INTERSTATE 5 COLUMBIA RIVER CROSSING

Geology and Soils Technical Report

May 2008

Columbia River CROSSING

TO: Readers of the CRC Technical Reports

FROM: CRC Project Team

SUBJECT: Differences between CRC DEIS and Technical Reports

The I-5 Columbia River Crossing (CRC) Draft Environmental Impact Statement (DEIS) presents information summarized from numerous technical documents. Most of these documents are discipline-specific technical reports (e.g., archeology, noise and vibration, navigation, etc.). These reports include a detailed explanation of the data gathering and analytical methods used by each discipline team. The methodologies were reviewed by federal, state and local agencies before analysis began. The technical reports are longer and more detailed than the DEIS and should be referred to for information beyond that which is presented in the DEIS. For example, findings summarized in the DEIS are supported by analysis in the technical reports and their appendices.

The DEIS organizes the range of alternatives differently than the technical reports. Although the information contained in the DEIS was derived from the analyses documented in the technical reports, this information is organized differently in the DEIS than in the reports. The following explains these differences. The following details the significant differences between how alternatives are described, terminology, and how impacts are organized in the DEIS and in most technical reports so that readers of the DEIS can understand where to look for information in the technical reports. Some technical reports do not exhibit all these differences from the DEIS.

Difference #1: Description of Alternatives

The first difference readers of the technical reports are likely to discover is that the full alternatives are packaged differently than in the DEIS. The primary difference is that the DEIS includes all four transit terminus options (Kiggins Bowl, Lincoln, Clark College Minimum Operable Segment (MOS), and Mill Plain MOS) with each build alternative. In contrast, the alternatives in the technical reports assume a single transit terminus:

- Alternatives 2 and 3 both include the Kiggins Bowl terminus
- Alternatives 4 and 5 both include the Lincoln terminus

In the technical reports, the Clark College MOS and Mill Plain MOS are evaluated and discussed from the standpoint of how they would differ from the full-length Kiggins Bowl and Lincoln terminus options.

Difference #2: Terminology

Several elements of the project alternatives are described using different terms in the DEIS than in the technical reports. The following table shows the major differences in terminology.

DEIS terms	Technical report terms
Kiggins Bowl terminus	I-5 alignment
Lincoln terminus	Vancouver alignment
Efficient transit operations	Standard transit operations
Increased transit operations	Enhanced transit operations

Difference #3: Analysis of Alternatives

The most significant difference between most of the technical reports and the DEIS is how each structures its discussion of impacts of the alternatives. Both the reports and the DEIS introduce long-term effects of the full alternatives first. However, the technical reports then discuss “segment-level options,” “other project elements,” and “system-level choices.” The technical reports used segment-level analyses to focus on specific and consistent geographic regions. This enabled a robust analysis of the choices on Hayden Island, in downtown Vancouver, etc. The system-level analysis allowed for a comparative evaluation of major project components (replacement versus supplemental bridge, light rail versus bus rapid transit, etc). The key findings of these analyses are summarized in the DEIS; they are simply organized in only two general areas: impacts by each full alternative, and impacts of the individual “components” that comprise the alternatives (e.g. transit mode).

Difference #4: Updates

The draft technical reports were largely completed in late 2007. Some data in these reports have been updated since then and are reflected in the DEIS. However, not all changes have been incorporated into the technical reports. The DEIS reflects more recent public and agency input than is included in the technical reports. Some of the options and potential mitigation measures developed after the technical reports were drafted are included in the DEIS, but not in the technical reports. For example, Chapter 5 of the DEIS (Section 4(f) evaluation) includes a range of potential “minimization measures” that are being considered to reduce impacts to historic and public park and recreation resources. These are generally not included in the technical reports. Also, impacts related to the stacked transit/highway bridge (STHB) design for the replacement river crossing are not discussed in the individual technical reports, but are consolidated into a single technical memorandum.

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Cover Sheet

Interstate 5 Columbia River Crossing

Geology and Soils Technical Report:

Submitted By:

Michael Marshall

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ACRONYMS

Acronym	**Description**
AASHTO	American Association of State Highway and Transportation Officials
ADA	Americans with Disabilities Act
APE	Area of Potential Effect
API	Area of Potential Impact
BRT	Bus Rapid Transit
CFR	Code of Federal Regulations
COE	U.S. Army Corps of Engineers
CRBG	Columbia River Basalt Group
CRC	Columbia River Crossing
DEIS	Draft Environmental Impact Statement
DGER	Washington State Department of Natural Resources, Division of Geology and Earth Resources
DOGAMI	Oregon Department of Geology and Mineral Industries
DRG	Digital Raster Graphic
EIS	Environmental Impact Statement
FEIS	Final Environmental Impact Statement
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
Ft	feet/foot
GIS	Geographic Information System
GPM	Gallons per Minute
HCT	High-Capacity Transit
HUC	Hydrological Unit Code
LRT	Light Rail Transit
M	Earthquake Magnitude
MDR	Methods and Data Report
NEPA	National Environmental Policy Act
NRCS	Natural Resources Conservation Service
OAR	Oregon Administrative Rule
ODOT	Oregon Department of Transportation
ORS	Oregon Revised Statutes
RCW	Revised Code of Washington
SGA	Sand and Gravel Aquifer
SRMA	Sandy River Mudstone Aquifer
TGA	Troutdale Gravel Aquifer
TSA	Troutdale Sandstone Aquifer
USA	Unconsolidated Sedimentary Aquifer
USGS	U.S. Geological Survey
WSDOT	Washington State Department of Transportation

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1. Summary

1.1 Introduction

The purpose of this technical report is to provide a summary of the geologic, soils, and hydrogeologic corridor assessment performed for the Interstate 5 (I-5) Columbia River Crossing (CRC) project. The Oregon Department of Transportation (ODOT) and Washington State Department of Transportation (WSDOT) will use this report to support the optimization of design concepts and the evaluation of alternatives in the Environmental Impact Statement (EIS). This report covers a key environmental element that is addressed as part of this project's National Environmental Policy Act (NEPA) compliance process.

The report includes the following elements:

- Descriptions of alternatives, the area of potential impact (API), and existing conditions in the affected environment
- Summaries of methods for data collection and analysis and project coordination activities
- Long-term, short-term and cumulative effects to geologic conditions
- Mitigation measures for long-term and short-term effects
- Required permits and approvals
- References

1.2 Description of the Alternatives

The alternatives being considered for the CRC project consist of a diverse range of highway, transit and other transportation choices. Some of these choices – such as the number of traffic lanes across the river – could affect transportation performance and impacts throughout the bridge influence area or beyond. These are referred to as "system-level choices." Other choices – such as whether to run high-capacity transit (HCT) on Washington Street or Washington and Broadway Streets – have little impact beyond the area immediately surrounding that proposed change and no measurable effect on regional impacts or performance. These are called "segment-level choices." This report discusses the impacts from both system- and segment-level choices, as well as "full alternatives." The full alternatives combine system-level and segment-level choices for highway, transit, pedestrian, and bicycle transportation. They are representative examples of how project elements may be combined. Other combinations of specific elements are possible. Analyzing the full alternatives allows us to understand the combined performance and impacts that would result from multimodal improvements spanning the bridge influence area.

Following are brief descriptions of the alternatives being evaluated in this report, which include:

- System-level choices,
- Segment-level choices, and
- Full alternatives.

