3.17 Geology and Groundwater

The Pacific Northwest is a complex, geologically active region. Bridges are vital links in the transportation system and are often especially vulnerable during seismic events. This section identifies, describes, and evaluates the long-term and temporary effects of geologic hazards, as well as geologic and hydrogeologic (groundwater) conditions. The information presented in this section is based on the Geology and Groundwater Technical Report.

3.17.1 Changes or New Information Since 2013

The Columbia River Crossing (CRC) Selected Alternative identified in the 2011 Record of Decision (ROD), as revised by the 2012 and 2013 re-evaluations, is referred to as the CRC Locally Preferred Alternative (CRC LPA). Over the past 10+ years since the CRC LPA was identified, the physical environment in the study area, community priorities, and regulations have changed, which necessitated design revisions and resulted in the IBR Modified LPA (see Section 2.5.2). Evaluation of potential impacts associated with geology and groundwater has been updated in this Draft SEIS to include:

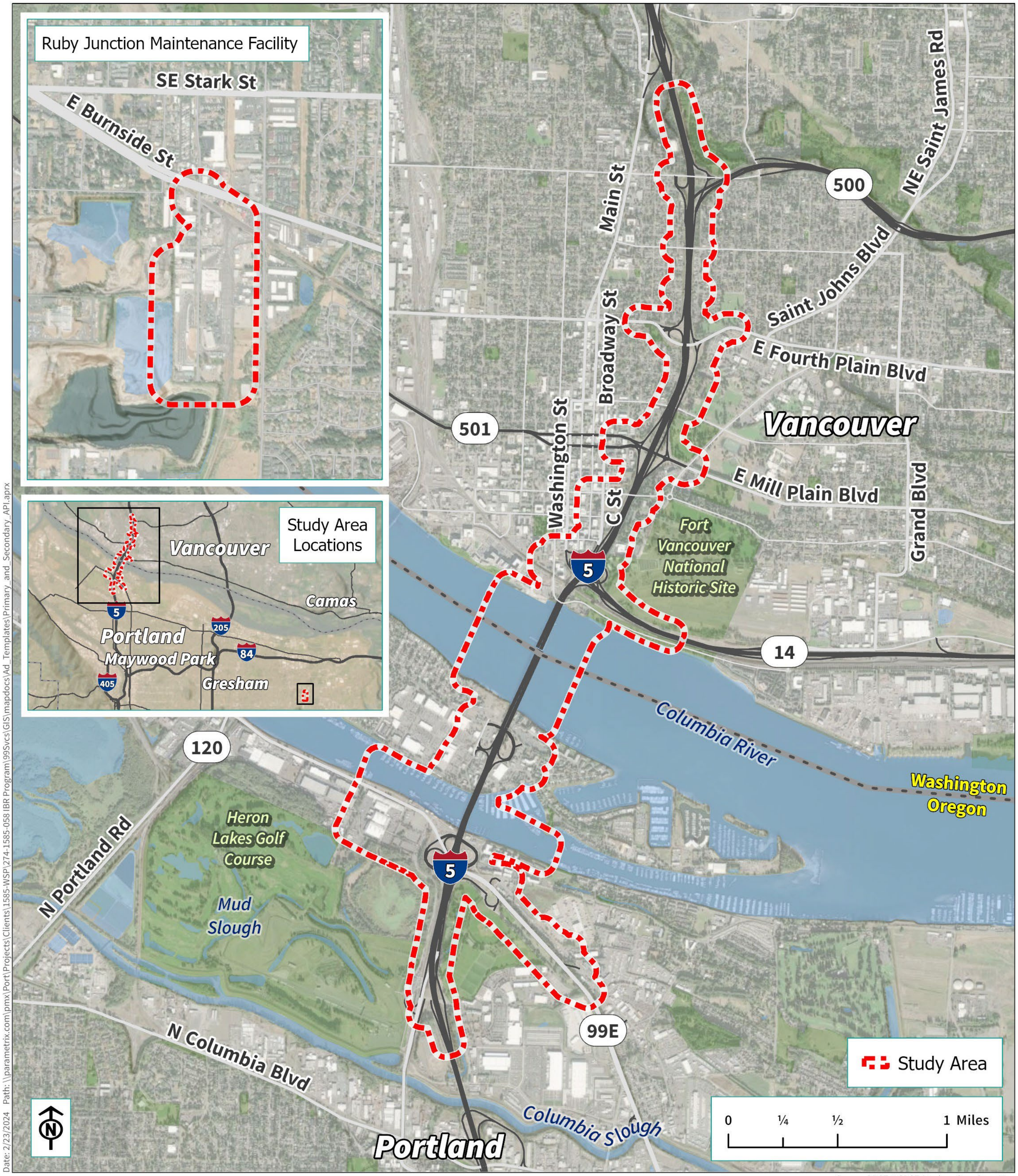
- Additional information about the increased risk for seismicity in the Cascadia Subduction Zone (CSZ).
- Additional consideration of geologic strata in the study area to accommodate new seismic standards.
- Changes in the project footprint necessitated by changed conditions resulted in shifting the LRT alignment and modifying interchange designs.
- Updated assessments of the long-term and temporary effects of geologic hazards on the Modified LPA.
- Updated engineering to address geological and seismic conditions, including new design requirements established by WSDOT and ODOT in 2020.

