# SECTION 3.1 EARTH
## (WAC 463-42-302)

### 3.1.1 INTRODUCTION

This section provides information on earth resources in the subsections listed below, including existing conditions, potential impacts, and where appropriate, mitigation measures. Included in this section are detailed descriptions for the following information:

- Hazard Maps (Section 3.1.2)
- Geologic Survey (Section 3.1.3)
- Seismic Activity (Section 3.1.4)
- Soils (Section 3.1.5)
- Topography (Section 3.1.6)
- Unique Physical Features (Section 3.1.7)
- Erosion and Enlargement of Land Area (Accretion) (Section 3.1.8)

The proposed pipeline and facilities will be located in both eastern and western Washington. Across the state, geology, soils, and seismicity differ with the diverse terrain and climate. Areas ranked as high erosion potential were generally avoided. However, the proposed pipeline corridor does cross several areas with mapped erosion potential. For these areas, site-specific measures have been developed during the project design to mitigate the potential hazards. Due to the corridor location and the use of both standard and site-specific mitigation measures, impacts on the natural earth environment from the pipeline construction and operation are expected to be minor.

### 3.1.2 HAZARD MAPS

Appendix B contains a series of maps that identify topography, geology, and erosion potential along the pipeline corridor. The maps were created beginning with a compilation of readily available geologic maps and a review of aerial photographs for the proposed alignment. This information was supplemented by an aerial reconnaissance of the entire route. Using these three sources of information (available geologic mapping, a review of aerial photography, and an aerial reconnaissance of the entire route), areas were selected for field reconnaissance to determine the extent (low, medium, or high) of the hazard. Relative mass wasting hazards and areas of potential liquefaction are also depicted on these maps.

### 3.1.3 GEOLOGIC SURVEY

#### 3.1.3.1 Overview

In much of Washington state, bedrock commonly underlies deposits left from the several glaciations that affected North America during the Pleistocene epoch (approximately 2 million to 10,000 years ago). These deposits are generally unconsolidated sands, silts, and gravels.

West of the Cascade Range, the deposits are generally characterized by glacial drift and reworked glacial deposits overlying bedrock. East of the mountains, the deposits are generally water or wind deposited glacial debris. Underlying the surficial deposits at variable depths across the proposed pipeline alignment are Mesozoic or younger sedimentary rocks and Tertiary volcanic rocks associated either with the Cascade volcanic chain or the flood basalts of the Columbia Plateau.

For portions of the area east of Ellensburg, the pre-existing soils were generally removed by the Bretz Flood which appears to have occurred at the time of the most recent glacial advance into the Pacific Northwest, approximately 11,000 years ago (Easterbrook, 1986). The flood water is theorized to have originated behind an arm of a glacier in the area of present-day Missoula, Montana. A series of floods apparently occurred which inundated portions of eastern Washington before draining to the west though the Columbia River Gorge. The flood waters deposited sand to cobble size material that is visible near the rivers throughout eastern Washington.

#### 3.1.3.2 Nature of Foundation Materials

This subsection summarizes the nature of the foundation materials within the pipeline corridor starting at the western end and progressing eastward.

Portions of the proposed corridor have relatively undisturbed near-surface soils. Within the BPA right-of-way, areas of the corridor have been modified by primitive road building to allow for the installation and maintenance of the transmission lines. The proposed corridor also crosses agricultural and mixed land use areas, as well as existing logging roads where the soils have been disturbed. For the purpose of discussion, the geologic and soil conditions have been divided into sections based on similarity. Reference throughout this section is made to specific page numbers of the Geologic, Topography & Mass Wasting Hazard (GTMWH) maps located in Appendix B.

**Thrasher Station to Snoqualmie:** The route begins at the Thrasher Pump Station. The Thrasher Pump Station site is mapped as underlain by dense to very dense glacial till soil.

Referring to the GTMWH map page numbers 1 through 14, the geology from the Thrasher Pump Station

to approximately Snoqualmie consists predominantly of material deposited during the advance and retreat of the most recent glaciation in the Puget Sound Region approximately 11,000 years ago (Easterbrook, 1986). The glacial action of thousands of feet of ice, originating in the area which is now British Columbia, carved the pre-existing topography and deposited soil materials removed by the advancing ice mass, including interlying sequences and dense mixtures of clayey silt, silt, sand, gravel and boulders.
Glacial outwash (Qgo), granular soil deposited by streams and rivers flowing from the glaciers, was deposited both during the advance and recession of the glacial events. Glacial outwash is found throughout this section, often within the vicinity of existing drainages. The outwash material normally has moderate densities.

The segment of soil deposited during the advance of the glacial ice mass was often overridden and consolidated to form a very compact soil, or glacial till (Qgt). The compact glacial till soils are generally present near the ground surface. Glacial till is relatively dense to very dense.

The lower sideslopes of the west bank of the first crossing of the Snoqualmie River (page number 5 of the GTMWH maps) has been mapped as underlain by glacial gravel (Qpg), as well as mixtures of glacial and non-glacial deposits (Qpf) consisting of clay and stratified sand and gravel which were apparently deposited before the Fraser glaciation. The glacial and non-glacial deposits are also present north of the Tolt River crossing (page number 11 of the GTMWH maps) and on the north and south sides of Griffen Creek (map Atlas Page Number 12). The proposed alignment crosses non-glacial deposits between stream crossing numbers 35 and 37 (GTMWH map Page Number 14).

During interglacial periods, relatively lower density silt to boulder-size materials, and organic peat, were deposited in lake and stream, or alluvial, environments. The alluvial deposits (Qa) are generally observed in lakes, streams and rivers present within the glaciated landscape, including the valleys of the Snohomish River, Cherry Creek, Tolt River, and Snoqualmie River. The alluvial materials normally have low to moderate densities. However, a geotechnical investigation was completed for this assessment at the proposed crossing of the Tolt River. One boring was completed for the investigation. The results of the investigation confirmed the presence of alluvium consisting of poorly-graded gravel underlain by silt and silty sand with depth. However, the alluvium was observed to be very dense. The density of the material indicates that the material has been reworked by the fluvial action.

Since the period of glaciation, the topography and surficial geology of the subject area has been modified mostly by erosional and weathering processes. These processes have included surface water action, including streams and sheet erosion, and mass wasting of slopes. The mapped mass wasting deposits (Qls) are limited to several relatively small areas on the south sides of Cherry Creek (GTMWH map Page Number 8) and the Tolt River (GTMWH map Page Number 11) and are discussed in the following subsection of this report.

Isolated areas of mapped shallow bedrock occur throughout this portion of the proposed alignment. More specifically, an outcropping of Tertiary-age sedimentary rock (Ts) is mapped to the north of the proposed alignment on GTMWH map Page Number 3. Approximately 1,500 feet of the alignment on GTMWH map Page Number 4 crosses an area mapped as underlain by Tertiary-age sedimentary rocks (Ts).

The segment of the proposed alignment from Peoples Creek (stream crossing 15 on GTMWH map Page Number 6) to the North Fork Cherry Creek Tributary (stream crossing 18 on GTMWH map Page Number 7), or approximately 4-1/2 miles of the proposed alignment, crosses portions of area mapped as underlain by Tertiary-aged volcanic (Tan). The andesite is volcanic in nature and can be relatively massive. An isolated section of the Tertiary-aged andesite, less than 1,500 feet in length, is crossed by the proposed alignment approximately 1-1/2 miles north of the Snoqualmie River, as shown on GTMWH map Page Number 14 (USGS Map, 1993).

**Snoqualmie to Interstate 90 East of North Bend:** The geology within the Snoqualmie River valley, from approximately stream crossing 37 (GTMWH map Page Number 14) to crossing 43 of the South Fork Snoqualmie River (GTMWH map Page Number 17) consists primarily of relatively loose alluvium composed of silt, sand and gravel (Qa). As noted in the previous section of the proposed alignment, the alluvial materials normally have low to moderate densities. The alluvium is underlain by bedrock at depth, but is expected to occur below the anticipated depths of installation for the pipeline. The depth of the alluvium has been noted to be in excess of 50 feet in the area of crossing 38 of the Snoqualmie River (GTMWH map Page Number 14)(Dames & Moore, 1977a and 1977b). Ground water has been noted to be relatively shallow and generally coincident with the levels of water within the Snoqualmie River.

**Interstate 90 East of North Bend to the Snoqualmie Tunnel Western Portal:** The geology for the portion of the proposed alignment between the crossing of stream 43 east of Interstate 90 (GTMWH map Page Number 17) and the western portal for the railroad tunnel immediately west of Rockdale Creek (stream crossing 84 on GTMWH map Page Number 24) has been mapped as consisting of the following: 1) relatively loose alluvium (Qa) and moderately dense glacial outwash (Qgo) (both consisting of mixtures of silt, sand and gravel) within the valley floors; 2) glacial ice contact soils (Qgi) consisting of relatively compact mixtures of fluvial clay, silt, sand, gravel, and minor till generally situated along isolated flanks of the valley; 3) isolated mapped landslide materials (Qls), and 4) relatively shallow bedrock for the portions of the alignment situated along the steeper valley sidewalls. The bedrock has been mapped as Tertiary argillite and graywacke (Tar) consisting of marine sandstone and argillite; volcanics (Tv); granite (Tg); metagabbro (Tmg); Tertiary rhyolite (Trh); and sedimentary sandstone, siltstone, shale, and conglomerate (Ts).

The alluvial and glacial soils are generally loose to moderately dense, and are anticipated to contain cobbles and boulders. In contrast, the sections of the proposed alignment which cross the Tertiary bedrock would likely encounter competent bedrock at depth.

The mapped strikes and dips of bedding and foliation within bedrock crossed by the proposed pipeline were relatively sparse but indicated orientations generally perpendicular to the valley walls, except for the section immediately west of the western tunnel portal, which was noted to dip downslope.

**Snoqualmie Tunnel Western Portal to the Crossing of the Yakima River:** The section of the proposed pipeline alignment from the western tunnel portal immediately west of Rockdale Creek (GTMWH map Page Number 24) to the crossing of the Yakima River (GTMWH map Page Number 41) generally consists of glacial materials near the surface of the valley floor and bedrock near the surface of the valley sideslopes (USGS Map, 1984). The proposed pipeline is situated both near the base of the slope and on the valley floor for this section of the alignment.