1.2.1 System-Level Choices

System-level choices have potentially broad influence on the magnitude and type of benefits and impacts produced by this project. These options may influence physical or operational characteristics throughout the project area and can affect transportation and other elements outside the project corridor as well. The system-level choices include:

- River crossing type (replacement or supplemental)
- High-capacity transit mode (bus rapid transit or light rail transit)
- Tolling (no toll, I-5 only, I-5 and I-205, standard toll, higher toll)

This report compares replacement and supplemental river crossing options. A replacement river crossing would remove the existing highway bridge structures across the Columbia River and replace them with three new parallel structures – one for I-5 northbound traffic, another for I-5 southbound traffic, and a third for HCT, bicycles, and pedestrians. A supplemental river crossing would build a new replacement bridge span downstream of the existing I-5 bridge. The new supplemental bridge would carry southbound I-5 traffic and HCT, while the existing I-5 bridge would carry northbound I-5 traffic, bicycles, and pedestrians. The replacement crossing would include three through-lanes and two auxiliary lanes for I-5 traffic in each direction. The supplemental crossing would include three through-lanes and one auxiliary lane in each direction.

Two types of HCT are being considered – bus rapid transit and light rail transit. Both would operate in an exclusive right-of-way through the project area, and are being evaluated for the same alignments and station locations. The HCT mode – LRT or BRT – is evaluated as a system-level choice. Alignment options and station locations are discussed as segment-level choices. BRT would use 60-foot or 80-foot long articulated buses in lanes separated from other traffic. LRT would use one- and two-car trains in an extension of the MAX line that currently ends at the Expo Center in Portland.

Under the efficient operating scenario, LRT trains would run at approximately 7.5 minute headways during the peak periods. BRT would run at headways between 2.5 and 10 minutes depending on the location in the corridor. BRT would need to run at more frequent headways to match the passenger-carrying capacity of the LRT trains. This report also evaluates performance and impacts for an increased operations scenario that would double the number of BRT vehicles or the number of LRT trains during the peak periods.

1.2.2 Segment-Level Choices

1.2.2.1 Transit Alignments

The transit alignment choices are organized into three corridor segments. Within each segment the alignment choices can be selected relatively independently of the choices in the other segments. These alignment variations generally do not affect overall system performance but could have important differences in the impacts and benefits that occur in each segment. The three segments are:

- Segment A1 – Delta Park to South Vancouver
- Segment A2 – South Vancouver to Mill Plain District
- Segment B – Mill Plain District to North Vancouver

In Segment A1 there are two general transit alignment options - offset from, or adjacent to, I-5. An offset HCT guideway would place HCT approximately 450 to 650 feet west of I-5 on Hayden Island. An adjacent HCT guideway across Hayden Island would locate HCT immediately west of I-5. The alignment of I-5, and thus the alignment of an adjacent HCT guideway, on Hayden Island would vary slightly depending upon the river crossing and highway alignment, whereas an offset HCT guideway would retain the same station location regardless of the I-5 bridge alignment.

HCT would touch down in downtown Vancouver at Sixth Street and Washington Street with a replacement river crossing. A supplemental crossing would push the touch down location north to Seventh Street. Once in downtown Vancouver, there are two alignment options for HCT – a two-way guideway on Washington Street or a couplet design that would place southbound HCT on Washington Street and northbound HCT on Broadway. Both options would have stations at Seventh Street, 12th Street, and at the Mill Plain Transit Center between 15th and 16th Streets.

From downtown Vancouver, HCT could either continue north on local streets or turn east and then north adjacent to I-5. Continuing north on local streets, HCT could either use a two-way guideway on Broadway or a couplet on Main Street and Broadway. At 29th Street, both of these options would merge to a two-way guideway on Main Street and end at the Lincoln Park and Ride located at the current WSDOT maintenance facility. Once out of downtown Vancouver, transit has two options if connecting to an I-5 alignment: head east on 16th Street and then through a new tunnel under I-5, or head east on McLoughlin Street and then through the existing underpass beneath I-5. With either option HCT would connect with the Clark College Park and Ride on the east side of I-5, then head north along I-5 to about SR 500 where it would cross back over I-5 to end at the Kiggins Bowl Park and Ride.

There is also an option, referred to as the minimum operable segments (MOS), which would end the HCT line at either the Mill Plain station or Clark College. The MOS options provide a lower cost, lower performance alternative in the event that the full-length HCT lines could not be funded in a single phase of construction and financing.

1.2.2.2 Highway and Bridge Alignments

This analysis divides the highway and bridge options into two corridor segments, including:

- Segment A – Delta Park to Mill Plain District
- Segment B – Mill Plain District to North Vancouver

Segment A has several independent highway and bridge alignment options. Differences in highway alignment in Segment B are caused by transit alignment, and are not treated as independent options.

A replacement crossing is located downstream of the existing I-5 bridge. At the SR 14 interchange there are two basic configurations being considered. A traditional configuration would use ramps looping around both sides of the mainline to provide direct connection between I-5 and SR 14. A less traditional design could reduce right-of-way requirements by using a "left loop" that would stack both ramps on the west side of the I-5 mainline.

1.2.3 Full Alternatives

Full alternatives represent combinations of system-level and segment-level options. These alternatives have been assembled to represent the range of possibilities and total impacts at the project and regional level. Packaging different configurations of highway, transit, river crossing, tolling and other improvements into full alternatives allows project staff to evaluate comprehensive traffic and transit performance, environmental impacts and costs.

Exhibit 1-1 summarizes how the options discussed above have been packaged into representative full alternatives.

Exhibit 1-1. Full Alternatives

	Packaged Options				
Full Alternative	**River Crossing Type**	**HCT Mode**	**Northern Transit Alignment**	**TDM/TSM Type**	**Tolling Method**[a]
1	Existing	None	N/A	Existing	None
2	Replacement	BRT	I-5	Aggressive	Standard Rate
3	Replacement	LRT	I-5	Aggressive	Two options[b]
4	Supplemental	BRT	Vancouver	Very Aggressive	Higher rate
5	Supplemental	LRT	Vancouver	Very Aggressive	Higher rate

[a] In addition to different tolling rates, this report evaluates options that would toll only the I-5 river crossing and options that would toll both the I-5 and the I-205 crossings.

[b] Alternative 3 is evaluated with two different tolling scenarios, tolling and non-tolling.

Modeling software used to assess alternatives' performance does not distinguish between smaller details, such as most segment-level transit alignments. However, the geographic difference between the Vancouver and I-5 transit alignments is significant enough to warrant including this variable in the model. All alternatives include Transportation Demand Management (TDM) and Transportation System Management (TSM) measures designed to improve efficient use of the transportation network and encourage alternative transportation options to commuters such as carpools, flexible work hours, and telecommuting. Alternatives 4 and 5 assume higher funding levels for some of these measures.

Alternative 1: The National Environmental Policy Act (NEPA) requires the evaluation of a No-Build or "No Action" alternative for comparison with the build alternatives. The No-Build analysis includes the same 2030 population and employment projections and the same reasonably foreseeable projects assumed in the build alternatives. It does not include any of the I-5 CRC related improvements. It provides a baseline for comparing the build alternatives, and for understanding what will happen without construction of the I-5 CRC project.

Alternative 2: This alternative would replace the existing I-5 bridge with three new bridge structures downstream of the existing bridge. These new bridge structures would carry Interstate traffic, BRT, bicycles, and pedestrians. There would be three through-lanes and two auxiliary lanes for I-5 traffic in each direction. Transit would include a BRT system that would operate in an exclusive guideway from Kiggins Bowl in Vancouver to the Expo Center station in Portland. Express bus service and local and feeder bus service would increase to serve the added transit capacity. BRT buses would turn around at the existing Expo Station in Portland, where riders could transfer to the MAX Yellow Line.