Based on the analysis described in this section, geologic and groundwater resource impacts of the Modified LPA would be similar to the CRC LPA. Despite changes in seismic standards since 2013, both the Modified LPA and CRC LPA would improve seismic resiliency compared to the existing Interstate Bridge. The improved seismic resiliency would improve public safety and structural stability in the event of a seismic event, reduce the potential for soil erosion and slope failure, and decrease the risk of damage to the new Columbia River bridges due to scour from a lahar event.

3.17.2 Existing Conditions

The geology and groundwater study area (Figure 3.17-1) is within the CSZ, a convergent plate boundary system where the Pacific Ocean plate descends beneath the North American plate. The CSZ makes the region subject to serious geologic and seismic hazards such as earthquakes, tsunamis, and volcanic eruptions that can put people and infrastructure at risk. The study area contains specific geologic and groundwater conditions that influence the design, location, and construction techniques.

Figure 3.17-1. Geology and Groundwater Study Area



Geologic Resources

The study area is relatively flat, with steeper slopes in the northern portion near Burnt Bridge Creek. Unconsolidated deposits of granular material such as sand, gravel, cobbles, and boulders underlie the study area and surrounding areas. These deposits provide a valuable aggregate mineral resource in the region. In addition, volcanic bedrock occurs deep below the surface.

What is moment magnitude (Mw)?

The moment magnitude scale, developed in the 1970s, is a method of measuring the strength of an earthquake. It has replaced the more familiar Richter scale because it can accurately measure a wider range of earthquake strengths. Like the Richter scale, the moment magnitude scale is *logarithmic*; an earthquake with M_w 6.0, for example, is about 32 times as strong as one with M_w 5.0. Moment magnitude scale measurements are similar to, but not precisely equal to, Richter scale measurements.

Geologic Hazards

Several types of earthquakes could occur in the study area. The most damaging potential earthquake would be caused by a shift in a large offshore fault located approximately 120 miles west of I-5. Such a shift could generate an earthquake with a moment magnitude (M_W) as high as M_w9.0. Effects from earthquakes result from ground motion amplification, soil instability, soil liquefaction, lateral spreading, seismic-generated water waves, and earthquake-induced landslides. Although moment magnitude is only one factor contributing to earthquake damage, earthquakes with high moment magnitudes can cause massive destruction.

Steep slopes, such as those in the Burnt Bridge Creek area, can be prone to erosion and landslides. However, there is no evidence of notable erosion or landslides in the study area.

Volcanic eruptions are not likely to occur within the study area. However, if Mt. Hood or another nearby Cascade volcano were to erupt, there is potential for some ashfall to accumulate in the study area and a large temporary increase in sediment load in the Columbia River. In the event of a Mt. Hood eruption, lahars (volcanic material flows) could carry sediment into the Sandy River, then into the Columbia River upstream of the study area.