More specifically, the geology for the existing tunnel at Snoqualmie Pass has been mapped as consisting primarily of Tertiary-age rhyolite (Trh) and sedimentary bedrock (Ts)(GTMWH map Page Number 24 and 25). The sedimentary bedrock has been mapped to include shale, siltstone, sandstone, and conglomerate. An anticline has been mapped as being oriented nearly north-south between Surveyors Lake and Hyak Lake. The bedding of the bedrock has been mapped to generally parallel the orientation of the anticline. As would be expected, the bedrock generally dips away from the axis of the anticline.

The segment of the alignment between the eastern tunnel portal (GTMWH map Page Number 25) and the proposed Stampede Pass Pump Station (GTMWH map Page Number 28) consists primarily of alpine glacial deposits (Qag) and Tertiary rhyolite (Trh), sedimentary (Ts), volcanics (Tv), tuff and breccia (Ttu). The orientation of foliation within the bedrock for the segment of the proposed alignment along the northern portion of Keechelus Lake was mapped as being generally parallel to the valley walls, and dipping downslope, resulting in some talus near the base of steep rock outcroppings. In contrast, foliation was not mapped for the remaining segment of the pipeline along Keechelus Lake, however, the bedrock bedding was mapped as being generally perpendicular to the valley walls.

The segment of the pipeline from the proposed Stampede Pass Pump Station to Lake Easton (GTMWH map Page Number 32) has been mapped as being underlain by Quaternary alluvium (Qa), glacial till (Qgt), and alpine glacial deposits (Qag) within the Yakima Valley bottom, and Tertiary bedrock along the valley walls consisting of rhyolite (Trh), volcanics (Tv), and Naches Formation (Tn) rock; the Naches Formation includes rhyolite, andesite, basalt flows, tuff, and breccia with interbeds of sandstone and siltstone and rare coal. The mapped bedrock bedding orientation for this section of the alignment is relatively random.

The glacial soils are anticipated to be moderately dense to dense and are anticipated to contain cobbles and boulders. A number of segments within this section of the proposed alignment are mapped as underlain with shallow bedrock, including: 1) approximately 4-1/2 miles on GTMWH map Page Numbers 25, 26, and 27; 2) approximately 1-1/2 miles on GTMWH map Page Numbers 29 and 30; approximately 2-1/2 miles on GTMWH map Page Numbers 31 and 32; 3) approximately 3,000 feet on GTMWH map Page Numbers 33 and 34; 4) approximately 2,300 feet on GTMWH map Page Number 35; 4) approximately 7,000 feet on GTMWH map Page Number 36; and 5) approximately 2,000 feet on GTMWH map Page

Number 37.

**Crossing of the Yakima River to the Kittitas Terminal:** The geology for the portion of the proposed alignment from the crossing of the Yakima River (GTMWH map Page Number 41) to the Kittitas Terminal (GTMWH map Page Number 52) has been mapped as alluvium (Qa) adjacent to the river, and a combination of basalt and landslide materials on the slope to the east of the crossing. From the top of the slope to the Kittitas Terminal, the near-surface geology has been mapped as a combination of alluvium of varying age, with local areas of shallow bedrock and glacial till.

The geology at the proposed crossing of the Yakima River was investigated for this assessment. The investigation consisted of three borings and a bathimetric survey of the Yakima River. Two of the borings were completed on the south side of the crossing in a landslide described in Dames & Moore, 1996. The borings encountered interlying low to moderate density sand and moderate density silt with low plasticity. The water depth at the crossing was disclosed to be less than 6 feet at the time of the survey (Dames & Moore, 1996).

From the top of the slope, the proposed pipeline alignment crosses moderate slopes underlain by glacial till (Qgt) and shallow Tertiary basalt (Tb). At the crossing of Swauk Creek (GTMWH map Page Number 43), the proposed alignment circumvents a mapped landslide deposit (Qls) before ascending a relatively steep slope (less than 45 degrees and 100 per cent) mapped as underlain by Tertiary basalt. The remainder of the alignment to the Kittitas Terminal consists of gentle to moderate slopes generally underlain by Quaternary aged alluvial deposits (Qa and Qoa). These sediments are clay-rich sands and gravels which were deposited from rapidly aggrading braided streams which flowed from the highlands to the north. In many places these streams eroded into Tertiary age alluvial gravels (Tal) of similar depositional style, but which now form higher terraces. An isolated exposure of Tertiary basalt has been mapped on GTMWH map Page Number 47; less than 1,500 feet of the basalt is crossed by the proposed alignment.
Northwest of Ellensburg, the pipeline corridor crosses Dry Creek (MP 100.5) and enters the Quaternary aged alluvial fan deposits of the Kittitas Valley. These sediments are clay-rich sands and gravels (SCS, unpublished data) which were deposited from rapidly aggrading braided streams which flowed from the highlands to the north. In many places these streams eroded into Tertiary age gravels of similar depositional style, but which now form higher terraces of consolidated gravel such as the Thorpe Gravels (Tabor, et al., 1982). At Reecer Creek Road, the alignment turns to the southwest, leaves the BPA easement, and continues across the fan deposits to the town of Kittitas.

**Kittitas Terminal to the Columbia River:** The section of the proposed pipeline from the Kittitas Terminal (GTMWH map page number 52) to the Columbia River (GTMWH map Page Numbers 62a, 62b, 63, 64, 64a, 65a) includes a series of alternate routes which are primarily underlain by Tertiary basalt (Tb) bedrock. Relatively narrow deposits of Quaternary alluvium (Qa) are present in Johnson Canyon and along Canyon Creek, and Quaternary fluvial gravels (Qfg) are present on the terraces above the west side of the Columbia River.

Specifically, the proposed alignment is parallel and adjacent to the north right-of-way line of I-90 to Park Creek for approximately 2.3 miles after leaving the Kittitas terminal. This portion of the proposed alignment is underlain by fill material, Quaternary alluvium (Qa) and Tertiary alluvium (Tal). The proposed alignment climbs a slope onto a ridge underlain by Tertiary basalt (Tb) bedrock north of Johnson Canyon (GTMWH map Page Number 54). The alignment then drops down the ridge and crosses recent alluvial fill (Qa) on the canyon floor (GTMWH map Page Number 55).

In the vicinity of stream crossing 208 (GTMWH map Page Number 55), the proposed route and two alternate routes proceed to the Columbia River to the east; the proposed route is north of I-90 and the two alternatives are south of I-90. The proposed route and alternatives are shown on Figure 2.1-2 in Section 2.1. The proposed route is made up of Segments #1, 2, 9, 14, 15, 17, 18, 21, and the horizontal directional drill across the Columbia River.

The proposed route crosses approximately 1,500 feet of Quaternary alluvium (Qa) and then rises up a Tertiary basalt (Tb) ridge and follows this ridge line to the west side of the Columbia River (GTMWH map Page Number 61a). The route then turns to the south crossing a dormant Quaternary landslide (Qls) approximately 4,000 feet wide (GTMWH map Page Numbers 61a and 62a), and then crossing an area of Tertiary basalt (Tb) before encountering the Quaternary alluvium (Qa) at the mouth of Canyon Creek. From Canyon Creek (GTMWH map page 63), the proposed route continues south across Tertiary basalt and approximately 2000 feet of Quaternary alluvium at the west bank of Columbia River (GTMWH map Page Numbers 63 and 64). The proposed route, which crosses the Columbia River immediately south of the Wanapum Dam, and the alternative route which would cross the river on the Beverly Railroad Bridge cross Tertiary basalt and fluvial gravels before reaching the river.

A variation of the northern route was analyzed to enable a connection with either the I-90 bridge crossing or the dredged crossing north of the I-90 bridge. This route (shown as Segment 3 on Figure 2.1-2) would continue to the east, briefly crossing a deposit of Quaternary fluvial gravels (Qfg), and then returning to the Tertiary basalt (Tb) before reaching the Columbia River (GTMWH map Page Number 62b). This route then splits into two segments: one which heads directly east approximately 2,000 feet across the fluvial gravels and fill, crossing the Columbia River at Interstate 90, and one which heads south parallel to river over the fluvial gravels for approximately 3.0 miles. (GTMWH map Page Number 62a).

One alternative route, described in the February 1996 Application for Site Certification, crosses the Yakima Training Center (YTC), and proceeds to the southeast in a relatively direct manner to Wanapum Dam. This route, and another alternative which is along the northern fence line of the Yakima Training Center, follow Johnson Canyon for approximately 2 miles before rising up a Tertiary basalt (Tb) ridge (GTMWH map Page Number 56). The two alternatives follow approximately parallel alignments up the ridge through the Ryegrass Mountains until one of the alignments diverges immediately northwest of a small Quaternary landslide (Qls) deposit (GTMWH map Page Number 61). This alternative heads south and eastward across Tertiary basalt (Tb) for approximately 4.5 miles until encountering Quaternary alluvium (Qa) associated with deposition along Canyon Creek (GTMWH map Page Number 63).

The second alternative (GTMWH map Page Number 61) traverses Tertiary basalt (Tb), avoiding small Quaternary landslide deposits (Qls), and continues as Segment #13. This alternative crosses a fault in the basalt and then turns south into the dormant landslide where it merges with the proposed pipeline route into a single alignment (GTMWH map Page Number 62a). The subalternative then again splits into two routes: one route heads southwest and encounters Quaternary alluvium (Qa) at Canyon Creek (near stream crossing 221) where it intersects the proposed alignment. To connect to an alternative crossing location at Wanapum Dam, the alternative route heads southeast crossing Canyon Creek at Gettys Cove and then continues across Tertiary basalt (Tb) and Quaternary alluvium (Qa) until it reaches Wanapum Dam (GTMWH map Page Number 64).