Alternative 3: This is similar to Alternative 2 except that LRT would be used instead of BRT. This alternative is analyzed both with a toll collected from vehicles crossing the Columbia River on the new I-5 bridge, and with no toll. LRT would use the same transit alignment and station locations. Transit operations, such as headways, would differ, and LRT would connect with the existing MAX Yellow Line without requiring riders to transfer.

Alternative 4: This alternative would retain the existing I-5 bridge structures for northbound Interstate traffic, bicycles, and pedestrians. A new crossing would carry southbound Interstate traffic and BRT. The existing I-5 bridges would be re-striped to provide two lanes on each structure and allow for an outside safety shoulder for disabled vehicles. A new, wider bicycle and pedestrian facility would be cantilevered from the eastern side of the existing northbound (eastern) bridge. A new downstream supplemental bridge would carry four southbound I-5 lanes (three through-lanes and one auxiliary lane) and BRT. BRT buses would turn around at the existing Expo Station in Portland, where riders could transfer to the MAX Yellow Line. Compared to Alternative 2, increased transit service would provide more frequent service. Express bus service and local and feeder bus service would increase to serve the added transit capacity.

Alternative 5: This is similar to Alternative 4 except that LRT would be used instead of BRT. LRT would have the same alignment options, and similar station locations and requirements. LRT service would be more frequent (approximately 3.5 minute headways during the peak period) compared to 7.5 minutes with Alternative 3. LRT would connect with the existing MAX Yellow Line without requiring riders to transfer.

1.3 Long-Term Effects

Long-term effects are future effects to resources within the region or segment that may occur after the completion of the I-5 CRC project.

1.3.1 Regional Effects

Regional effects to resources are those that extend from the API into the greater Clark, Clackamas, Multnomah, and Skamania County areas. With respect to regional geologic and hydrogeologic resources, the following beneficial long-term effects could occur:

- Protection of groundwater resources in the primary API through better management and treatment of stormwater runoff.

The following adverse long-term effects could occur:

- Reduced recharge to groundwater due to placement of low permeability materials (i.e. fill material, asphalt).
- Induced growth could put a strain on groundwater resources outside the API.
- Project construction could require consumption and depletion of aggregate resources and enlargement of pits and quarries.

1.3.2 Segment-Level Effects

Segment-level effects to resources are those that occur within the API.

With respect to geologic and hydrogeologic resources the following beneficial long-term effects could occur within Segment A:

- Reduced erosion of open surfaces
- Seismic upgrades to structures and roadways

The following adverse long-term effects could occur within Segment A:

- Change in localized riverbed topography due to changes in bridge prier locations

With respect to geologic and hydrogeologic resources the following beneficial long-term effects could occur within Segment B:

- Stabilization of steep slopes or potential landslides
- Reduced erosion of open surfaces
- Seismic upgrades to structures and roadways

The following adverse long-term effects could occur within Segment B:

- De-stabilization of steep slopes or potential landslides

1.4 Temporary Effects

Temporary effects to resources within the region or the locality from the project are those that occur prior to and during construction of the I-5 CRC project. With respect to geologic and hydrogeologic resources the following beneficial temporary effects could occur:

- Economic benefits to local quarry and aggregate mining industry

The following adverse temporary effects could occur:

- Induced erosion from construction
- Degraded groundwater quality from construction

1.5 Mitigation

To offset or avoid effects to geology and soils, the following potential mitigation and minimization measures were identified:

- Avoidance of steep slopes identified in the Burnt Bridge Creek drainage, in the northern portion of Segment B.
- Recycling of on-site borrow pit and aggregate materials.
- Seismic upgrades to existing or newly proposed structures within the API susceptible to earthquake hazards.
- Future identification and characterization of geologic hazards such as ancestral landslides, or soils with potential liquefaction.
- Erosion controls through the implementation of erosion control plans and grading permits
- Protection of groundwater resources through stormwater management and treatment
- Evaluation of future groundwater beneficial use for induced growth.

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2. Methods

2.1 Introduction

The purpose of this Geology and Soils Technical Report is to identify potentially appreciable adverse impacts and/or beneficial effects to the existing geologic, hydrogeologic, and soil conditions within the study corridor. The analysis was developed to comply with the National Environmental Policy Act of 1969 (NEPA), applicable state environmental policy, legislation, local and state planning, land-use policies, and design standards.

This technical report presents the geologic conditions within the I-5 CRC primary and secondary APIs. These results help determine to what extent the proposed design options may impact geologic and hydrologic resources or may be impacted by geologic hazards in the APIs. Information from this determination will be used to analyze effects from the proposed alternatives.

Data sources and data collection methodologies presented in this technical report are consistent with those described in the Methods and Data Report (MDR) for geology and soils. This report includes information on regional geology, hydrogeology, geologic hazards (steep slope areas, landslides, and earthquake hazard prone areas), and soils.

2.2 Study Area

Data used in the impact analysis were obtained for the following study areas.

2.2.1 Primary API

The primary API extends about five miles from north to south. It starts north of the I-5/Main Street interchange in Washington, and runs to the I-5/Delta Park interchange in Oregon. North of the river, the API expands west into downtown Vancouver, and east near Clark College to include potential high-capacity transit alignments and park and ride locations. Around the actual river crossing, the eastern side extends 0.25 mile from the I-5 right-of-way, and extends west of the crossing to accommodate Columbia River current. South of the river crossing, this width narrows to 300 feet on each side.

The primary API is the area most likely to experience direct impacts from construction and operation of proposed design options. Most physical project changes would occur in this area, though mitigation could still occur outside of it. Project activities analyzed for the primary API consist of foundations, ground improvement, excavations, tunneling, cuts and fills, retaining walls, construction, fixed guideways, and utilities to support the construction of new roadways, interchanges, bridges, overpasses, underpasses, and areas where excavation and/or dewatering to lower groundwater elevations may occur. Regional geologic conditions such as faults, which have the capacity for regional effects, are also considered.

2.2.2 Secondary API

The secondary API is the area that may receive indirect impacts, such as soil erosion, from the construction and operation of the project. This API is a 1,000-foot periphery around the primary API, described above.

2.3 Data Collection Methods

Existing maps and technical reports published by the United States Geological Survey (USGS), Oregon Department of Geology and Mineral Industries (DOGAMI), Washington State Department of Natural Resources Division of Geology and Earth Resources (DGER), and the Natural Resources Conservation Service (NRCS) were reviewed for the geologic, hydrogeologic, geologic hazard, and soils summaries.

2.4 Effects Guidelines

The effects guidelines consider how the project could affect geologic and hydrologic resources, expose people to injury or death, or expose structures to damage or loss. Such impacts could be due to severe ground shaking, liquefaction associated with a seismic event, construction on expansive or hydric soils and landslides, or impacts to geologic resources.

2.5 Analysis Methods

Potential cumulative effects from this project are evaluated in the Cumulative Effects Technical Report. Please refer to this report for an evaluation of possible cumulative effects.

2.5.1 Long-Term and Short-Term Effects Approach

Long-term and short-term effects were assessed qualitatively using existing information in conjunction with professional judgment. Short-term effects from the project will be addressed by evaluating the results of subsurface investigations conducted in proposed construction areas. The investigations were conducted in accordance with generally accepted industry practice and collected information to establish the design criteria for built structures. A separate geotechnical report will be prepared during the engineering design phase of the project. The geotechnical report will quantify the potential impacts to and from geologic or hydrologic conditions.

2.5.2 Cumulative Effects Analysis Approach

Cumulative impacts may occur when a project's effects are combined with those from past, present, and reasonably foreseeable future projects. They can also result from individually small but collectively significant actions that occur over a long period of time. The project team will address cumulative impacts qualitatively using existing information in conjunction with a best professional judgment approach. This approach will be further refined in the NEPA scoping process, which provides the necessary forum for addressing these items, as well as the overall framework for cumulative effects.

