generally very hard and compacted as a result of the weight of the glaciers. More recently, erosional processes and landform changes resulting from human development have modified the regional topography. Geology in the region generally includes recent surficial soils over a thick sequence of glacially consolidated soils and then bedrock. Subsurface conditions may vary greatly and unpredictably over short distances due to changes in depositional history and urban development. Today, the topography of the region is characterized by rolling hills interrupted by troughs that were carved by the ice sheet and later occupied by large freshwater lakes and rivers (Liesch et al., 1963; Galster and Laprade, 1991; Troost and Stein, 1995; Yount et al., 1993).

2.2.2 Geology

The project is located along the north shore of Salmon Bay in a glacially exposed and eroded trough that is filled with glacial till, outwash, and lacustrine (lake) sediments. These glacial sediments were deposited directly by the glacial ice and by glacial meltwater and can be well over 1,000 feet thick in areas. As the glaciers retreated, glacial meltwater accumulated in lowland troughs, forming large bodies of deep fresh water, such as the pre-historic Glacial Lake Russell and Glacial Lake Bretz. The study area was under water within these large glacial lakes while they existed.

Increased contribution of glacial meltwater into the oceans at the end of the Pleistocene caused sea level to rise around the world until the land rebounded from the weight of the glacial ice. As a result of rebound, relative sea level in the Puget Lowland dropped below the modern shoreline during the early Holocene, about 11,000 years ago, exposing the study area (Dragovich et al., 1994). During historical times, deposition of industrial fill was commonplace along the Salmon Bay shoreline in the 1890s. Canal spoils were later placed along the shoreline during construction of the Lake Washington Ship Canal (Ship Canal). As a result, the wetlands along the coast were filled and the Salmon Bay shoreline was extended south of its original position.

Numerous previous geotechnical investigations have occurred within the study area, and the logs of 38 borings from 25 previously completed geotechnical investigations were reviewed to identify the underlying materials.[1] The boreholes from these investigations show that there is between 1 and approximately 17 feet of mixed clayey, gravelly, silty, sandy fill immediately beneath the study area. The fill is reportedly thickest along the Shilshole North and Shilshole South Alternatives within the area of the historical shoreline. Table 2-1 details the thickness of the fill along each alternative at various cross-streets.

Table 2-1. Estimated Fill Thickness in Feet from East to West Along Each Alternative Corridor

	Alternative			
Location	*Preferred Alternative*	*Shilshole South and Shilshole North*	*Ballard Avenue*	*Leary*
11th Ave NW	8.5	8.5	9	12
14th Ave NW	15	15	7.5	9.5
15th Ave NW	17	17	6	5
17th Ave NW	15.5	15.5	6	3
20th Ave NW	14.5	14.5	9.5	7
22nd Ave NW	7	7	3.5	9.5
24th Ave NW	7	7	1	7.5
26th Ave NW	13	13	11	8
28th Avenue NW	8	8	10.5	10.5
30th Avenue NW	8.5	8.5	N/A	9.5

[1] Aspect Consulting, 2002; Associated Earth Sciences, Inc., 2000; Converse Consultants NW, 1994a, 1994b; Converse, Davis and Associates, Inc., 1975; Dames and Moore, 1968, 1971, 1980; Dodds GeoSciences, Inc., 2003; Fowler, 2000; Geotech Consultants, Inc., 1998, 2004; Huckabay, 1979; Mann, 1989; Metropolitan Engineers, 1968; Rice, 1989; Seattle Department of Engineering, 1995; Seattle Public Utilities Materials Laboratory, 1969, 1970, 1972, 2002; Shannon & Wilson, Inc., 1973, 1999; Terra Associates, Inc., 2003; Tobin, 1999.

According to the borelogs, the fill includes debris such as brick, metal, and wood. The findings of these geotechnical investigations suggest that two former dump sites existed in the area, one near 11th Ave NW and NW 46th St, and the other near 28th Ave NW and NW Market St.

The fill is reportedly underlain by silty and organic-rich Holocene-aged alluvium or weathered gravelly, silty, and sandy glacial till. Where present, the Holocene-aged sand, silt, and peat beds derived from intertidal deposition are found between an average of 9.5 and 14 feet below ground surface (fbs). Holocene-aged deposits were most commonly encountered at the east and west ends of the project. Pleistocene till deposits were logged below the fill and Holocene-aged sand, silt, and peat beds across the study area.

2.2.3 Geologic Hazards

A consideration for the construction and operation of the alternatives would be the potential to encounter geologic hazards, erosion, seismicity, and settlement due to soft or unstable soils.