**Columbia River Crossing:** On the west side of the river, the surficial deposits consist of either fill, Quaternary alluvium (Qa) or Quaternary fluvial gravels (Qfg) at each of these four crossings. On the east side of the river, a band of Quaternary fluvial gravels (Qfg) approximately 2,000 to 5,000 feet wide is present at each of these crossings. Tertiary basalt (Tb) or Quaternary fluvial gravels (Qfg) are mapped at the surface on both sides of the river at the two crossings.

The Quaternary fluvial gravels (Qfg) described above consists of Pleistocene aged (approximately 20,000 years before present) materials associated with the Bretz Floods. The remainder of the proposed alignment from the Columbia River to the terminus at Pasco, Washington, follows land which in one way or another has been affected by these floods.

**Columbia River Crossing to Corfu Reroute:** This section of the proposed pipeline from the Columbia River (GTMWH map Page Numbers 62b, 63, 64, and 65a) to the junction with the Corfu alternate route (GTMWH map Page Number 77) includes the five alternate routes which cross the river and then rise out of the river gorge. The proposed alignment is a horizontal directional drill across the river approximately 3,000 feet downstream of Wanapum Dam. This alignment crosses Quaternary fluvial gravels (Qfg) and Tertiary basalt (Tb). On the east side of the river, the proposed alignment and the alternatives from the north and south converge into a single alignment at the Beverly-Burke Pump Station. East of the Beverly-Burke pump station, the proposed alignment then crosses primarily onto beds of the Tertiary Ringold Formation (Tre, Trl, and Tru) with minor occurrences of Tertiary basalt (Tb). The Ringold Formation (Tre) in this area is a weakly indurated fine, silty sand which weathers to a loamy fine sand. Just west of stream crossing number 229 (GTMWH map Page Number 68), the proposed alignment turns northeast and then continues east on similar soils for approximately 3.6 miles. The proposed pipeline then continues southeast for approximately 9 miles parallel to State Route 26 crossing primarily Tertiary basalt with only minor occurrences of Ringold Formation and Quaternary fluvial gravels. Immediately east of stream crossing 240 (GTMWH map Page Number 75), the Tertiary basalt ends and the pipeline crosses Quaternary fluvial gravels until the end of this section.

**Corfu Landslide and Reroute Around Corfu Landslide:** This section from the beginning of the Corfu Alternate Route (GTMWH map Page Number 77) to the end of the alternate route (GTMWH map page number 80) bypasses the Corfu landslide by following the alignment of Highway 26.

The proposed route crosses over deposits of Quaternary fluvial gravels (Qfg), Quaternary alluvium (Qa), and Tertiary basalt (Tb) for approximately 5 miles. Through this section, the pipeline crosses Lower Crab Creek and several of its tributaries. The alternate route then turns south (GTMWH map Page Number 80) and crosses the Tertiary Ringold Formation lacustrine deposits (Trl) before intersecting with the original pipeline route.

**Corfu to Wahluke Slope:** East of the Corfu Landslide (GTMWH map Page Number 80) to the Wahluke Slope (GTMWH map Page Number 82), the proposed pipeline alignment follows Kuhn Road and crosses through approximately 3.6 miles of the Tertiary Ringold Formation lacustrine deposits (Trl) along the northern edge of the Saddle Mountains. The pipeline then crosses folded Tertiary basalt (Tb) and Quaternary loess (Ql) deposits at the Wahluke Slope.

**Wahluke Slope to the Othello Channel:** From the Wahluke Slope (GTMWH map Page Number 82) to the Othello Channel (GTMWH map Page Number 86), the proposed pipeline alignment crosses deposits consisting of Quaternary loess (Ql), Quaternary fluvial gravels (Qfg), and Quaternary fluvial lacustrine sand (Qs).

At the Wahluke Slope, the pipeline turns south crossing Quaternary loess (Ql) and passes the Othello Pump Station (GTMWH map Page Number 83). Further to the south, the deposits change to Quaternary fluvial lacustrine sand (Qs) and as the alignment turns to the southeast it crosses undifferentiated portions of the Tertiary Ringold Formation (Tru). As the pipeline continues to the southeast, it crosses another deposit of Quaternary fluvial lacustrine sand and Quaternary fluvial gravels (Qfg) of the Bretz floods.

**Othello Channel:** From GTMWH map Page Numbers 86 to 90, the proposed pipeline alignment crosses the Othello Channel which was eroded during the Bretz floods. This channel is reported to be eroded approximately 330 feet into the underlying basalt bedrock and extends from north of Othello, Washington, southwest to the Columbia River. Flood gravel bars and late-stage lacustrine sediments are mapped on the channel bottom from Basin City to the south edge of the channel.

As the pipeline enters the channel, it drops down in elevation approximately 200 feet passing through lacustrine deposits of the Tertiary Ringold Formation (Trl). At the base of the channel wall (GTMWH map Page Number 87), the ground surface levels out and the pipeline crosses approximately 3 miles of Tertiary basalt (Tb) followed by alternating deposits of Quaternary fluvial gravel (Qfg) and Quaternary fluvial lacustrine sands (Qs). As the pipe line reaches the eastern wall of the channel, it rises back up through deposits of the Tertiary Ringold Formation (GTMWH map Page Number 90).

**Othello Channel to Pasco:** The proposed pipeline alignment continues south and southeast from the Othello Channel (GTMWH map Page Number 90) to the to the terminal at Pasco, Washington (GTMWH map Page Number 100). The geology throughout this section is characterized primarily by Quaternary fluvial and lacustrine sand (Qs) with minor deposits of Quaternary fluvial gravels (Qfg), Quaternary alluvium (Qa) and the Tertiary Ringold Formation lacustrine clay, silt and fine sand (Trl).

South of the Othello Channel, the proposed pipeline route crosses Quaternary fluvial gravels (Qfg) for approximately 2.5 miles followed by approximately 5 miles of alternating deposits of Tertiary Ringold Formation lacustrine sands (Trl) and Quaternary fluvial and lacustrine sands (Qs). Vegetation stabilized dunes were identified in aerial photographs in areas mapped as Ringold Formation by the Grolier and Bingham (1971). Beginning at GTMWH map Page Number 93, the proposed pipeline route crosses over Quaternary fluvial and lacustrine sands (Qs) until it reaches Quaternary fluvial gravel (Qfg) and Quaternary alluvium (Qa) in the vicinity of the Esquatzel Coulee on GTMWH map Page Number 96. After crossing the Esquatzel Coulee, the proposed pipeline route turns to the southeast and continues for approximately 6 miles crossing over Quaternary fluvial and lacustrine sands (Qs). The pipeline then turns to the south and encounters Quaternary fluvial gravels (Qfg) before reaching the terminal at Pasco, Washington located adjacent to the Snake River (GTMWH map Page Number 100).

## 3.1.4 POTENTIAL SEISMIC ACTIVITY

### 3.1.4.1 Overview

The tectonic setting of the Pacific Northwest for the last 60 million years has been dominated by collisions between tectonic plates. These plates of solid rock float on semi-plastic rock of the earth's interior and move in response to large, planet-scale currents in the mantle. Interactions between the plates result in the forces which shape the earth's surface. The collision between the oceanic plate of the northern Pacific (i.e., the Juan de Fuca Plate) and the continental plate of North America resulted in a subduction zone and has given rise to the present morphology of Washington State and is the origin of its current seismic activity.

The Pacific Northwest and adjacent continental margin have been divided into four major tectonic terrains reflecting the regional tectonic setting of the converging plates. These are the continental margin, the fore-arc, the volcanic arc, and the back-arc terrains (see Figure 3.1-1). The dynamic interaction between the two major converging plates (Juan de Fuca and the North American) defines the characteristic structure and location of these four terrains with respect to plate geometry and configuration (Atwater, 1970).

Figure 3.1-1 Tectonic Setting of the Cascadia Subduction Zone

The continental margin includes the continental slope and the shelf west of Washington State. The continental slope is an area of active continental accretion and the site of deposition of marine and continentally derived sediments. The western edge of the continental margin is marked by the suboceanic trace of the Cascadia Subduction Zone (CSZ), which occurs 60 to 100 miles (100 to 175 kilometers) west of the Washington coastline (see Figure 3.1-1).

The fore-arc is the area between the CSZ and the volcanic arc of the Cascade Mountains. It is characterized by deformed and metamorphosed sedimentary and igneous rocks accreted to the continental plate during the plate convergence. Volcanic activity in the fore-arc occurred principally during the early stages of subduction (Kobayashi, 1983).

The Cascade volcanic arc was caused by the melting of continental margin rocks during the subduction of the Juan de Fuca Plate beneath the North American Plate, which has been occurring for the past 38 million years (Vance, 1982). The prominent volcanic cones of the Cascade Mountains were formed on top of the older landscape (McKee, 1972).

The back-arc terrain located east of the Cascade Mountains and is underlain primarily by granitic and metamorphic rocks which, in the Columbia Plateau region, are overlain by thick layers of basalt flows. Because rocks underlying the Cascade volcanics and back-arc area are composed of the accreted terrains of past collisions, and is thus a region of complex bedrock geology.

Earthquakes are the result of sudden releases of built-up stress within the tectonic plates that make up the earth's surface. The stresses accumulate because of friction between the plates as they attempt to move past one another. The movement can be between plates such as when one plate moves over another, as in subduction zones or within the plates themselves. Earthquakes in the Pacific Northwest can originate from four different types of sources: (1) interplate earthquakes occur on the CSZ, (2) intraplate earthquakes occur within the subducting Juan de Fuca plate as it sinks and breaks up below the North American plate, (3) shallow crustal earthquakes on faults within the North American plate, and (4) volcanic earthquakes such as those associated with the eruption of Mount St. Helens. These sources are depicted in Figure 3.1-2.

Figure 3.1-2  Cross-Sections of Earthquake Hypocenters Beneath Western Washington

The relatively short duration of the historic record in the Pacific Northwest (approximately 150 years) is insufficient to indicate whether the CSZ has generated or is capable of generating a great earthquake of magnitude (i.e., M8 or greater). This type of event apparently occurs every several hundred years and results in major earthquakes. Geologic studies during the last 10 years have suggested that great earthquakes have occurred on the CSZ during the Holocene (Atwater, 1987a,b, 1992; Carver and Burke, 1987; Darienzo and Peterson, 1987, 1990; and Grant and McLaren, 1987). Geologic evidence for the most recent event (approximately 300 years before present [b.p.]) has been found at many coastal locations in Washington and Oregon. It is uncertain whether a single earthquake or several separate earthquakes closely spaced in time caused the geologic effects at these locations. However there is a general consensus that the CSZ has generated earthquakes of M8 or larger in the past few thousand years (Atwater et al., 1995). A subduction-zone earthquake causing fault rupture over this length would have a moment magnitude, M, of about 8.5.