2.5.3 Mitigation Measures Approach

The approach for potential long-term and short-term mitigation and minimization measures include avoidance of geologic hazards such as landslides, steep slopes, and soils that have a potential for liquefaction; and measures to limit erosion and degradation of groundwater resources through management and treatment of stormwater runoff and infiltration.

Long-term and short-term effects to the project from existing geologic conditions will be mitigated in part through focused subsurface investigations, which help to evaluate geologic hazards in the proposed construction areas and by designing components of the built structures to reduce the impacts of these effects. These investigations will be conducted in accordance with generally accepted industry practice and will collect information to establish the design criteria for built structures. A separate geotechnical report(s) will be prepared as part of mitigation measures during the engineering design. The geotechnical report will assess liquefaction, settlement, slope stability, and other geologic hazards.

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3. Coordination

Results of the geological analysis were reviewed by ODOT, WSDOT, and other appropriate agencies before the completion of the DEIS.

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4. Affected Environment

4.1 Introduction

This section presents the existing geologic and hydrogeologic conditions within the I-5 CRC project area.

4.2 Regional Conditions

4.2.1 Geologic Setting

The project area is located in the northern extent of the Willamette Valley, within the Portland Basin. The Portland Basin, a northwest trending structural basin, encompasses approximately 1,310 square miles and is characterized by relatively low topographic relief with areas of buttes and valleys containing steep slopes (McFarland and Morgan 1996). The basin is bordered to the east by the foothills of the Cascade Mountains, to the west by the Tualatin Mountains, to the south by the Clackamas River, and to the north by the Lewis River. It was formed by the folding and faulting of Eocene to Miocene basement rock due to the regional tectonic compressional regime (described below), contributing to the formation of the Tualatin Mountains west of the project area as well as the Portland Basin and Cascade Mountains east of the project area.

Sedimentary deposits have filled the topographic depressions created by crustal down-warping of the basin. Sedimentary deposits in the basin consist of conglomerate, gravel, sand, silt, and some clay from volcanic, fluvial, and lacustrine material (Pratt et al. 2001). Late Pleistocene catastrophic flood deposits cover much of the surface within the project area (Waitt 1985). Deposits originating from an ancestral Columbia River underlie the catastrophic flood deposits. These sedimentary deposits overlie Miocene basalt flows of the Columbia River Basalt Group (Swanson et al. 1993). The Columbia River Basalt Group overlies lava flows and volcanic breccias of Oligocene age (Schlicker and Finlayson 1979). No lahars, mudflows, or lava flows within the past 20,000 years has substantially impacted the geologic processes within the project area, although ash fall from nearby volcanic eruptions has occurred.

4.2.2 Geologic Units

A geologic unit is a general term for a volume of rock or sediment that has similar characteristics and origins. Geologic units are named and defined by geologists based on their observations, geochemical analysis, depositional environment, and age of the rocks. As geologists discover new information about geologic units, leading to a better understanding of how these units were formed, the classification or grouping of particular units could change. A geotechnical evaluation of the project area will be required to define the physical properties of each geologic unit that will be encountered during construction. Geologic units that are present within the study area are described below by increasing age. Exhibit 4-1 shows a summary of geologic units in the study area.

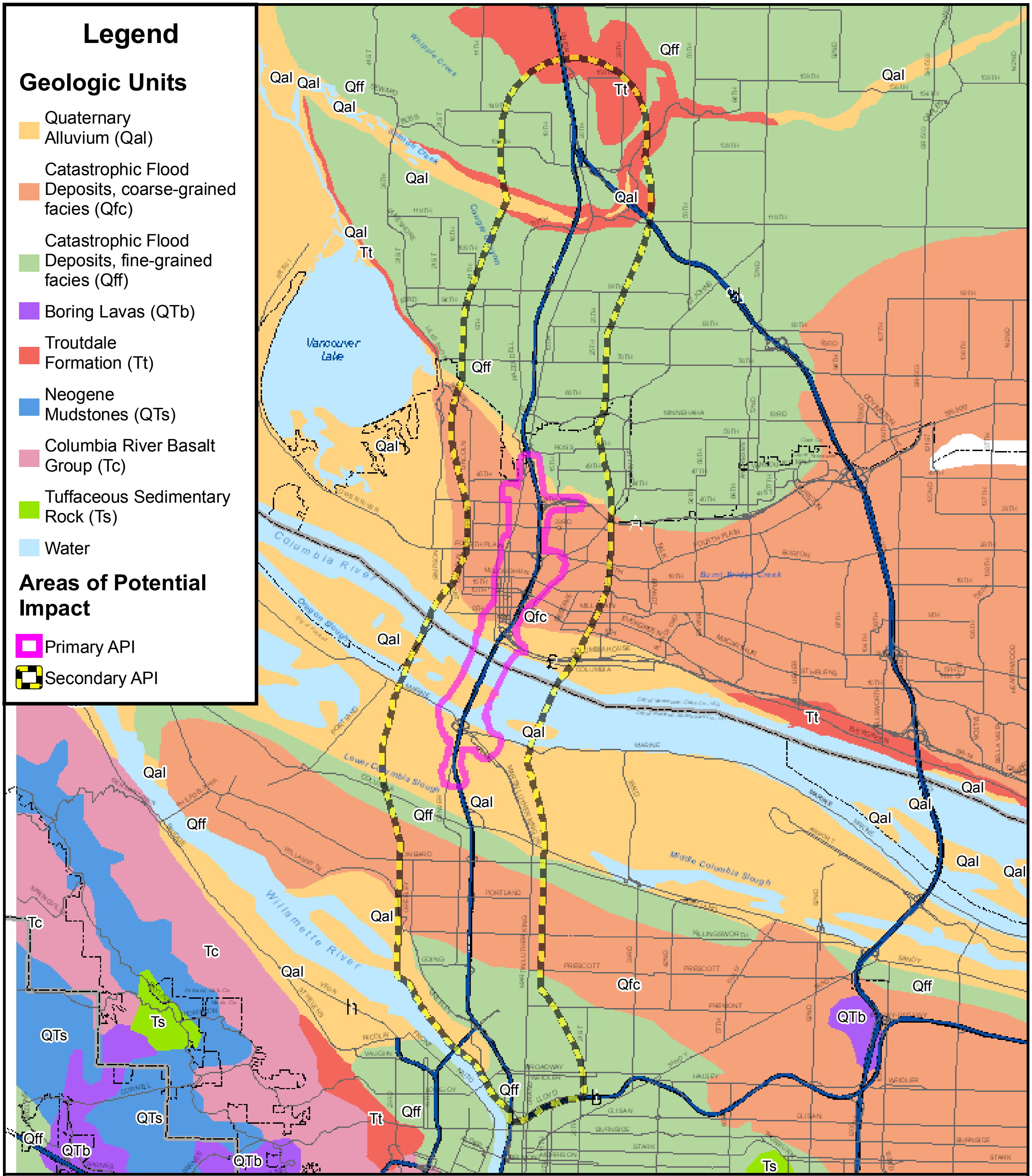


Exhibit 4-1: Geology

Columbia River CROSSING

Analysis by C. Hainey; Analysis Date: Jul-2007; Plot Date: Jul-2007; File Name: Ex_1_Geology.mxd

4.2.2.1 Artificial Fill (Qaf)

Artificial fill material was used to modify existing topographic relief and typically consists of sand, silt, and clay with some gravel and debris and local areas of sawdust and wood debris. Fill areas mapped with inferred contacts represent lakes and marshes that may have been drained rather than filled. Fill 5 to 10-feet thick is common in developed areas of the Willamette River and Columbia River floodplains; however, thickness and distribution are highly variable (Beeson et al. 1991).