Erosion Hazards

Erosion hazards occur where soils may experience severe to very severe erosion from construction activities, or through changes in surficial conditions that expose soils to new erosive forces. Erosive forces can come from precipitation, changes in drainage patterns, removal of vegetation, wind, or wave action. Certain types of soil, such as silts, are generally more prone to erosion hazards.

Seismic Hazards

The Puget Sound basin is located within a seismically active area dominated by the Cascadia subduction zone, which forms the boundary between two tectonic plates: the North American plate and the Juan de Fuca plate. The project vicinity has been subject to earthquakes in the historic past and will undoubtedly undergo shaking again in the future.

Earthquakes in the Puget Sound region result from one of three sources:

- The Cascadia subduction zone off the coast of Washington,
- The deep intraslab subduction zone located approximately 20 to 40 miles below the Puget Sound area, or
- Shallow crustal faults.

The closest active crustal source is the Seattle Fault Zone, which runs roughly east-west approximately 6 miles south of the study area. A fault is considered active when it has shown evidence of displacement within the last 11,000 years. An earthquake on the Seattle Fault poses the greatest risk to the Seattle urban region (City of Seattle, 2017).

Deep quakes are the most common large earthquakes that have occurred in the Puget Sound region. Quakes larger than magnitude 6.0 occurred in 1909, 1939, 1946, 1949, 1965, and 2001 (City of Seattle, 2017). However, shallow quakes are the type expected on the Seattle Fault Zone, which can create more damage than deep quakes because of the proximity to the epicenter. However, damage from earthquakes depends on many factors including distance to epicenter, soil and bedrock properties, and duration of shaking.

Seismic hazards include the primary effects of earthquakes, such as ground displacement from fault rupture and ground shaking, as well as secondary effects including liquefaction, settlement, tsunamis, and seiche waves.

Earthquake-Induced Ground Rupture/ Ground Shaking. Earthquake-induced ground rupture is defined as the physical displacement of surface deposits in response to an earthquake's seismic waves. The magnitude, sense, and nature of fault rupture can vary for different faults or even along different strands of the same fault. Strong ground shaking from a major earthquake can produce a range of intensities experienced at any one location. Ground shaking may affect areas hundreds of miles distant from the earthquake's epicenter. The ground shaking can result in slope failure, settlement, soil liquefaction, tsunamis, or seiches, all of which pose a risk to the public.

Liquefaction. Liquefaction is of particular concern because it has often been the cause of damage to structures during past earthquakes. Liquefaction occurs where soil consistency is primarily loose and granular and located below the water table. Saturated loose soils within 50 feet of the ground surface are at most risk of liquefaction. The consequences of liquefaction include loss in the strength and settlement of the soil. The loss of strength can result in lateral spreading, bearing failures, or flotation of buried vaults and pipes.

Tsunamis/Seiche Waves. Tsunamis or seiches are possible secondary effects from seismic events. Tsunamis, often incorrectly described as tidal waves, are sea waves usually caused by displacement of the ocean floor. Typically generated by seismic or volcanic activity or by underwater landslides, a tsunami consists of a series of high-energy waves that radiate outward like pond ripples from the area in which the generating event occurred. For the Puget Sound region, either a large subduction zone quake off the coast or along the Seattle Fault could produce a tsunami. However, while a tsunami generated by a distant or Cascadia subduction earthquake could result in much damage to the coast, the impact in King County would not be as great. In the case of a subduction zone quake, a tsunami would travel from the coast through the Strait of Juan de Fuca into Puget Sound, and then south to Seattle. As a result, primary concerns lie with a tsunami or seiche generated by a land movement originating on the Seattle Fault (King County, 2009).

Seiche waves consist of a series of standing waves of an enclosed body or partially enclosed body of water caused by earthquake shaking, similar to what could be described as sloshing action. Seiche waves can affect harbors, bays, lakes, rivers, and canals. Both Puget Sound and Lake Washington could experience a seiche, as they did in 1891, 1949, and 1964. The "sloshing" effect of a seiche could damage facilities close to the water.

Other Hazards

Soft soil conditions can also be a form of geologic hazard, causing subsidence or settlement over the short or long term. Soft soils have low strengths and are compressible. Without appropriate design consideration, soft soils can lead to embankment failures during construction or long-term settlement after construction if left unaddressed. The presence of soft soils or soils that are not suitable to support new loadings (i.e., placement of fill or concrete) can only be determined on a site-specific basis through observation and laboratory testing of subsurface materials.

2.2.4 Hazardous Materials Sites

Each Build Alternative, including the Preferred Alternative, would include earthwork activities to relocate utilities, remove existing concrete and asphalt, construct railway crossings and stormwater drainage controls, and reconstruct driveways as well for the installation of other improvements. These include traffic controls, warning signs, and signals.