Rogers (1988) and Heaton and Hartzell (1986) suggest that a moment magnitude M=9.1 CSZ earthquake could occur that would rupture the entire 900 km length of the Juan de Fuca plat between the Explorer and Gorda plates. In the Final Safety Analysis Report (FSAR) for the Washington Public Power Supply System, Nuclear Project No.3 (WPPSS, 1988), theoretical arguments are presented that the CSZ is segmented and that earthquakes would be confined within any of three segments of the CSZ. Because of its limited length (less than 300km) each segment is only capable of generating earthquakes of M8 to 8.5.

A review of the existing literature suggests that a M8.5 earthquake is a reasonable estimate of the largest event that could occur on the CSZ, and can be considered to be the maximum credible earthquake for this region (Atwater et al., 1995). This type of event would generate long period ground motions for a relatively long duration in the western portion of the pipeline route.

Intraplate seismic events appear to be more widespread geographically and result from various structural sources in the shallow crust. Often these events occur along mapped or postulated faults in the earth's surface. Based primarily on the historical seismicity of intraplate origin in western Washington and other subduction zones of the world, the intraplate zone is considered capable of generating earthquakes as large as M7.5. This source has generated two of the largest historical seismic events to affect the Pacific Northwest, the 1949 Olympia earthquake of magnitude M7.1 and the 1965 M6.5 Seattle earthquake. Because intraplate earthquakes do not cause deformation at the ground surface that can be distinguished from other types of earthquakes, the typical frequency of these earthquakes cannot be readily assessed. However these types of earthquakes have historically caused the greatest amount of damage in the Puget Sound region.

Shallow crustal seismic events appear to occur more widespread geographically relative to the other sources of historical seismicity, and result from various structural sources in the shallow crust. These events often occur along mapped or postulated faults exposed at the earth's surface. Based primarily on historic and paleo seismicity, the Quaternary shallow crustal faults are considered capable of generating earthquakes greater than M6 and potentially as large as M7.0-7.5, such as the 1872 North Cascade event which was estimated to be a M7.3

One of the most seismically active regions of the state with respect to shallow earthquakes of this sort is on the Columbia Plateau in the region known as the Yakima Fold Belt (Geomatrix Consultants, 1990, 1996). Earthquakes in the M7-7.25 range are predicted to recur in this region at intervals ranging from 13,000 to 50,000 years and a M6 or greater is expected to occur once every 5,000 years (Geomatrix Consultants, 1990, 1996). The largest instrumented earthquakes of the Columbia Plateau were M5.0 events in 1918 at Corfu, and at the Royal Slope of the Frenchman Hills in 1973 (Geomatrix Consultants, 1990).

The Seattle and Whidbey Island faults (see Figure 2.15-1a) are the most potentially significant Quaternary faults west of the Cascades. These faults have not generated earthquakes greater than M6 historically but the Seattle fault last ruptured the ground surface approximately 1100 years ago during an earthquake estimated to be M 7-7.25 (Bucknam et al., 1992; Johnson and Potter, 1994). The largest instrumentally recorded shallow crustal earthquake in the Puget Sound area is the 1996 M 5.3 Duvall earthquake which has not been associated with a recognized Quaternary fault.

### 3.1.4.2 Seismicity

Table 3.1-1 lists 28 moderate to large historical earthquakes that have occurred in the Pacific Northwest region (Noson, et al., 1988; EERI, 1993, University of Washington, 1996). Figure 3.1-3 shows the instrumentally recorded seismicity for the project region for the period of 1970-1993. The location of historical earthquakes of potential engineering significance in Washington and northern Oregon are presented in Figure 3.1-4. The largest historical earthquake in the state of Washington was probably the 1872 event in the North Cascade Mountain Range. This event has been estimated to have a magnitude M 7.3. Three events between M7.0 to M7.5 have occurred this century in the region: two beneath central Vancouver Island (1918, M 7.0; 1946, M 7.3), and one near Olympia, Washington (1949, M 7.1). The most recent large earthquake occurred in 1965 between Seattle and Tacoma and was M 6.5. Both the 1949 and 1965 earthquakes occurred at a depth of about 60 km, whereas the 1872 event probably occurred at a shallow depth within the North American crustal plate.

figure 3.1-3  Pacific Northwest Seismicity, 1970-1993

Figure 3.1-4  Epicenters and Dates of Larger Pacific Northwest Earthquakes

## TABLE 3.1-1
## LARGEST KNOWN EARTHQUAKES FELT IN WASHINGTON[a]

| Year | Date | Time (PST) | North Latitude | West Longitude | Depth (km) | Mag[b] (felt) | Mag[c] (inst) | Max. Mod. Mercalli Intensity | Felt Area (sq km) | Location |
|---|---|---|---|---|---|---|---|---|---|---|
| 1872 | 12-14 | 2140 | 48°48'00" | 121°24'00" | shallow | 7.3 | none | IX | 1010000 | North Cascades |
| 1877[d] | 10-12 | 1353 | 45°30'00" | 122°30'00" | shallow | 5.3 | none | VII | 48000 | Portland, Oregon |
| 1880 | 12-12 | 2040 | 47°30'00" | 122°30'00" | | | none | VII | | Puget Sound |
| 1891 | 11-29 | 1521 | 48°00'00" | 123°30'00" | | | none | VII | | Puget Sound |
| 1893 | 3-6 | 1703 | 45°54'00" | 119°24'00" | shallow | 4.7 | none | VII | 21000 | Southeastern Washington |
| 1896 | 1-3 | 2215 | 48°30'00" | 122°48'00" | | 5.7 | none | VII | | Puget Sound |
| 1904 | 3-16 | 2020 | 47°48'00" | 123°00'00" | | 5.3 | none | VII | 50000 | Olympic Peninsula, eastside |
| 1909 | 1-11 | 1549 | 48°42'00" | 122°48'00" | deep | 6 | none | VII | 150000 | Puget Sound |
| 1915 | 8-18 | 605 | 48°30'00" | 121°24'00" | | 5.6 | none | VI | 77000 | North Cascades |
| 1918[d] | 12-6 | 41 | 49°37'00" | 122°55'00" | | 7 | 7 | VIII | 650000 | Vancouver Island |
| 1920 | 1-23 | 2309 | 48°36'00" | 123°00'00" | | 5.5 | none | VII | 70000 | Puget Sound |
| 1932 | 7-17 | 2201 | 47°45'00" | 121°50'00" | shallow | 5.2 | none | VII | 41000 | Central Cascades |
| 1936 | 7-15 | 2308 | 46°00'00" | 118°18'00" | shallow | 6.4 | 5.75 | VII | 270000 | Southeastern Washington |
| 1939 | 11-12 | 2346 | 47°24'00" | 122°36'00" | deep | 6.2 | 5.75 | VII | 200000 | Puget Sound |
| 1945 | 4-29 | 1216 | 47°24'00" | 121°42'00" | | 5.9 | 5.5 | VII | 128000 | Central Cascades |
| 1946 | 2-14 | 1918 | 47°18'00" | 122°54'00" | 40 | 6.4 | 6.3 | VII | 270000 | Puget Sound |
| 1946[d] | 6-23 | 913 | 49°48'00" | 125°18'00" | deep | 7.4 | 7.3 | VIII | 1096000 | Vancouver Island |
| 1949 | 4-13 | 1155 | 47°06'00" | 122°42'00" | 54 | 7 | 7.1 | VIII | 594000 | Puget Sound |
| 1949[d] | 8-21 | 2001 | 53°37'20" | 133°16'20" | | 7.8 | 8.1 | VIII | 2220000 | Queen Charlotte Isl., B.C. |
| 1959 | 8-5 | 1944 | 47°48'00" | 120°00'00" | 35 | 5.5 | 5 | VI | 64000 | North Cascades, east side |
| 1959[d] | 8-17 | 2237 | 44°49'59" | 111°05' | 10-12 | 7.6 | 7.5 | X | 1586000 | Hebgen Lake, Montana |
| 1962[d] | 11-5 | 1936 | 45°36'30" | 122°35'54" | 18 | 5.3 | 5.5 | VII | 51000 | Portland, Oregon |
| 1965 | -25 | 728 | 47°24'00" | 122°24'00" | 63 | 6.8 | 6.5 | VIII | 500000 | Puget Sound |
| 1965 | 4-29 | 728 | 47°24'00" | 122°24'00" | 63 | 6.8 | 6.5 | VIII | 500000 | Puget Sound |
| 1981 | 2-13 | 2209 | 46°21'01" | 122°14'66" | 7 | 5.8 | 5.5 | VII | 104000 | South Cascades |
| 1983[d] | 10-28 | 606 | 44°03'29" | 113°51'25" | 14 | 7.2 | 7.3 | VII | 800000 | Borah Peak, Idaho |
| 1993[d] | 3-25 | 535 | 45°02'00" | 122°36'26" | 16 | | 5.6 | VII | | Scotts Mills, Oregon |
| 1996[e] | -28 | 1511 | 47°23'24" | 121°21'36" | 16 | | 5 | | | Robinson Pt., Vashon Island |
| 1996[e] | 5-02 | 2104 | 47°45'36" | 121°51'00" | 7 | | 5.3 | | | Duvall |

(a) Data from Noson et al. (1988); EERI (1993)
(b) Mag (felt) = an estimate of magnitude, based on felt area; unless otherwise indicated, it is calculated from Mag (felt) = -1.88 + 1.53 log A, where A is the total felt area in km²; from Toppozada (1975).
(c) Mag (inst) = instrumentally determined magnitude; refer to references listed in the original Table 2 of Noson et al. (1988) for magnitude scale used.
(d) Earthquakes with epicenters outside Washington.
(e) Data from University of Washington Geophysics Program via http://www.geophys.washington.edu/seis/.