What is a lahar?

A lahar is a flow of volcanic material (such as rock debris and gases) and water that travels quickly and can cover great distances. Lahars typically flow downstream of a volcano within a river valley.

Groundwater Resources

The primary groundwater resource in the study area is the Troutdale Aquifer System in Clark County, Washington and Multnomah County, Oregon. Within Clark County, the aquifer is designated as a sole source aquifer (SSA). In addition, Vancouver has designated the entire area within the city boundaries as a Critical Aquifer Recharge Area. Groundwater from the SSA in Washington and in Oregon is used for industry, irrigation, heat exchange, and drinking water. Under Section 1424(e) of the Safe Drinking Water Act, projects that seek federal funding and have the potential to contaminate an SSA are subject to U.S. Environmental Protection Agency review and approval.

Within the study area, the Troutdale Aquifer System is composed of multiple unconsolidated sedimentary deposits in the Portland Basin and includes aquifer recharge areas and discharge areas. In aquifer recharge areas, groundwater is replenished through precipitation, infiltration from the Columbia River and streams, percolation of water through pervious surfaces, and contributions from drywells and underground sewage disposal. Discharge areas are where groundwater is withdrawn from wells or where it emerges from the subsurface in springs, streams, or underwater where it discharges to the Columbia River.

> **What is a sole source aquifer?**
>
> EPA defines a sole source aquifer as an aquifer or aquifer system that supplies at least 50% of the drinking water consumed in the area overlying the aquifer and one for which there is no alternative source or combination of drinking water sources that could physically, legally, and economically act to supply those dependent upon the aquifer.

No drinking water supply wells are currently used within the study area in Oregon. Within the study area in Washington, the city of Vancouver relies entirely on groundwater from the Troutdale Aquifer System. Within downtown Vancouver, groundwater flow is influenced by pumping from water supply wells. In accordance with federal and state regulations, Vancouver has established Special Wellhead Protection Areas around these wells, within which certain activities, such as hazardous material and municipal waste disposal, septic systems, and infiltration systems, are restricted to protect groundwater quality. A Special Wellhead Protection Area is located within the northern portion of the study area.

Groundwater Quality

Contaminants from commercial and industrial activities in Vancouver and Portland have resulted in areas of diminished groundwater quality. Information available from the Oregon Department of Environmental Quality and Washington Department of Ecology indicates that contaminants such as chlorinated solvents, petroleum products, and metals are found in groundwater at various locations in the study area.

As stipulated in the Safe Drinking Water Act and Washington Administrative Code Chapter 290, suppliers of drinking water must monitor for and meet primary and secondary drinking water standards. Beginning in approximately January 1979, the City of Vancouver has sampled and analyzed groundwater from its wells for the following classes of compounds: inorganics, volatile organic compounds, herbicides, pesticides, insecticides, radionuclides, fumigants, dioxins, and nitrate. A review of water quality data by the Washington State Department of Health indicates that none of these contaminants have been detected at or above their allowable limits in groundwater at any Vancouver water stations since the 1980s.

3.17.3 Long-Term Benefits and Effects

Table 3.17-1 summarizes the effects of the No-Build Alternative, Modified LPA, and design options on geology and groundwater. Detailed analysis of the effects is provided in the following sections.

Table 3.17-1. Summary of No-Build Alternative and Modified LPA Effects on Geology and Groundwater

1	2	3
No-Build Alternative	Modified LPA with Double-Deck or Single-Level Fixed-Span Configuration,[a] One or Two Auxiliary Lanes, with or without C Street Ramps, Centered I-5 or I-5 Westward Shift, all Park-and-Ride Site Options	Modified LPA with Single-Level Movable-Span Configuration, One Auxiliary Lane, C Street Ramps, Centered I-5, all Park-and-Ride Site Options
• No change (seismic deficiencies remain, would not affect geologic resources, would sustain existing impacts to degradation of the groundwater quality).	• Improved public safety, minimizing damage to infrastructure, and limiting potential economic disruption due to seismic improvements. • Slight potential for increased use of materials that could spur expansion and/or opening of surface mines. • Benefits to groundwater as a result of stormwater management and treatment.	• Similar to effects listed in Column 2, but would require more substantial river piers and pier foundations to support the movable spans.

a The long-term effects associated with the single-level fixed-span configuration would be the same for all bridge type options, unless otherwise specified.