The study area has historically been used for industrial and commercial purposes since at least the late 1800s and is currently heavily developed for commercial, retail, and industrial use. Hazardous materials use is commonly associated with these types of land uses; with the long history, there is concern for past industrial and commercial land uses to have released hazardous materials and/or wastes to the subsurface.

A regulatory database review by EDR was conducted for the areas surrounding the entire study area. The EDR report was done in accordance with the U.S. Environmental Protection Agency's (EPA) Standards and Practices for All Appropriate Inquiries (40 Code of Federal Regulations [CFR] Part 312) and the American Society for Testing and Materials (ASTM) Standard Practice for Environmental Site Assessments (E 1527-13).

The databases reviewed and the number of sites included (see Appendix B for explanation of all databases reviewed):

- Federal National Priorities List (NPL) – 0;
- Federal Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) list – 0;
- Federal CERCLIS NFRAP – 6;
- Federal Resource Conservation and Recovery Act (RCRA) Corrective Action Sites (CORRACTS) Facilities List – 0;
- Federal RCRA non-CORRACTS TSD Facilities List – 0;
- Federal RCRA Generators List – 17;
- Federal Institutional Controls/Engineering Controls Registries – 0;
- Federal Emergency Response Notification System (ERNS) List – 238;
- State- and Tribal-Equivalent NPL – 7;
- State- and Tribal-Equivalent CERCLIS – 35;
- State and Tribal Landfill and/or Solid Waste Disposal Sites – 0;
- State and Tribal Leaking Storage Tank Lists – 11;
- State and Tribal Registered Storage Tank Lists – 40;
- State and Tribal Institutional Controls/Engineering Controls Registries – 5;
- State and Tribal Voluntary Cleanup Sites – 50;
- State and Tribal Brownfield Sites – 1;

- Local Brownfield Lists – 2;
- Local Lists of Landfill/Solid Waste Disposal Sites – 2;
- Local Lists of Hazardous Waste/Contaminated Sites – 209;
- Local Land Records – 0;
- Records of Emergency Release Reports – 95;
- Other Ascertainable Records – 297;
- EDR High Risk Historical Records (e.g., gas stations, dry cleaners) – 182;
- Exclusive Recovered Government Archives – 39.

The area searched varied for these databases and ranged from a quarter mile up to 1 mile in accordance with ASTM E 1527-13. A total of 1,747 sites were identified within the 1-mile search area with 1,235 located either along the different alternative alignments or within one-eighth mile of the study area. These databases include sites that have identified releases of hazardous materials into the environment and sites that have identified the use of hazardous materials and not necessarily any known releases (e.g., the RCRA small and large generators list, solid waste disposal sites, and identified underground storage tank sites). Sites with known releases can be in varying stages of investigation and cleanup, from attempting to determine the lateral and vertical extent of contamination up to nearing completion of remediation.

2.3 Potential Impacts

2.3.1 No Build Alternative

Construction

Under the No Build Alternative, there would be no new construction activities and therefore no disturbance of soils that could lead to erosion or loss of topsoil.

Operation

Any existing geotechnical hazards, such as ground shaking or settlement of soils, would remain for existing structures and improvements. Otherwise, there would be no new trail improvements and therefore no new risks associated with any hazards that may be present within the study area.

2.3.2 Preferred Alternative

Each element of the Preferred Alternative was previously analyzed in the DEIS (except for an approximately 125-foot section on the west side of 24^{th} Ave NW, as described in Chapter 1). The Preferred Alternative does not result in any newly identified geotechnical hazards. As such, the previously identified impacts and mitigation relating to construction and operation would still occur, as described below.

Construction

Earthwork activities during construction could encounter contaminated soils from past land uses that released hazardous materials to the subsurface. As described in Section 2.2, Affected Environment, the study area contains a large number of sites (1,235 somewhat evenly spread throughout the study area and immediate vicinity) associated with current hazardous materials use and past release incidents. The release sites can range from relatively minor incidents with little to no threat to human health or the environment, to more extensive sites affecting areas beyond site boundaries and requiring substantial remediation efforts. According to information obtained from the database search, many of the contaminated sites in the study area are associated with leaking underground storage tanks (former automobile service stations), dry cleaning operations, industrial manufacturing, and mechanical maintenance facilities (EDR, 2015). No federal NPL sites (also referred to as Superfund) were identified in the database search (EDR, 2015).