The April 29, 1945 earthquake is identified as being located southeast of Seattle with minor damage (i.e., cracked plaster, windows and chimneys) at Cle Elum, Elma, Greenwater, Index, Leavenworth, North Bend, Palmer, Snoqualmie, and Stampede Pass, and rockslides on the west face of Mount Si. The epicenter is based on reports from individuals which indicate an epicenter within the Cascades, but its actual location relative to the pipeline route is uncertain. Estimates of the magnitude of this earthquake range from 5.5 to 5.9 (Noson et al., 1988; Coffman and Von Hake, 1973).

Instrumentally recorded strong ground motions (peak horizontal acceleration) associated with the historical (1949 and 1965) intraplate earthquakes were on the order of 0.1g in the Seattle area and thus would have been less at the more distant pipeline route. Recorded peak horizontal accelerations were 0.17g-0.19g for the 1996 Duvall earthquake and 0.07 for the 1995 Robinson Pt. earthquake near Vashon Island.

Impacts and mitigation measures against seismic activity are presented in Section 2.15.2. The effects of construction operations (e.g., trench blasting) will not affect seismic activity, therefore no mitigation measures are proposed. In general, avoidance has been selected as the most effective mitigation measure against damage due to semismic hazards (e.g., fault rupture). Faults cannot be precluded from rupturing the ground surface in the event of a large earthquake. However, there are no known Quaternary faults within the pipeline corridor. Pre-Quaternary faults which are located wihtin the pipeline corridor are shown in the geologic and hazard maps in Appendix B.

## 3.1.5 SOILS

### 3.1.5.1 Erosion Potential

Erosion is the breakdown and transport of soils and bedrock by natural processes including water, wind, and glaciation. Of these processes, water caused erosion has the most potential for impact along the alignment to the west of the Cascades. Particularily where glacial soils are exposed. East of the Cascade Range, the proposed corridor has soils which are also susceptible to wind erosion.

The susceptibility of any material to erosion is dependent upon: 1) chemical and physical characteristics (e.g., cohesion); 2) topography; 3) the amount and intensity of precipitation and surface water; 4) the intensity of wind; and 5) the type and density of vegetative ground cover, if present. Erosion-susceptible soils are present for portions of the proposed alignment, but are most commonly found on relatively steep slopes within drainages.

In general, erosion potential on slopes is principally a factor of soil cohesion and slope angle given the same amount and intensity of surface runoff. The less cohesive the soils and the steeper the slope angle, the higher the potential for significant soil erosion. Erosion of sidewalls along creeks and rivers is a function of the flow rate, bed morphology, and soil/rock type. The Soils and Erosion Maps located in Appendix B illustrate erosion potential for the pipeline corridor and alternative routes.

For example, a review of aerial photographs indicates potential for erosion associated with the lower slopes of the Saddle Mountains from Corfu east to the Saddle Gap. Rilling and incised drainages were observed in short sections of the lower slopes where slope angle appears to increase. The Soil Survey of Grant County indicates that the loess soils mantling the mountain ridge are susceptible to erosion.

The sidewalls of the major stream and river drainages for the entire corridor contain soils which have been mapped by the Natural Resources Conservation Service (NRCS) to have high potential for erosion. Aerial photographs and reconnaissance also indicate a high potential for erosion along the steep sides of Othello Channel underlain by erodible Ringold Formation deposits.

**Construction**

Trench Excavations

All of the excavations will result in ground disturbance, thereby changing the engineering characteristics of the soils, including density and permeability. Excavations in bedrock may require blasting and/or the use of special rock removal equipment, although overblasting will be prevented. Blasting operations will be conducted only by explosives professionals. Some of the techniques used to prevent over blasting will include the use of mat overlays, saw cuts to precut the trench, and the possible use of shaped charges.

Normally, trench materials near the optimum moisture content expand approximately ten percent when they are removed from the trench. As the trench materials are replaced, they will be compacted to a density condition equal or greater than when they were removed. The only excess anticipated will result from the volume of material displaced by the pipe itself; 0.85 cubic feet per linear foot for the 12 inch diameter pipe, and 1.07 cubic feet per foot for the 14 inch diameter pipe. If this volume of trench material is spread out over the sixty foot right-of-way width, it will add approximately two tenths of an inch to the over all depth of cover; approximately four tenths over a thirty foot wide right-of-way. Trench material will not be disposed of but will be evenly distributed over the right-of-way. If for some reason the trench excavation is backfilled with imported soils, the original material will be disposed of in accordance with the wishes of the landowner, hauled to a location requiring clean fill or taken to a land fill for disposal. Backfilled soils will be adequately compacted to reduce the potential for post-construction settlement as outlined below.

The impacts of trench excavations are expected to be minor due to the implementation of mitigation measures described below in Section 3.1.5.2.

The placement of the pipeline in the existing tunnel will be performed by trenching into the tunnel floor. This placement is not anticipated to have an adverse impact on the geology.

Fill Placement

Excess soils will be generated as a result of the pipeline installation. The exposed relatively silty disturbed soil would be susceptible to erosion, and a sedimentation and erosion control plan will be prepared and implemented prior to the start of construction to control erosion. The fill soils will be properly compacted to reduce the potential for post-installation erosion and settlement. Soils containing more than 5 percent fines by weight (that portion passing the No. 200 sieve) will be moisture-sensitive and site-specific mitigation measures will be implemented to protect exposed soils from precipitation prior to recompaction.

The weight of the heavy construction equipment rolling over the trench is normally found to bring the compaction level to as high as 90% depending on moisture content and material type. In areas that are resistant to compaction, the moisture content will be modified and densified with appropriate vibratory compaction equipment. At locations where greater than 90% compaction is necessary, such as at road crossings, the trench will be compacted in six inch to one foot lifts until the backfill is flush with the original grade.

Construction specifications will require that the pipe be protected during backfill using only 1" material placed around the pipe or rock shield. The specific method will be at the discretion of the contractor. The contractor may choose to a select rock shield from a list of OPL approved materials; imported backfill of a specified material and maximum size or a ditch padding machine capable of producing backfill of those qualities. Once the space around the pipe is filled with the proper material, no other gradation requirements will apply until the final grade is reached. Final grade will be in accordance with the landowner and the various federal, state and local agency stipulated agreements.

Soil stabilization, whether on steep slopes, in piles , or on flat terrain will be part of the erosion control plan to be developed in negotiations with federal, state and local agencies and will become conditions of the EFSEC permit through stipulated agreements with those agencies. Some techniques which will be employed are sedimentation ponds, diversion berms, filter fabrics, and straw bale filters.

With the mitigation measures discussed below in Section 3.5.1.2, impacts from fill materials would be low.

River, Stream, and Irrigation Canal Crossings

The majority of the stream crossings are planned with the use of open cut methods. Although, the excavation could suspend sediment (see also Section 3.3 Water), streambanks will be protected after disturbance to limit post-installation erosion, and permanent slope stabilization measures would be used as necessary to minimize slope instability.

Dry irrigation canals are proposed to be open trenched. Wet, unlined canals, depending on the flow volume, are proposed to be either jack-and-bored under, or the water will be diverted and the canal trenched. Wet, lined canals are proposed to be jack-and-bored under. All repairs to irrigation canals will be done in accordance with the Reclamation District repair specifications.

Activities at bored crossings are proposed to be restricted to the expanded right-of-way described in the application. The right-of-way will be re-vegetated and reclaimed as per provisions in the application and with stipulated agreements with intervening agencies.

One major river, the Columbia, will be crossed using directional drilling. The drilling operation requires an area for staging and drilling. The clearing and grading of the work area will disturb the ground and create the potential for increased erosion. As noted above, a sedimentation and erosion control plan will be developed and implemented prior to beginning construction. This plan will include limits on the area to be disturbed, the retention of vegetation where feasible, drainage retention during construction, soil replacement, and replanting after construction. With these measures and the mitigation measures listed below, impacts are expected to be low.

Steep rock-walled slopes such as those present at the Columbia River Crossing are a potential rockfall hazard during construction. Adequate protection such as rock nets and safety benches will be used to protect workers, equipment, and the pipeline from damage or injury from rockfall.

**Operation**

The operation of the pipeline and related facilities is not anticipated to have an adverse impact on the existing geology.

Soil Settlement

Foundation design and pipeline placement will be based on site-specific geological information. Following construction, soils will be adequately recompacted to reduce the potential of soil settlement.

### 3.1.5.2 Mitigation Measures

**Construction**

Site-specific geotechnical engineering evaluations have and will be conducted prior to design of the project to identify design methods to address the potential impacts presented above. In addition to the potential mitigation measures outlined for areas of potential mass wasting in Section 2.15.7, the following mitigation measures will be included:

- All of the excavations in high hazard prone areas mapped as high hazard to erosion and/or mass wasting (based on mapping completed for the preparation of the application) will be monitored by a geologist or engineer during construction to verify proper excavation methods for the soils and/or rock encountered. Blasting of the bedrock will be conducted by experienced blasting personnel who will control overblasting.