4.2.2.2 Alluvium (Qal)

Alluvial deposits (Holocene in age) include material derived from present day streams and rivers, their floodplains, and abandoned channels. The alluvial deposits are typically Holocene to upper Pleistocene in age. Alluvial material consists of unconsolidated gravel, medium to fine sand, silt, and organic-rich clay. Cobble-sized material may be present within existing or abandoned stream channels. Thickness is typically less than 45 feet, but may be up to 150 feet thick locally. Within the project area, alluvium is exposed at the surface from just south of the Columbia Slough in Oregon to approximately 0.25 mile north of the Columbia River in Washington (Beeson et al. 1991; Phillips 1987).

4.2.2.3 Catastrophic Flood Deposits (Qff/Qfc)

The catastrophic flood deposits resulting from the Pleistocene-aged Missoula Floods described by Bretz et al. (1956) derive from the repeated failure of ice dams located on the Clark Fork River in northwestern Montana. Glacial Lake Missoula was created by ice dams from the advancing front of the Purcell Trench lobe of the Cordilleran ice sheet. The floods released approximately 500 cubic miles of water during each event, flooding portions of eastern Washington, the Columbia Gorge, and the northern Willamette Valley (Bretz et al. 1956; Allen et al. 1986). The flooding occurred at least 40 times during the Pleistocene (16,000 to 12,000 years ago), depositing boulders, cobbles, gravel, sand, and silt (Waitt 1985).

This deposit is subdivided into two facies by Madin (1994): a fine-grained facies (Qff) and coarse-grained facies (Qfc). Both are present in the project area. The finer sediments consist of primarily coarse sand to silt-sized particles. The fine sand and silt is composed of quartz and feldspar with white mica. The coarser sand is composed primarily of basalt. Soil development in the upper 5 to 10 feet of the deposit produces significant clays and iron oxides as a result of physical and chemical weathering. This unit is a maximum of 130 feet thick. It is located primarily south of the Columbia Slough to Lombard Street in Oregon and north of Burnt Bridge Creek to Salmon Creek within the secondary API in Washington.

The coarse-grained facies (Qfc) consists of pebble- to boulder-sized rock with a coarse sand to silt matrix. Grains are subangular to well-rounded in shape and are poorly sorted by size. The coarse-grained facies in Washington is further described by Phillips (1987) as composed of mafic volcanic fragments, quartz, and muscovite. The maximum thickness of the unit is approximately 100 feet. In Oregon, the unit is exposed at the surface beginning south of Lombard Street and extending to the southern limit of the secondary API. In Washington, the coarse-grained facies begins north of SR 14 and extends to Burnt Bridge Creek.

4.2.2.4 Boring Lava (QTb)

The Boring Lava unit (Pliocene to Pleistocene in age) consists of basalt to basaltic andesite flows that erupted to the surface from several vents located throughout the project area. There are 12 chemically distinct flows associated with the Boring Lava, several of which occur in the vicinity of the project area. The vents erupted tuff breccias and agglomerate to lava material, and occur as blocky intercanyon flows, volcanic cones, and shield volcanoes. This unit is typically exposed at higher elevations on the Tualatin Mountains and Mount Tabor; thickness varies from 25 to 500 feet.

4.2.2.5 Neogene Mudstone (QTs)

The Neogene Mudstone (Miocene to Pleistocene in age) is interlayered with Boring Lava (Qtb) flows and is exposed at higher elevations in the Tualatin Mountains southwest of the project area. The unit is composed of thinly bedded siltstone and claystone. The mudstones have a maximum thickness of 200 feet.

4.2.2.6 Tuffaceous Sedimentary Rocks (Ts)

Tuffaceous sedimentary rock (Miocene to Pliocene in age) consists of semi- to well-consolidated lacustrine tuffaceous sandstone, siltstone, and mudstone. The unit is composed of pumiceite, diatomite, and air- and water-deposited vitric ash, palagonitic tuff, and tuff breacia. The unit is found mostly in Eastern Oregon but has exposures along the Tualatin Mountains near the study area.

4.2.2.7 Troutdale Formation (Tt)

The Troutdale Formation (Miocene to Pliocene in age) underlies the catastrophic flood deposits and consists of coarse- to fine-grained fluvial sedimentary rock derived from the ancestral Columbia River. The unit is a friable to moderately strong conglomerate with minor sandstone, siltstone, and mudstone. Pebbles and cobbles are composed of Columbia River Basalt (described below), foreign volcanic, metamorphic, and plutonic rocks. The matrix and interbeds are composed of feldspathic, quartzo-micaceous, and volcanic lithic and vitric sediments. The formation exhibits cementation mantling on some of the grains. Thickness of the Troutdale Formation typically ranges between 200 and 300 feet in the study area.

4.2.2.8 Sandy River Mudstone (Tsr)

The Sandy River Mudstone (Pliocene in age) underlies the Troutdale Formation and consists of fine-grained, predominantly fluvial and minor lacustrine sediments. The unit is a friable to moderately strong sandstone, siltstone, and claystone. The mudstone is composed of primarily quartz-feldspathic and white mica sediments. The Sandy River Mudstone is up to 900 feet thick (Beeson et al. 1991).

4.2.2.9 Miocene and Older Rocks

The Columbia River Basalt Group (CRBG) (late Miocene and early Pliocene in age) consists of numerous basaltic lava flows that cover approximately 63,000 square miles and extend to thicknesses greater than 6,000 feet. The CRBG is composed of dark gray to black, dense, crystalline basalt and minor interbedded pyroclastic material. Beneath the CRBG is upper Eocene to lower Miocene volcanic and marine sedimentary rocks. The volcanic rocks typically consist of altered basalt, basaltic andesite, and pyroclastic rocks. The marine sedimentary rocks typically consist of fossiliferous tuffaceous shale and sandstone with minor conglomerate lenses (Madin 1994).