In general, releases affect areas localized to the source (e.g., the underground storage tank) and typically only affect soils within a limited area. Many times, these affected subsurface soil areas are found within a site boundary but can extend off site. Incidents that represent large releases or small releases that occur slowly over long periods of time, such as a leaking underground storage tank, can adversely affect underlying groundwater. Depending on site-specific conditions, releases of water soluble hazardous materials (such as many solvents and gasoline) can migrate considerable distances from the source. For many of the identified release sites within the study area, the releases have been adequately investigated and have received the appropriate remediation such that no further threat to human health or the environment exists. Other cases are in various stages of characterization to define the lateral and horizontal extent of contamination or are in the process of remediation activities.

Therefore, based on the high volume of identified sites within the study area as well as the history of commercial and industrial land uses, there is a relatively high probability of encountering legacy contaminants during construction of the Preferred Alternative. If not managed appropriately, construction workers could be exposed to these contaminants in soil or groundwater through excavation or other ground-disturbing activities. However, a Soil Management Plan, as included in the mitigation measures below, would establish appropriate methods for the identification of suspect soils, handling requirements to limit exposure, as well as any follow-up that may be required to protect the workers or the public from any adverse effects.

Operation

Operation of the trail would have minimal impacts to soil and geology in the study area. Once construction is complete, the potential for erosion or contact with legacy contaminants would be largely eliminated through the replacement of any excavation with compacted soils or engineered fill and covering by asphalt.

Seismic activity is likely to occur during the life of the proposed improvements and could be substantial, resulting in significant damage to the region. Seismic activity can cause primary hazards such as ground shaking or secondary effects including liquefaction. Liquefaction of soils during an earthquake could result in vertical and lateral displacements of paved areas and subsurface utilities, potentially resulting in substantial damage or injury. The liquefaction potential along the alignment for the Preferred Alternative would be confirmed during the design stage through preliminary geotechnical investigations. Design of improvements and utilities to resist seismic forces and secondary effects such as liquefaction would be required. Liquefiable soils can be addressed through excavation and replacement with engineered fill, treatment of site soils, or use of flexible utility connections.

In general, proposed improvements would be relatively minor and not very susceptible to settlement or instability. Geotechnical investigations would identify underlying materials and their engineering properties. Soils unsuitable for use as structural fill, such as expansive soils or compressible soils, could require removal and off-site disposal. However, with implementation of geotechnical recommendations by a state-licensed geotechnical engineer, the engineering properties of the underlying soils would be identified and any hazards ameliorated such that subsurface soils are suitable for the overlying improvements enabling long-term stability.

2.3.3 Shilshole South, Shilshole North, Ballard Avenue, and Leary Alternatives

Construction

Potential impacts for these Build Alternatives would be similar to those described above for the Preferred Alternative. While the Shilshole South, Shilshole North, Ballard Avenue, and Leary Alternatives would disturb different locations than the Preferred Alternative, they would all still have a relatively high probability of encountering legacy contaminants. As described in Section 2.3.2 for the Preferred Alternative, the implementation of the mitigation measures below would reduce potential impacts to less than significant levels.

Operation

As described in Section 2.3.2 for the Preferred Alternative, all grading and construction would adhere to the specifications, procedures, and site conditions in the final design plans, which would comply with applicable seismic recommendations.

2.3.4 Connector Segments

Potential impacts for the connector segments would be similar to what is described in Section 2.3.2 for the Preferred Alternative. The connector segments would represent a reduced area of disturbance, and thus the erosion potential would be reduced as well as the likelihood of encountering legacy contaminants.

2.4 Avoidance, Minimization, and Mitigation Measures

2.4.1 Measures Common to All Alternatives

The following measures would be used to minimize impacts related to soils and hazardous materials:

- Have a Washington-licensed geotechnical engineer design the project facilities to withstand probable seismically induced ground shaking, as well as any other geotechnical hazards that may be present.

- All grading and construction would adhere to the specifications, procedures, and site conditions in the final design plans, which would comply with applicable seismic recommendations.

- Use construction best management practices (BMPs) as detailed in a Stormwater Pollution Prevention Plan (SWPPP) to minimize the potential for erosion; this may include the installation of silt fences, use of hay bales, or application of soil stabilization measures.

- Implement BMPs such as dedicated refueling areas, following manufacturer's specifications on hazardous materials storage and disposal, and having on-site spill response supplies to control accidental upset conditions.
- Prepare and implement a Soil Management Plan during all earthwork activities.
- Stop construction activities upon the discovery of potentially contaminated soils or groundwater (e.g., petroleum odor and/or discoloration) in order to isolate, cover, and sample the material to determine appropriate disposal in accordance with SDOT construction standards and applicable regulations.
- Dispose of contaminated materials at a licensed facility in accordance with transportation laws, the requirements of the receiving facility, and all other applicable regulations.

2.4.2 Specific Mitigation

There would be no specific mitigation measures for geology, soils, and hazardous materials associated with the different alternatives.