- Dry unlined irrigation canals are proposed to be open trenched.
- Wet, unlined canals, depending on the flow volume, are proposed to be either jack-and-bored under, or the water will be diverted and the canal trenched. Wet, lined canals are proposed to be bored under. All repairs to irrigation canals will be done in accordance with the Reclamation District repair specifications.
- Activities at bored crossings will be restricted to the expanded right-of-way described in the application. The right-of-way will be re-vegetated and reclaimed as per provisions in the application and with stipulated agreements with intervening agencies.
- The placement of fill consisting of moisture-sensitive soils will be limited to the drier months between July and October. If the construction schedule requires backfilling during other periods, additional mitigation measures will be used. The fill placement will be monitored during construction by a geologist or engineer to verify proper compaction of the fill soils.
- The contractor will be allowed to work in wet weather provided that the contractor is able to demonstrate the capability of construction at the same level of quality control as during dry weather and as established by on site inspection personnel. The contractor will need to demonstrate a safe work environment while subscribing to all provisions of the project specifications, the various stipulated agreements and the erosion control provisions in particular.
- The banks of streams will be protected after disturbance to limit post-installation erosion.
- Permanent slope stabilization measures and/or dewatering systems will be utilized as necessary during the pipeline installation to minimize slope instabilities. Two areas where these measures are likely are the south slopes of Cherry Creek and Tolt River crossings.
- The directional drilling operations will be monitored to minimize adverse impacts during the construction of the staging areas, as well as the drilling. An erosion control plan will be completed and implemented to minimize erosion.
- In steep, rock-walled slopes, protection such as rock nets and safety benches will be incorporated in the final design of the pipeline to protect workers, equipment, and the pipeline from damage or injury from rockfall. A construction plan will be completed and implemented to limit impacts.
- In the areas where saturated liquefiable soils have been identified, if the depth to non-liquefiable soils is not too great, over-excavation and replacement with non-liquefiable soils may be used as a mitigation measure.
- To mitigate potential seismic impact to the pipeline, the final design will incorporate measures to enable the pipeline to reasonably withstand anticipated ground motion.

**Operation**

- Potential geologic hazard areas will be further mapped as part of the "as built" survey and these areas will be visually inspected as part of the routine inspection program.
- A schedule of visual inspection will be instituted which will be used during increased precipitation or following abnormal seismic activity. These inspections will look for signs of incipient mass movement in those areas identified as potentially susceptible to such failures.
- Potential mitigation measures for mass movement include installation of the pipe with its longitudinal axis parallel to the direction of potential ground movement; anchoring the pipe to stable underlying rock; or installation of ground motion or pipe stress sensors, if feasible.

## 3.1.6 TOPOGRAPHY

A detailed aerial survey was completed to document the topography within the proposed ½ mile-wide pipeline corridor. Topographic maps were developed from the survey with an appropriate level of ground truthing and the resulting contours are shown on the GTMWH maps located in Appendix B.

Along a large portion of the route, the proposed pipeline alignment and alternative alignments follow existing right-of-ways (ROW), utility, rail, trail and highway corridors. The topography within existing ROW has already been altered by cut-and-fill or other construction activity. Along these existing ROW and areas of new construction the project design does not include significant changes to the topography. Therefore, no significant impacts upon topography are anticipated as a result of the construction and operation of the proposed pipeline and facilities. Consequently, no mitigation measures will be required. For completeness, a description of the existing topography is provided in the following subsection.

### 3.1.6.1 Existing Topography

Presented in this subsection is a general description of the topography along the alignment. Reference throughout this section is made to specific page numbers of the GTMWH maps located in Appendix B.

**Thrasher Pump Station to Snoqualmie:** Referring to the GTMWH map page numbers 1 through 15, the topography from the Thrasher's Pump Station (MP 0) to approximately Snoqualmie (MP 33) is generally rolling and traverses several prominent river valleys. The elevation of the Thrasher Pump Station is approximately 400 feet above mean sea level (MSL). The proposed alignment gently climbs to the east to an elevation of approximately 600 feet before descending several slopes less than 30 degrees (65 per cent) to the elevation of the proposed bridge crossing across the Snoqualmie River at approximately elevation 40 feet MSL (GTMWH map page numbers 4 and 5).

The route then crosses the Snoqualmie River valley and climbs moderately steep slopes. The steepest portions mapped are generally less than 30 degrees (65 per cent). West of Peoples Creek (GTMWH map page number 6), the proposed alignment crosses several relatively short sections which have been mapped as steeper than 30 degrees (65 per cent). The elevation at the highest point has been mapped as 1,400 feet MSL.

The proposed route then turns south and crosses generally moderate slopes separated by several prominent creeks. The elevations of the upper portions of the proposed alignment generally ranges between 500 and 1,000 feet above MSL. The elevations of the major river crossings range between approximately 300 and 500 feet above MSL.

Portions of the sideslopes of the Cherry Creek (GTMWH map page number 8) and Harris Creek (GTMWH map page number 9) are relatively steep, with isolated sections in excess of 30 degrees (65 per cent). The proposed route then crosses the Tolt River (GTMWH map page number 11). The northwestern slope leading into the river drainage is generally less than 30 degrees (65 per cent) with several sections slightly steeper in slope. In contrast, the southeastern slope leading out of the Tolt River drainage is generally steeper than 30 degrees (65 per cent).

From the top of the Tolt River drainage crossing, the proposed pipeline route crosses rolling topography with elevations ranging from approximately 500 to 1,000 feet above MSL to the crossing of Griffin Creek with the sideslopes of the drainage generally is excess of 30 degrees (65 per cent). From the Griffin Creek crossing, the proposed route continues across rolling topography to the sideslopes of the Snoqualmie River drainage. The sideslopes for the last approximately 3,000 feet leading into the Snoqualmie River are generally steeper than 30 degrees (65 per cent), with the slope height of steeper segment less than approximately 500 feet. The Snoqualmie River is noted to be at an elevation of approximately 400 feet.

**Snoqualmie to Interstate 90 East of North Bend:** The topography for the section of the pipeline between the community of Snoqualmie to the crossing of Interstate 90 east of North Bend is within an alluvial valley and relatively flat. The elevation of this segment ranges from approximately 400 to 500 feet above MSL. The proposed pipeline route crosses the Snoqualmie River, as well as the South Fork of the Snoqualmie River. The bank heights at these crossings of the river are noted to be generally less than 50 feet in height. One section of the proposed alignment is situated within 200 feet of meanders in the Snoqualmie River. The banks of the river at this point were noted to be less than 20 feet with slope angles less than 6 percent.

**Interstate 90 East of North Bend to the Western Tunnel Portal:** The topography from the crossing of Interstate 90 east of North Bend to the western tunnel portal at Snoqualmie Pass is typical of mountain valley terrain. The relatively flat, wide valley narrows and winds to Snoqualmie Pass, with the Snoqualmie River confined to a relatively narrow area at the bottom of the valley. The proposed pipeline alignment generally follows the southern side of the river valley, with the proposed route placed on the lower slopes of the valley wall.

The proposed pipeline route climbs relatively gently from approximately 500 feet near the crossing of Interstate 90 (GTMWH map page number 17), to an elevation of approximately 2,500 feet at the western tunnel portal at Snoqualmie Pass (GTMWH map page number 24). This segment of the proposed alignment is approximately 18 miles in length. The slopes crossed by the proposed alignment range are generally less than 30 degrees (65 percent). However, several sections of the proposed alignment are relatively steep (more than 30 degrees or 65 per cent). The steeper sections are shown on GTMWH map pages 17, 18, 20, 21, 23, and 24.

**Western Tunnel Portal to the Crossing of the Yakima River:** The topography from the western tunnel portal at Snoqualmie Pass to the Yakima River (GTMWH map pages 24 to 41) is representative of mountain valley terrain with moderate to steep slopes. After exiting the eastern tunnel portal across Snoqualmie Pass, the proposed pipeline alignment follows the western side of the Lake Keechelus with the proposed route placed on the lower slopes of the valley wall (GTMWH map pages 25 to 27). East of the lake, the pipeline follows the east and northern slopes of Stampede Pass (GTMWH map page 28), Cabin Mountain (GTMWH map page 30), Hicks Butte (GTMWH map page 35) and South Cle Elum Ridge (GTMWH map pages 37, 38 and 39). The slopes crossed by the proposed alignment are generally less than 30 degrees (65 percent). However, slopes of 30 to 45 degrees are present along the proposed alignment along the slopes of these mountains.

The proposed pipeline route elevation decreases from approximately 2,600 feet near the tunnel egress and lake (GTMWH map page 24) to approximately 1,800 feet at the Yakima River (GTMWH map page 41). The decrease is relatively consistent, except for an increase to 2,550 feet over a ridge on the northeastern slope of Cabin Mountain (GTMWH map page 31).

**Yakima River to the Kittitas Terminal:** The topography of the plateau section is generally low to moderate relief with the elevation ranging from 2200 feet above MSL near the west end of the valley to 1600 feet above MSL near Kittitas (GTMWH map pages 41 to 52). The section begins at the Yakima River crossing and extends through foothills and alluvium of the east slope of the Cascades (GTMWH map pages 41 to 45) before crossing into an alluvial fan terrain between the Dry Creek stream crossing (GTMWH map page 45) and the Kittitas Terminal (GTMWH map page 52). Several short, relatively steep sections of the route are located near terraces. The length of the terraces are generally less than 1000 feet (GTMWH map pages 43, 44, and 48) with the longest sections being at the Swauk Creek Valley crossing (GTMWH map page 43). The slope of these terraces is 30 degrees or less.

**Kittitas Terminal to the Columbia River:** From the Kittitas Terminal (GTMWH map page 52), the proposed route follows a series of flat-topped structural ridges with deeply incised drainages. Elevations along the ridgetops are typically in the range of 1,100 to 2,500 feet. The proposed route encounters gentle to moderate slopes along the ridgetops, only encountering steeper slopes where route alternatives descend and/or climb from drainages or into the Columbia River channel itself. These slopes, of up to 30 percent, are found along the wet trench crossing (WTC) and Ginkgo (GTMWH map page 61a), Ginkgo North

(GTMWH map page 62a), WTC (GTMWH map page 62b), Ginkgo (GTMWH map page 63), and Ginkgo South/Burlington Railroad Bridge (GTMWH map page 64a). These slopes are short, with a maximum distance of 750 feet. The slopes occur at drainage crossings and descend into the Columbia River drainage, where the various alignment options cross the river.

The alternatives which are south of I-90 on the Yakima Training Center enters Johnson Canyon and from there to the Columbia River follows a series of flat-topped structural ridges with deeply incised drainages. Elevations of the ridge tops are approximately 2100 feet above MSL at the western end of this section and decrease to 1000 feet on the cliffs above the Columbia River. Up to 200 feet of relief is present from ridge top to coulee bottom in this section. Slopes along the ridgetops are less than 30 percent, with the steepest slopes present where the alignment crosses a creek drainage (GTMWH map page 61). The alignment crosses Middle Canyon and Johnson Creek Canyons (GTMWH map page 63), descending from an elevation of 1000 feet to 650 feet, with a maximum slope of 30 percent. After crossing Johnson Creek, the alignment climbs sharply up the south slope of the canyon, with a maximum 50 percent slope over 700 feet distance. The alignment crosses a ridgetop parallel to the Columbia River before descending to the terrace of the river southwest of Wanapum Dam..