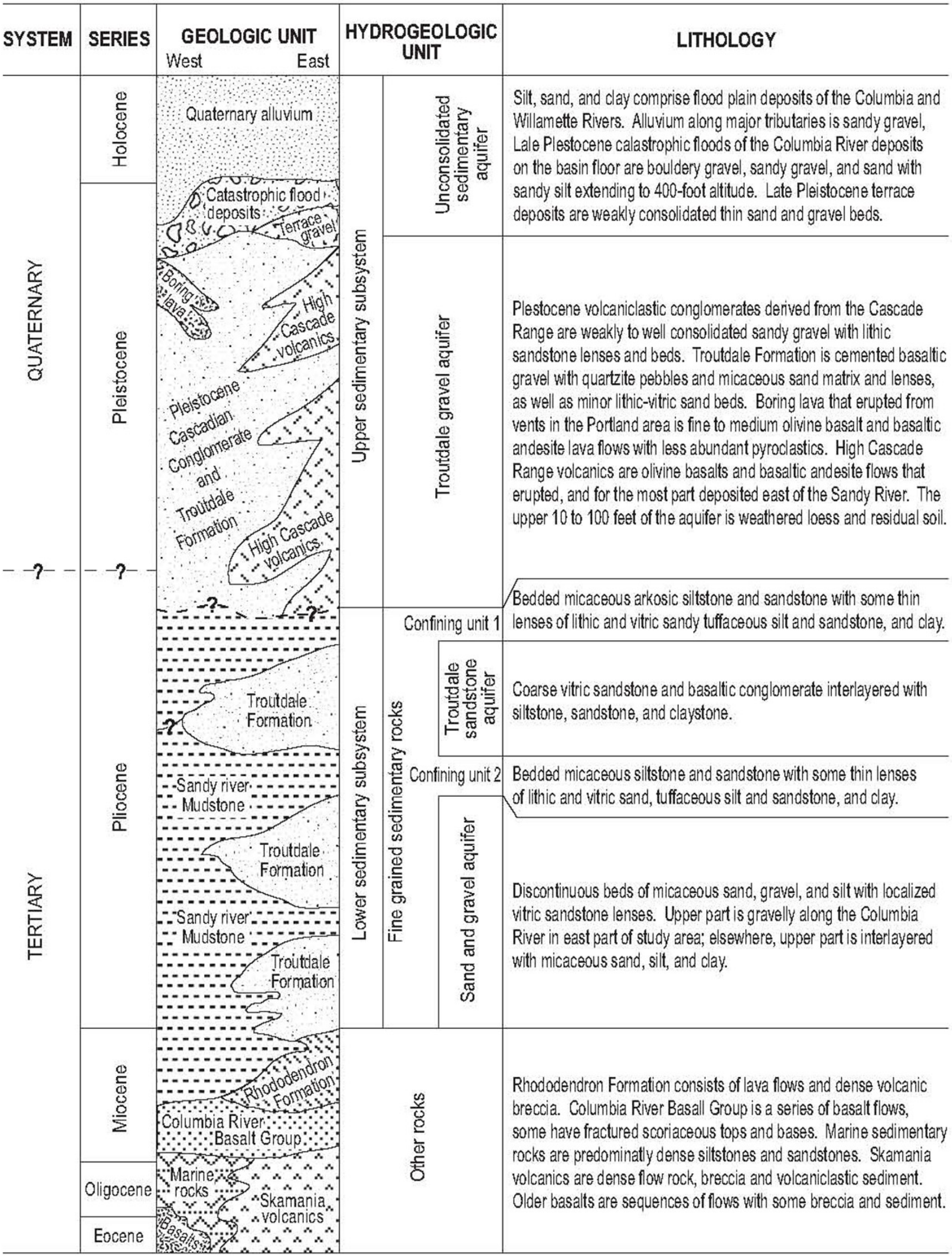
4.2.3 Hydrogeology

Hydrogeology concerns the occurrence, distribution, and effect of groundwater in the subsurface. Considering hydrogeologic conditions is critical if there is a potential to contact groundwater during construction. This section presents an overview of the hydrogeologic units present in the Portland Basin and describes how these units interact to create the hydrogeologic system in the project area. The section further elaborates on important physical characteristics of the hydrogeologic system. This summary can be used as a basis to identify areas to be excavated during construction where dewatering may be required. Evaluating this information helps determine the depth of dewatering wells (if needed), pumping rates, and the time frame for depressing the local groundwater table during construction. Exhibit 4-2 illustrates a comparison of geologic units and hydrogeologic units (Swanson et al. 1993). Within these hydrogeologic units in the Vancouver portion of the project lies the Environmental Protection Agency-designated Troutdale sole source aquifer.

4.2.3.1 Hydrogeologic Units

In 2004, Parametrix (2004) conducted extensive research of previously published documents to develop an understanding of the stratigraphic and hydrogeologic nature of a site near the CRC project area. Results of the research that apply to the project area are discussed below. Swanson et al. (1993) identify eight major hydrogeologic units in the Portland Basin. From youngest to oldest, these units are:

1. Unconsolidated Sedimentary Aquifer (USA)
2. Troutdale Gravel Aquifer (TGA) or the Consolidated Gravel Aquifer
3. Confining Unit 1
4. Troutdale Sandstone Aquifer (TSA)
5. Confining Unit 2
6. Sand and Gravel Aquifer (SGA)
7. Older Rocks
8. Undifferentiated Fine-Grained Sediments.



Silt, sand, and clay comprise flood plain deposits of the Columbia and Willamette Rivers. Alluvium along major tributaries is sandy gravel, Late Plestocene catastrophic floods of the Columbia River deposits on the basin floor are bouldery gravel, sandy gravel, and sand with sandy silt extending to 400-foot altitude. Late Pleistocene terrace deposits are weakly consolidated thin sand and gravel beds.

Plestocene volcaniclastic conglomerates derived from the Cascade Range are weakly to well consolidated sandy gravel with lithic sandstone lenses and beds. Troutdale Formation is cemented basaltic gravel with quartzite pebbles and micaceous sand matrix and lenses, as well as minor lithic-vitric sand beds. Boring lava that erupted from vents in the Portland area is fine to medium olivine basalt and basaltic andesite lava flows with less abundant pyroclastics. High Cascade Range volcanics are olivine basalts and basaltic andesite flows that erupted, and for the most part deposited east of the Sandy River. The upper 10 to 100 feet of the aquifer is weathered loess and residual soil.

Bedded micaceous arkosic siltstone and sandstone with some thin lenses of lithic and vitric sandy tuffaceous silt and sandstone, and clay.

Coarse vitric sandstone and basaltic conglomerate interlayered with siltstone, sandstone, and claystone.

Bedded micaceous siltstone and sandstone with some thin lenses of lithic and vitric sand, tuffaceous silt and sandstone, and clay.

Discontinuous beds of micaceous sand, gravel, and silt with localized vitric sandstone lenses. Upper part is gravelly along the Columbia River in east part of study area; elsewhere, upper part is interlayered with micaceous sand, silt, and clay.

Rhododendron Formation consists of lava flows and dense volcanic breccia. Columbia River Basalt Group is a series of basalt flows, some have fractured scoriaceous tops and bases. Marine sedimentary rocks are predominatly dense siltstones and sandstones. Skamania volcanics are dense flow rock, breccia and volcaniclastic sediment. Older basalts are sequences of flows with some breccia and sediment.

Swanson 1993

Exhibit 4-2: Geologic Units and Hydrogeologic Units

Columbia River CROSSING

The eighth unit is applied in areas of the basin where the TSA and the SGA appear to have pinched out or where there is insufficient information to characterize the aquifer units within the fine-grained Sandy River Mudstone. The older rock subsystem, consisting of older volcanic and marine sedimentary rocks of generally low permeability, is present at depths estimated to range up to 1,600 feet in the central area of the basin. With the exception of lava flows associated with the CRBG, these older rocks are poor aquifers and too deep to be used as a primary source of water in the region. Due to these conditions, no further discussion is presented regarding the older rock unit. Detailed descriptions of the hydrologic units can be found in Swanson et al. (1993).

The Portland Basin aquifer system can also be grouped into three major subsystems (upper sedimentary subsystem, lower sedimentary subsystem, and older rocks). This description of the hydrogeologic units focuses on those units that are part of the upper and lower sedimentary subsystems.

4.2.3.2 Upper Sedimentary Subsystem

The upper sedimentary subsystem consists of the TGA and the overlying USA. The TGA consists of material associated with the Pleistocene-aged Troutdale Formation, and the USA consists of material associated with the Pleistocene-aged catastrophic flood deposits and Quaternary alluvium deposits. Deposition of the TGA was followed by a period of erosion and subsequent deposition of unconsolidated sediments. Both the TGA and the overlying USA consist of coarse-grained materials, predominantly sands and gravels that can be difficult to differentiate on the basis of drilling conditions and/or the presence of cementation or a sandy matrix. The base of the USA is most commonly identified by the transition to the underlying conglomerate or weathered gravel of the Pleistocene-aged Troutdale Formation. The contact between the TGA and the overlying USA is also marked by a permeability contrast, although both aquifers are permeable and productive.