No-Build Alternative

Geologic Hazards

The No-Build Alternative would maintain the existing I-5 infrastructure in the study area and would not provide seismic improvements to the Interstate Bridge or other I-5 structures. The existing structures were built before modern seismic codes were developed and could be substantially damaged in an earthquake. The No-Build Alternative would also not address the risks of increased scour from potential flooding and sediment load due to upstream, seismic induced landslides or lahars resulting from regional volcanic activity.

Geologic Resources

The No-Build Alternative would have limited need for geologic resources for I-5 operation and maintenance. The No-Build Alternative would not affect local surface mining resources or expand local quarries.

Groundwater Resources

The No-Build Alternative would not provide stormwater management or treatment, and therefore existing impacts to degradation of the groundwater quality in the study area would continue.

Modified LPA

Geologic Hazards

Earthquakes

The Modified LPA would have the long-term benefit of improving public safety, minimizing damage to infrastructure, and limiting potential economic disruption in the event of an earthquake. The new Columbia River and North Portland Harbor bridges, as well as ramp and interchange structures and transit facilities, would be built to modern seismic safety standards. Design of the Modified LPA would apply advancements in earthquake engineering, structural safety standards, and site-specific geological and seismic risk information in the study area, which would improve public safety and structural stability during an earthquake. To meet current design standards, the Columbia River bridges with the Modified LPA would include more substantial foundation elements than the existing Interstate Bridge. The single-level movable-span configuration may require more substantial foundation elements than the fixed-span configurations. This is because mechanical tolerances for this type of bridge may require additional support for a seismic event.

The Modified LPA would stabilize weak soils along the Columbia River, on Hayden Island, around Marine Drive, and at Burnt Bridge Creek that are susceptible to liquefaction during seismic events through ground improvements such as soil mixing or stone columns.

The Ruby Junction Maintenance Facility expansion area lies entirely within an area classified as Seismic Hazard Zone D – Least Hazard. Construction of the Modified LPA would not increase seismic effects hazards at the facility.

Soil Liquefaction

Soil liquefaction is a phenomenon associated with earthquakes in which sandy to silty, water-saturated soils behave like fluids. As seismic waves pass through saturated soil, the structure of the soil distorts, and spaces between soil particles collapse, causing ground failure. In general, young, loose sediment and areas with high water tables are the most vulnerable to liquefaction.

Non-Seismic Settling

In the Portland area, there are a number of flood control levees located within the study area. Additionally, enhancements to the levee system and some new structures that will be a part of the levee system are in the planning stages. The Modified LPA includes structures and significant fills placed in the vicinity of the existing or planned levee sections that could induce longer term settling of soils, which may cause a reduction in the overflow elevations for the levees. Structure foundation elements that penetrate the levees can compromise the ability of the levee to retain water and increase seepage.

In areas on both sides of the Columbia River, Hayden Island, and throughout the study area, the placement of construction fill, retaining walls, or other structures for the Modified LPA could result in non-seismic soil settling. The potential for non-seismic settling would be addressed as a part of the geotechnical design for the Modified LPA.

Steep Slopes, Soil Erosion, and Landslides

The Modified LPA would minimize construction on steep slopes. The roadway design would include retaining walls or other stabilization techniques to reduce the potential for soil erosion and slope failure hazards. In the Burnt Bridge Creek area, which has steep slopes, the design includes grading of slope angles, management of stormwater volume and flow to reduce erosion, and revegetation of disturbed areas.

As noted above, landslides are not known to occur within the study area. The Modified LPA would address the risks of increased scour that could result from potential landslides upstream caused by a major CSZ event. New bridge pier design would decrease the risk of bridge damage in the event of changes in river flow and/or sediment loads due to upstream landslides in the river.

The Ruby Junction Maintenance Facility expansion area is generally flat without steep slopes. No long-term effects on geologic hazards are anticipated in this area.