**Columbia River Crossings:** Five river crossings options are assessed as part of the proposed alignments. The proposed crossing is by way of a horizontal directional drill (HDD) across the Columbia River approximately 3,000 feet downstream of Wanapum Dam.

The proposed route bears north of Johnson Creek from the ridge north of Interstate 90 (GTMWH map Atlas Page 61a), then turns east down a drainage, dropping from 700 feet to 600 feet over approximately 1000 feet (10 percent slope) (GTMWH map Atlas Page 62b). The proposed alignment extends south along the east ridge of the Saddle Mountains (GTMWH map Atlas Pages 63 and 64a) dropping in elevation from 900 feet to 600 feet as the alignment approaches the river terrace below Wanapum Dam over a distance of two miles (GTMWH map Atlas Page 64). At the river terrace, the alignment turns east-northeast, and the actual crossing will be accomplished with a horizontal directional drill beneath the river. The alignment then bears north-northeast along the river terrace, climbing gently from 600 to 900 feet over approximately two miles west of the Beverly-Burke Pump Station (GTMWH map Atlas Page 65).

The other four alternative river crossings are discussed below from north to south.

The wet trench crossing alignment bears north of Johnson creek from the ridge north of Interstate 90 (GTMWH Map Atlas Page 61a), then turns east down a drainage, dropping from 700 feet to 600 feet over approximately 1000 feet (10 percent slope) (GTMWH Map Atlas page 62b). The actual crossing will be accomplished by dredging the bottom of the river. On the east river bank, the alignment bears south, climbing from 600 to 700 MSL over 5,000 feet before rejoining the Interstate 90 alignment.

The I-90 Bridge alignment follows a gentle slope of approximately 4 percent (3 degrees) east from the realignment to the bridge. The alignment climbs another gentle slope on the east side of the river, then turns south along the river terrace at and elevation of 600 to 700 feet. After about a mile (GTMWH map Atlas Page 63a) the alignment climbs to 900 feet and bears southwest to south across the top of the plateau before rejoining the original alignment at the Beverly-Burke pumping station (GTMWH map Atlas Page 66).

The Wanapum Dam (GTMWH map Atlas Page 64) crossing alternative begins with a 100 foot drop from the realignment to the river terrace adjacent west of the dam (approximately 45 degree slope). The pipeline crosses the dam, then turns south along the base of the basalt cliffs facing the river before rejoining the original proposed alignment at the base of the cliffs.

The Beverly Railroad Bridge Alternative continues south along the east ridge of the Saddle Mountains (GTMWH map atlas pages 63 and 64a) dropping in elevation from 900 feet to 600 feet as the alignment approaches the river terrace over a distance of two miles. At the river terrace, the alignment turns east-northeast crossing the river on the bridge. The alignment then bears north-northeast along the Beverly Burke Road, climbing gently from 600 to 900 feet over approximately one mile before rejoining the original alignment approximately two miles west of the Beverly-Burke Pump Station (GTMWH map atlas page 65).

**Columbia River Crossing to Corfu Reroute:** From the Columbia River, the proposed alignment bears east for four miles across relatively gentle slopes, climbing the gentle slope along a stream drainage to the plateau and the Beverly-Burke Pump Station, elevation approximately 1,050 feet (GTMWH map page 66). The route crosses minor streams with bank slopes of less than 50 feet in 1,000 feet. The alignment turns northeast then east (GTMWH map page 68) encountering flat, scoured terrain from outwash flood events. The elevation along this length generally decreases from 1,100 feet to 800 feet (GTMWH map pages 69 to 77).

**Corfu Reroute:** The Corfu reroute bears southeast from Corfu (GTMWH map page 77). The realignment continues across relatively flat scoured plateau, crossing shallow coulees near Crab Creek. These coulees are generally 50 feet deep, and the pipeline slopes approximately 10 percent entering and exiting the coulees (GTMWH map pages 78 and 79). The elevation across the realignment averages about 700 feet. The realignment turns south, rejoining the original alignment along the north slope of the Saddle Mountains, crossing Lower Crab Creek, and climbing from 700 feet to 1,050 feet over a mile. The realignment crosses a short slope of 30 percent north of Lower Crab creek. This slope is less than 300 feet in length (GTMWH map page 80).

**Corfu to Wahluke Slope:** From this point the alignment turns east and follows the base of the Saddle Mountains. The topography of this section is irregular, but of generally moderate relief. Elevations range from 600 feet to 800 feet above MSL before the alignment turns south to climb a steep slope to approximately 1100 feet above MSL on the north slope of the Saddle Mountains (GTMWH map page 81).

The alignment traverses the north slope of the Saddle Mountains, climbing to an elevation of 1300 feet above MSL (GTMWH map page 82). The slope which this section crosses is a moderately steep north facing flank of the Saddle Mountains (approximately 25 percent) and represents the only mountain crossing for the alignment east of the Cascades. The alignment turns south at a pass in the range southwest of Othello (GTMWH map page 83), and drops down the south or Wahluke Slope remaining at elevations of 1100 to 1200 feet.

**Wahluke Slope to the Othello Channel**: Past the Wahluke Slope, the pipeline alignment turns southeast across fluvial deposits and scoured terrain from the Bretz floods (GTMWH map pages 83 to 86). The topography is relatively flat, with elevation gently sloping downward over seven miles from 1,100 feet to 900 feet, with no notable topographic slopes other than the banks of the Wahluke Branch Canal (GTMWH map page 84). The banks of the canal are less than 30 feet in height. The alignment turns south along the west slope of the Othello Channel (GTMWH map page 86). The west slope of the Channel has a moderate slope of 15 degrees, and the pipeline alignment runs along the slope, decreasing in altitude from 950 feet to 820 feet (GTMWH map page 86) before turning southeast across the channel floor.

**Othello Channel:** From this point to the south, the alignment will cross a relatively flat plain sloping gently south to the Columbia and Snake Rivers which is dissected by a series of southwestward trending bedrock channels (GTMWH map pages 86 to 97). The Othello and Esquatzel Channels represent floodways of the late Pleistocene Bretz Floods. The channels are steep sided, with irregular but generally low relief bottoms. Many slopes are gentle, and channels of canals and streams in the floor of the channel all have banks of generally less than 40 feet at the alignment crossings. Elevation changes from approximately 900 feet on the plain between the channels to less than 750 feet in the channel bottoms.

**Othello Channel to Pasco:** The topography between the Esquatzel and Othello Channels to the end of the pipeline at Pasco is relatively flat, crossing fluvial outwash flood sands (GTMWH map pages 97 to 100). The alignment climbs from the channels along a gentle slope, then crosses flat terrain. The alignment crosses two shallow channels (GTMWH map page 100). The banks of these channels are less than 30 feet. The elevation at the south terminus of the pipeline alignment is approximately 400 feet above MSL.

**Thrasher's Pump Station:** The pump station is situated on a glacially deposited till and outwash plain. The topography of the site slopes down towards the north and east from an elevation of approximately 400 feet at the southwest corner to approximately elevation 370 feet at the northeast corner. Adjacent to the pump station, the land surface slopes to the east with a slope of approximately 7 percent towards the Bear Creek drainage.

**North Bend Pump Station:** The pump station is situated within the alluvial valley of the Middle Fork of the Snoqualmie River. The topography at the pump station is nearly level, with an approximate elevation of 460 feet above MSL.

**Stampede Pump Station:** The pump station is situated on alpine glacial deposits west of the Yakima

River Valley. The topography at the pump station is nearly level, with an approximately elevation of 2000 feet above MSL.

**Kittitas Pump Station:** The topography at the pump station location is flat, with little relief. The location is on an alluvial plain between Parke and Caribou Creeks which are tributary to the Yakima River.

**Beverly-Burke Pump Station:** The pump station is located on a plateau east of the Columbia River. There is low relief in the vicinity, with a slope of approximately 3 percent to the southwest. The pump station elevation is approximately 1,050 feet above MSL.

**Othello Pump Station:** The pump station is located on lacustrine deposits south of the Wahluke Slope and Saddle Mountains. There is low relief in the vicinity, with a slope of less than 2 percent to the west. The pump station elevation is approximately 1,190 feet above MSL.

### 3.1.7 UNIQUE PHYSICAL FEATURES

There are two unique features along the pipeline route, the Chicago-Milwaukee-St. Paul Railroad Tunnel at Snoqualmie Pass and the Corfu Landslide. The tunnel was formerly used for the railroad, and is currently a part of the John Wayne-Iron Horse Trail System. The pipeline corridor is proposed to be located within the tunnel with the pipeline buried in the tunnel floor. The proposed pipeline alignment will avoid the Corfu Landslide.

#### 3.1.7.1 Chicago-Milwaukee-St. Paul Railroad Tunnel

Currently, AT&T and WorldCom have lines buried within the floor of the tunnel. The pipeline will also be buried in the floor of the tunnel and located on the opposite side of the centerline from the AT&T and WorldCom lines. The pipe will be buried in a trench 24 inches wide by 36 inches that will be cut into the rock. A one inch thick rock jacket will cover the pipe and the backfill will include two inches of lean concrete poured flush with the rock floor of the tunnel and covered with gravel.

A visual inspection of tunnel was conducted on July 30, 1997. The purpose of the inspection was to make observations of existing conditions and assess potential impacts to the pipeline.

The tunnel has finished inside dimensions of 24 feet high and 16 feet wide with an 8-foot radius arch at the tunnel crown and vertical ribs (sides). Both portals have built-up concrete structures and doors. The walls and ceiling of the tunnel are concrete lined throughout its entire length. The majority of the concrete lining dates from construction during the period 1912-1914, however some local sections of lining have recently been replaced. The concrete lining nominally 12 inches thick.