Different terminology for the USA has been used in the South Clark County area to further differentiate the unit based on lithology, depositional environment, or groundwater levels. Robinson, Noble and Carr, Inc. (1980) refer to the USA in the South Clark County area as the Orchards aquifer. They further subdivide this aquifer into upper and lower units based on the separation of the aquifer into two distinct geographic areas with greatly differing water level elevations. The lower Orchards aquifer has water levels that are near the elevation of the Columbia River, while the upper Orchards aquifer is described as that part of the Orchards aquifer with a water level above 50 feet elevation (Robinson, Noble and Carr, Inc. 1980). The transition zone between the upper and lower Orchards aquifers occurs along the northeast side of Vancouver Lake, extends along Burnt Bridge Creek, and continues along the west side of McLoughlin Heights. This transition area is created by a difference in the permeability of the Pleistocene deposits that make up the USA.

Pleistocene deposits north and east of the transition zone are layered and contain more quartzite and feldspathic minerals, while deposits south and west of the zone are massive (no layering) and contain primarily lithic material (Parametrix 2004). Due to this difference, the USA is more transmissive south and west of the transition zone (i.e., lower

Orchards aquifer) than north and east of the zone (i.e., upper Orchards aquifer). The lower Orchards aquifer has also been associated with the Columbia River sands aquifer (Gray & Osborne, Inc. 1996). The unit name, Columbia River sands aquifer, is applied to quartz-rich basaltic sand deposits that filled the lower part of a Pleistocene channel segment of the ancestral Columbia River (Hartford and McFarland 1989). More recently, Pacific Groundwater Group (PGG 2002) segmented the USA into the Pleistocene alluvial aquifer and the recent alluvium, which is further subdivided into sand and silt subunits.

4.2.3.3 Lower Sedimentary Subsystem

The lower sedimentary subsystem extends basinwide and overlies the older rocks. The SGA is the lowermost hydrogeologic unit within the lower sedimentary subsystem. This aquifer has also been referred to as the Sandy River Mudstone Aquifer (SRMA) in several reports (Willis 1977, 1978; Robinson and Noble 1992; Gray & Osborne, Inc. 1996). The SRMA is believed to be the lower unit of the SGA (Robinson and Noble, Inc. 1992). The SGA occurs in material associated with Tertiary-aged Troutdale Formation material. The SGA is overlain by a siltstone and sandstone that functions as a confining unit, or aquitard, and is referred to as confining unit 2 or the lower silt-clay aquitard. Situated above the lower silt-clay aquitard is the Troutdale Sandstone Aquifer (TSA). Overlying the TSA is confining unit 1, also referred to as the upper silt-clay aquitard. This deep aquifer is also part of the lower sedimentary subsystem and is present in the east Portland and Clark County areas. It may be present within the project area. Mapping completed by Swanson (1995) suggests that the TSA is not present in the site area, where it has been identified as undifferentiated fine-grained sediments. The TSA is a productive aquifer in the east Portland area. It does not appear to be as thick or extensive in the South Clark County area.

4.2.3.4 Hydraulic Characteristics

The TGA and USA are used extensively as water supply sources in the Portland Basin. In Clark County, over 90 percent of the 7,111 wells inventoried are less than 300 feet in depth, demonstrating that most wells produce from these two aquifers (Gray & Osborne, Inc. 1996). Wells completed in the consolidated TGA commonly yield up to 1,000 gallons per minute (gpm) (Swanson et al. 1993). The overlying USA, consisting primarily of unconsolidated flood deposits, represents one of the most productive aquifers in the Portland Basin. Wells completed in the USA have maximum yields between 1,000 and 6,000 gpm. The most productive area of the USA appears to be in the lower floodplain area of the Columbia River.

The permeability and thickness of the USA contribute to its transmitting capacity and well yields. Mundorff (1964) estimated that the transmissivity of the lower Orchards aquifer portion of the USA ranges from 1,900,000 to 3,500,000 gallons per day per foot (gpd/ft), based on aquifer tests completed at the former ALCOA facility located west of the project area. The aquifer tests indicate that the aquifer’s transmissivity is fairly uniform throughout the facility’s well field. The calculated transmissivities for City of Vancouver Water Stations 1, 3, and 4, all producing from the lower Orchards aquifer, are 2,000,000 gpd/ft, 878,900 gpd/ft, and 586,000 gpd/ft, respectively (Robinson, Noble and Carr, Inc. 1980). Based on a review of transmissivities calculated by consultants for the

City of Vancouver water stations, and transmissivities estimated from reported pump test yields and drawdown, Swanson and Leschuk (1991) assign a hydraulic conductivity of 1,000 feet/day to the lower Orchards aquifer, and a hydraulic conductivity of 390 feet/day to the upper Orchards aquifer in the area of City of Vancouver Water Stations 8, 9, 14, and 15. Swanson and Leschuk (1991) assign a slightly lower hydraulic conductivity value (300 feet/day or 100 feet/day) to the upper Orchards aquifer in areas where the aquifer thins to less than 40 feet or may be unsaturated due to the rising elevation of the underlying Troutdale Formation.

Historically, there has been very little use of the deeper SGA in Oregon or Washington. More recently, a number of public water supply wells have been advanced to this widespread, deep, and confined aquifer. Robinson and Noble, Inc. (1992) note that the transmissivity of the SGA is approximately 10 percent of the transmissivity observed in the USA. Consequently, compared to wells completed in the USA, SGA wells have greater drawdown and more interference with nearby wells in the same aquifer.

Due to the high transmissivity of the USA, groundwater gradients in the project area are relatively flat. The groundwater table elevation along the banks of the Columbia River and Columbia Slough is heavily influenced by tidal fluctuations and upstream dam releases, and rises and falls rapidly in conjunction with changes in Columbia River stage (Parametrix 2002). The rapid response between changes in river stage and corresponding changes in groundwater levels indicates a high interconnectivity between the river, the USA, and the upper portion of the TGA. Groundwater table fluctuations due to river stage changes are less significant with increasing distance from the Columbia River and Columbia Slough.

The generalized groundwater levels within the primary API are typically less than 20 feet in elevation near the Columbia River and Columbia Slough, and increase in elevation with distance from the river and slough (McFarland and Morgan 1996). Groundwater flow direction in the northern portion of the primary API in Washington is north-northeast due to the zone of influence created by the City of Vancouver public drinking water supply wells located near the intersection of Fort Vancouver Way and Fourth Plain Boulevard. Groundwater flow direction in the southern portion of the primary API in Oregon is north-northwest to near Killingsworth Boulevard, and west-southwest south of Killingsworth Boulevard (McFarland and Morgan 1996).

Separate municipal water systems operate in the Washington and Oregon segments of the API. City of Portland drinking water originates from the Bull Run Reservoir, and is augmented with water from the Portland Well Field located east of the Portland International Airport. City of Vancouver drinking water originates from several groundwater extraction points operated by Clark Public Utilities and City of Vancouver.

4.3 Tectonic Setting

Oregon and Washington are located on the North American continent crustal plate near a convergent plate boundary with the Juan de Fuca oceanic crustal plate, which is located approximately 100 miles off the coast of Oregon and Washington. The oblique convergence of the North American Plate with the Juan de Fuca Plate has created northwest-trending fault zones and crustal blocks (Baldwin 1976). This regional tectonic regime is capable of producing subduction zone earthquakes of magnitude (M) 8 or greater. The convergence of the two crustal plates has caused folding and faulting of rocks and shallow crustal ruptures in the vicinity of the project area.

Seismicity in the Vancouver and Portland areas has historically produced earthquakes at magnitudes of M5.3 in 1877, M5.5 in 1962, and M5.6 during the Scotts Mills earthquake in 1993. Pratt et al. (2001) suggest that these late Pleistocene to Holocene faults may still be active, but state that other interpretations are possible. Several crustal faults are mapped by Beeson et al. (1991) southwest and by Phillips (1987) northeast of the project area.