Volcanoes

The Modified LPA would include design measures to address the risks of increased scour from potential volcano-related impacts and decrease the risk of damage to the new Columbia River bridges due to lahar effects upstream of the study area.

In the event of a volcanic eruption within the Cascade region, the prevailing wind patterns would carry the majority of ash to the northeast, away from the study area. Therefore, ash accumulation is not anticipated to pose risks to the new bridges under the Modified LPA.

Groundwater Resources

The Modified LPA would provide long-term benefits to groundwater as a result of stormwater management and treatment throughout the study area. The associated reduction in pollutants from treatment of highway runoff would benefit the groundwater quality for the Troutdale SSA and groundwater flows that contribute to the Columbia River and Burnt Bridge Creek. There would be no adverse effects on groundwater resources.

3.17.4 Temporary Effects

No-Build Alternative

The No-Build Alternative would not have construction-related temporary effects on existing geologic hazards, geologic resources, or groundwater resources.

Modified LPA

The Modified LPA would require excavating filling, drilling, and grading activities during construction. Because the movable parts would be more sensitive to foundation settlement and movement during a seismic event, the single-level movable-span configuration may require slightly more construction effort and materials to construct the relatively larger river piers and pier foundations.

Geologic Hazards

Earthquakes

Construction of the Modified LPA, including construction of the new bridges and removal of the existing Interstate Bridge, would follow the American Association of State Highway and Transportation Officials standards. Temporary structures would incorporate appropriate seismic design. Although this would not provide the same level of resiliency as the completed infrastructure, it would minimize risks from earthquakes during construction.

Non-Seismic Settling

Although the design of the Modified LPA would address potential non-seismic settlement, if not correctly designed and constructed, new structures with the Modified LPA could experience settling during construction. Settling around structures occurs as soil conditions adjust to the weight of new structures. Settling can result in various adverse effects, such as roadway cracks and compromised foundations, which would require repair during construction. The greatest potential for settling is likely to occur on Hayden Island and along the shoreline of the Columbia River, where fill materials were previously used to extend shorelines and fill depressions.

In the Portland area, there are a number of flood control levees located within the study area. These levees could be impacted by the proposed construction and settlements could generate low spots in the levee system.

Potential non-seismic settlement could be present in areas of the Modified LPA where retaining walls and other structures are planned. Construction of retaining walls and backfilling could result in adverse effects from settling, if not properly engineered and compacted. In addition, ground improvement methods could be used during construction to provide beneficial structural performance in the Modified LPA. In areas where retaining walls are proposed at the edge of the project footprint, the Modified LPA would comply with current standards for geotechnical assessment, design, and construction to minimize the potential for settlement on adjacent properties. With the correct design and construction methods, the risks of settlement would be minimal.

Soil Erosion

Soil erosion could occur during construction if not controlled. Construction activities could expose erosive soils to wind and stormwater. Soil erosion has the potential to temporarily plug stormwater catch basins; deposit soil surface water on roadways; diminish surface water quality in the Columbia River, Vanport Wetland, and Burnt Bridge Creek; and undermine existing roadways and structures. The Modified LPA would expose approximately 415 acres of near-surface soils to potential erosion from excavation, fill, clearing, and grading during construction. Best management practices for erosion control, as described in Section 3.17.5, would be incorporated into construction specifications to minimize the potential for these hazards.

Geologic Resources

The Modified LPA would require large amounts of geologic resources during construction, including topsoil, fill, aggregate, and rock. Project-created demand could require existing aggregate mines to expand or new mine sites to be developed. Local geologic resources are not unique but are limited in number, material types, and volumes; approximately 33 mine sites are present within 10 miles of the study area.

Groundwater Resources

The Modified LPA is not expected to have substantial temporary effects on groundwater resources. Construction techniques for deep bridge foundations would be designed to minimize the need for groundwater dewatering. Dewatering may be necessary in areas where roadway sections are depressed and there is a shallow water table, but the volume of water produced is expected to be small and would come from shallow depths, not connected with groundwater resource production. Stormwater protection measures, including spill prevention plans, would be in place during construction to protect groundwater and surface water.