Approximately every 300 feet, a block-out is located in the lining. These block-outs were originally intended as refuge chambers and more recently have been used for electrical equipment which has been abandoned in place. Abandoned metal electrical conduits extend about 500 feet into the east portal and are located 10 to 15 feet above the invert. Concrete gutters run the length of the tunnel along both sides.

The geologic maps and construction records indicate that the tunnel was driven through an anticline, whose axis is oriented nearly perpendicular to the tunnel axis with limbs steeply dipping (50 to 80 degrees). The geology of the tunnel area is sedimentary with interbedded volcanics. The construction records indicate much of the rock encountered was massive black slate and that groundwater was encountered during mining of the tunnel. Gravel covers the floor of the tunnel.

Table 3.1-2 summarizes the results of the visual inspection. The major features observed during the site visit were groundwater seepage and degradation of the concrete lining. Groundwater was observed seeping from cracks and joints in the tunnel liner from the crown to the lower ribs at various locations through the length of the tunnel. The flows varied from drips to 1 to 2 gallons per minute. The concrete liner varied in condition from intact to spalled and decomposed up to 1 foot behind the finished face. At locations of deeper spalling reinforcing steel was exposed. No rock exposures were visible anywhere throughout the length of the tunnel.

Because the pipeline would be buried in the tunnel floor, there would be no impacts to the pipeline from spalling or rock falls from the tunnel liner.

**TABLE 3.1-2**
**OBSERVATION FROM TUNNEL INSPECTION**

| From | To | Observations |
|---|---|---|
| 1+70 | | 1 gpm seep from crown |
| 2+00 | | 1 gpm seep from crown |
| 2+00 | 3+00 | liner spalled 6-12", locally replaced north rib |
| 6+40 | | liner spalled at crown; mineral staining |
| 6+80 | | liner spalled 6-12" @ rebar exposed; from invert to 6" |
| 12+00 | | drain in crown mineral staining |
| 15+00 | | 0.1 gpm seep at crown |
| 14+25 | 15+00 | calcite staining crown to south invert; stalactites |
| 15+25 | | 0.1 gpm seep from drain at crown |
| 16+00 | | <0.05 gpm seep from drain at crown |
| 22+65 | 24+00 | lining spalling 3-9" @ 0-10= from invert |
| 24+00 | 24+75 | lining spalling 6-12@ deep 50% 0-10= from invert |

## TABLE 3.1-2 (CONTINUED)
## OBSERVATION FROM TUNNEL INSPECTION

| From | To | Observations |
|---|---|---|
| | | seepage mineralization |
| 27+15 | | mineral staining at crown |
| 27+75 | 28+20 | liner spalling 6-9@; friable, groundwater drips |
| 29+10 | | staining, groundwater drips, slight liner spalling |
| 30+00 | 31+50 | frequent groundwater drips, most ribs spalled |
| | | locally 6-12@ deep |
| 32+80 | | 1 gpm seep from roof drain |
| 33+00 | 36+00 | minor lining spalling |
| 42+00 | 45+50 | Frequent calcite staining/coating, local lining |
| | | spalling, friable, groundwater drips |
| 45+50 | | 0.1 gpm seep 10= above invert, south rib |
| 49+50 | 51+00 | Seepage at crown, calcite staining and stalactites |
| 51+00 | 51+50 | Drips from crown |
| 54+00 | 57+00 | Frequent mineral staining, surficial spall @ crown |
| 57+00 | 60+00 | Occasional drips, staining, spalling |
| 61+30 | | 0.2 gpm seep south rib spring line, iron staining |
| 67+10 | 67+50 | Staining south rib |
| 69+50 | 70+50 | Staining, surficial spalling, drips |
| 72+00 | | Occasional seep north rib, iron staining |
| 75+00 | 78+00 | Occasional calcium and iron stains, drips, spalling |
| 83+55 | | Seep at crown |
| 84+50 | 87+00 | Frequent seeps south rib above spring line, iron and calcium staining |
| 90+00 | 93+00 | Frequent calcium staining on joints and cracks |
| 93+00 | 99+00 | Occasional calcium staining on joints and cracks |
| 111+00 | 114+00 | occasional seeps spring line to crown |
| 114+00 | | 0.1 gpm seep at spring line |
| 114+00 | 117+00 | 3-6@ deep spalling |
| 117+00 | | Extensive spalling 3-6@ deep south rib |
| 118+85 | | 1-2 gpm seep south spring line |

### 3.1.7.2 Corfu Landslide

The landslide is located near the townsite of Corfu at the base of the north slope of the Saddle Mountains. Repeated slope failures may have occurred, in part, in response to repeated seismic activity or ground movement along the adjoining Saddle Mountain Fault. If this is the case, the Corfu Landslide may preserve a detailed paleoseismic record of the local seismicity. The construction of the pipeline will not affect Corfu Landslide, therefore, no mitigation measures are required.

### 3.1.8 EROSION/ENLARGEMENT OF LAND AREA (ACCRETION)

The potential for erosion, deposition or change of land surface from the placement of pipeline would primarily occur during construction and would be caused, if not mitigated by the measures described in Section 2.10, by erosion. Presented in this section is an assessment of the erosion potential for the proposed and alternative pipeline corridors (Section 3.1.8.1), planned facilities (3.1.8.2), and potential for enlargement of the land area and accretion (3.1.8.3). The assessment of erosion potential is principally based on the erosion potential specified for the surficial soils by the NRCS and DNR. Again, the mitigation measures to lessen or prevent erosion are described in Section 2.10 and above in Subsection 3.1.5.

#### 3.1.8.1 Erosion Potential for Proposed Pipeline Corridor and Alternative Routes

**Thrasher Pump Station to Snoqualmie:** Referring to GTMWH map page 5, a portion of the slope leading into the west side of the Snoqualmie River crossing, approximately 200 to 300 feet wide, has been mapped as moderate erosion potential. The eastern slopes of the Snoqualmie River (GTMWH map page 5), as well as the nearby stream crossing 13, were noted to be underlain by soil with high erosion potential. A large portion of the slope noted on GTMWH map page 6, which was described above to be underlain by relatively shallow soil over bedrock, was mapped to have moderate erosion potential.

**Snoqualmie to Interstate 90 East of North Bend:** This segment of the proposed alignment is generally mapped as underlain by soils with slight to no hazard to water erosion. Several locations along this segment of the proposed alignment were identified with the potential for encroachment by potential future meandering of the Snoqualmie River.

**Interstate 90 East of North Bend to the Western Tunnel Portal:** The Barneston soils have a moderately rapid permeability and slight hazard to water erosion. The Tokul-Pastik soils have a slow to moderate permeability and the hazard to water erosion has been mapped as moderate to severe.

**Western Tunnel Portal to the Crossing of the Yakima River:** The majority of soils listed above have moderate to high erosion potential, as determined by the NRCS and DNR from water and wind erodability criteria.

**Yakima River to the Kittitas Terminal:** The majority of soils crossed within this segment are listed as having a moderate to high erosion potentials, as determined by the NRCS and DNR from water and wind erodability criteria.

**Kittitas Terminal to the Columbia River:** The available soils erosion data for this section of the pipeline route is less comprehensive than for other pipeline segments. However, soils which do have recorded erosion potentials are commonly determined to be moderate to high erosion potential soils.

**Columbia River Crossing to Corfu:** The primary erosion concern for the majority of soils along the alignment through this portion to the pipeline route is wind erosion. The majority of the soils in this section are derived from outwash or eolian deposits, and are made up partially of fine silty material susceptible to wind. Water erosion is a lesser concern, with the majority of the soils of low to moderate water erosion potential. The particular soils are summarized above.

**Corfu to Wahluke Slope:** The primary erosion concern for the majority of soils along the alignment through this portion to the pipeline route is wind erosion. The majority of the soils in this section are derived from outwash or eolian deposits, and are made up partially of fine silty material susceptible to wind. Water erosion is a lesser concern, with the majority of the soils of low to moderate water erosion potential. The particular soils are summarized above.

**Wahluke Slope to the Pasco:** The primary erosion concern for the majority of soils along the alignment through this portion to the pipeline route is wind erosion. The majority of the soils in this section are derived from outwash or eolian deposits, and are made up partially of fine silty and sandy material susceptible to wind. Water erosion is a lesser concern, with the majority of the soils of low to moderate water erosion potential.

### 3.1.8.2 Erosion Potential for Proposed Pump Station Sites

**Thrasher's Pump Station:** The erosion potential for the Ragnar series soils at the Thrasher Pump Station site is classified as low by the NRCS.

**North Bend Pump Station:** Runoff from the Edgewick series soils at the North Bend Pump Station site is slow, and the NRCS classifies the erosion hazard is slight.

**Stampede Pass Pump Station:** The erosion potential for the Kachess series soils at the Stampede Pass Pump Station site is classified as low by the NRCS.

**Kittitas Pump Station:** DNR classifies the Mitta series soils at the Kittitas Pump Station site as having a low erosion potential.

**Beverly-Burke Pump Station:** Permeability of the Quincy series soils at the Beverely Burke Pump Station is rapid and runoff is slow to medium. The series is low (97, 98) to moderately (96, 99) water erodible and wind erodability is high for the series.

**Othello Pump Station:** The Shano series soils at the Othello Pump Station site is moderately water erodible and wind erodability is low.

### 3.1.8.3 Enlargement of Land Area

In general, the proposed pipeline corridor and facility sites are not located in areas expected to experience accretion by natural depositional processes. The potential exception is within creek and river channels crossed by the pipeline where natural processes could cause aggradation of sediments on top of the pipeline. Because the pipeline is already buried, aggradation would not affect the pipeline integrity.

Excess soils would be generated as a result of the pipeline installation. The volume of the excess soils would be slightly more than the volume of displacement by the pipe; this is the result of the change in soil density resulting from the ground disturbance. Relatively silty exposed disturbed soil would be susceptible to erosion, however erosion potential will be minimized through the use of erosion and sedimentation control measures.

As described above, there are two primary concerns for soil erosion: on the west side of the Cascade Mountains, there is a greater concern over water erosion. On the east side, the concern is over wind erosion. The measures described in Section 2.10 have been designed to prevent and lessen the amount of erosion during construction, and thus to decrease the accretion of land area as a result of this project to a low level.

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