3.17.5 Indirect Effects

Geologic Hazards

The greatest risk from earthquakes under the Modified LPA occurs on Hayden Island and near the Columbia River and North Portland Harbor. Earthquake effects include ground motion amplification and soil liquefaction, which have a high potential to impact public safety, cause structural damage, and result in economic disruption. Compared to the No-Build Alternative, the Modified LPA may attract development near Vancouver's waterfront and Hayden Island, which is consistent with local land use plans (see Section 3.4.4). New and retrofitted buildings and structures would be built to current seismic safety standards, potentially enhancing public safety and decreasing the likelihood of structural and economic damage and disruption.

A flood protection system consisting of levees and flood walls is presently located on the southern edge of the Oregon Slough. The Modified LPA would necessarily cross these embankments and structures. Construction for the Modified LPA could introduce additional loads on the ground around these and cause some settlements, potentially generating low spots in the flood control system. Proper design and planning for the foundation elements would minimize these risks. In addition, the Program would carefully design foundation elements that might be required to penetrate any levee elements or affect the stability of the levees in any way.

Groundwater Resources

Currently, stormwater in the study area is not treated. Over time, enhanced stormwater management requirements and treatment standards would likely improve local groundwater quality, particularly for the Troutdale Aquifer System.

Geologic Resources

Depending on the nature of long-term maintenance needs for the Modified LPA, there is the potential for increased use of materials such as aggregate and concrete for the project. This slight increase in demand for these materials could sustain mines or quarries over the long term. Mining operators would have to comply with federal, state, and local laws to minimize potential environmental damage.

3.17.6 Potential Avoidance, Minimization, and Mitigation Measures

Long-Term Effects

Regulatory Requirements

- Design structures to comply with federal, state, and city building seismic codes and standards and apply advancements in earthquake science and construction materials and updates in the conceptual model.
- Design systems to minimize contamination of groundwater resources in compliance with Vancouver Municipal Code Chapter 14.26 Water and Sewers – Water Resources Protection and Portland City Code Title 21.35, Well Head Protection, and any applicable Washington and Oregon regulations.

Program-Specific Mitigation

- Design structures to consider stormwater infiltration or other changed conditions near shallow footings, retaining walls, and other structures that could increase the potential for soil liquefaction during a future seismic event.
- Design the Modified LPA to accommodate a range of future conditions resulting from climate change to provide resilience for geologic concerns, such as increased erosion and scour, as feasible.
- Conduct site-specific assessments of existing geologic hazards such as, but not limited to, faults, ancient landslides, steep cut slopes, non-seismic settlements, and soil liquefaction during design of the Modified LPA, as feasible. Site-specific assessments should include the use of geotechnical drilling, test pitting, material testing, geophysical techniques, subsurface displacement monitoring (inclinometers) and monitoring well installation, as feasible. Assessment would include recommended options for avoiding or mitigating geologic hazards.
- Consider the use of light weight fills or geoform in areas adjacent to existing flood control levees and structures to minimize the potential for settlements.
- Assess soil stabilization techniques to minimize the potential for soil liquefaction and non-seismic settlements during design of the Modified LPA. Stabilization techniques may include, but are not limited to, the use of soil mixing, compaction grouting, jet grouting, and stone columns.
- Locate stormwater treatment facilities, to the extent possible, away from City of Vancouver well head protection zones for WS-1 and WS-3, and the Cascade Expansion groundwater protection area in Gresham for the Ruby Junction location.

Temporary Effects

Regulatory Requirements

- Prepare and implement erosion control and stormwater pollution prevention plans and grading plans during construction. Plans would adhere to ODOT and WSDOT guidelines.
- Prepare and implement stormwater discharge permits for construction.
- Conduct inspection and observation monitoring of all Modified LPA elements during construction and long-term operations to ensure that appropriate construction and maintenance measures are being taken.

Program-Specific Mitigation

- Evaluate local geologic resources for future material needs.
- Recycle or reuse aggregate, quarry rock, asphalt, and concrete materials to the extent practical.