4.4 Geologic Hazards

4.4.1 Steep Slopes

Problems with stormwater runoff, erosion, and slope instability are hazards presented by steep slopes. Steep slope hazard areas are typically defined as areas where there is no mapped or designated landslide hazard, but where there are slopes equal to or greater than 25 percent (Das Braja 1983). Such slopes exist within the primary and secondary APIs (Exhibit 4-3).

In Washington, these slopes typically occur within the drainages of Burnt Bridge Creek, Whipple Creek, Salmon Creek, Mill Creek, Cougar Canyon, and Cold Canyon, which are located in the northern half of the project area. Topographic highs containing slopes greater than or equal to 25 percent exist at Hazel Dell and just northeast of the intersection of I-5 and Interstate 205 (I-205). In Oregon, steep slopes are located along Greeley Road at the southwestern extent of the secondary API and along Lloyd Boulevard in the southeastern extent of the secondary API. The presence of steep slopes suggests that slope stability, erosion, and stormwater runoff problems are possible.

4.4.2 Landslides

Landslide hazard areas are typically defined as areas that, due to a combination of slope inclination, soil type, geologic structure and presence of water, are susceptible to failure and subsequent downhill movement. Historic landslides are typically masses of soil and/or rock that at one time in the past were moving rapidly or may have been moving slowly, but may be currently stable. Active landslides are masses of soil and/or rock that are currently undergoing some sort of failure, either rapidly or slowly. Data from Metro and the City of Vancouver do not differentiate between active or historically active landslides in their hazard area demarcations.

An active or historic landslide is located on the north slope of Burnt Bridge Creek along the western border of the secondary API. Several active or historically active landslides are mapped along Greeley Road and Lloyd Boulevard, within the southern portion of the secondary API. Active and historically active landslides mapped within the project area are shown in Exhibit 4-3.

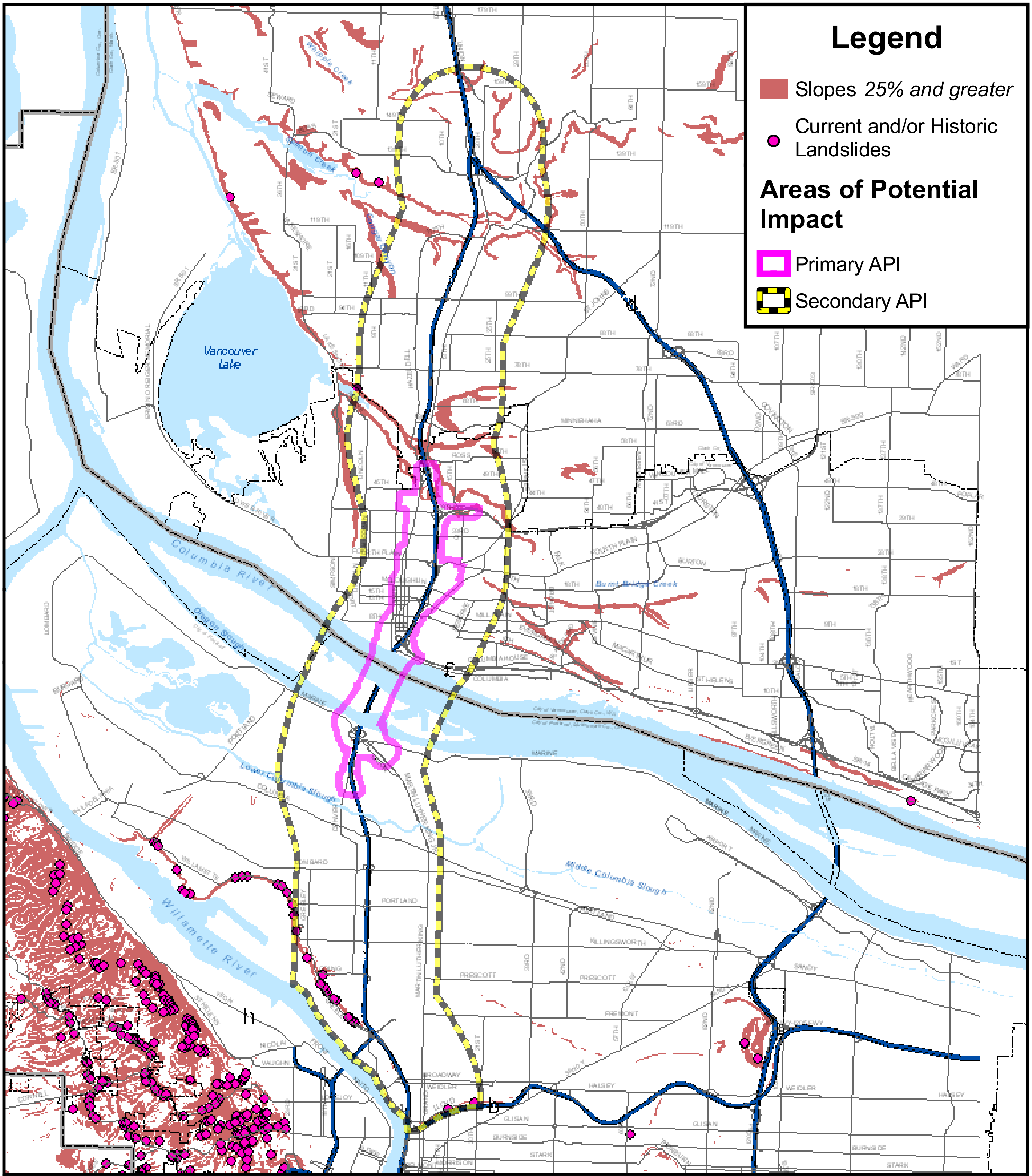


Exhibit 4-3: Steep Slopes and Landslides

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Analysis by C. Hainey; Analysis Date: Jul-2007; Plot Date: Jul-2007; File Name: Ex_2_Slopes.mxd

4.4.3 Earthquake Effects

The ability to estimate the occurrence and frequency of earthquakes is difficult because fault activity in the region is poorly understood. However, an estimate of the maximum plausible earthquake magnitude can be made based on several seismicity studies that have been conducted in the region over the past 10 years. In general, three types of earthquake scenarios have been identified within the project area: subduction zone, intraplate, and crustal earthquakes.

4.4.3.1 Subduction Zone Earthquakes

Large subduction zone earthquakes could be generated by failure of the contact between the Juan De Fuca and North American tectonic plates. The plate boundaries interact within the Cascadia Subduction Zone, located approximately 100 miles west of the Pacific coast. Maximum plausible event magnitudes of M8 to M9 on the moment magnitude scale could occur as the result of plate interface failure. An evaluation of subduction zone earthquake recurrence, based on the historical record, indicate that these earthquakes occur, on average, every 350 to 700 years. Geologic evidence suggests that the last subduction zone earthquake occurred around the early 1700s (Mabey et al. 1993). Subduction earthquake ground displacement would occur within the subduction zone off the Pacific coast.

4.4.3.2 Intraplate Earthquakes

Intraplate earthquakes occur within the remains of the Juan De Fuca Plate ocean floor that has been subducted beneath North America. Maximum plausible earthquake magnitudes for intraplate earthquakes may be as large as M7.5 (Mabey et al. 1993). Earthquake intensity and duration would be less severe than what is produced during subduction earthquakes. Intraplate fault displacement occurs at pre-existing zones of weakness typically called failed rifts. Failed rifts occur 25 to 37 miles deep (Wang and Clark 1999). Mabey et al. (1993) indicate intraplate earthquakes epicenters could occur within the project area.

4.4.3.3 Crustal Earthquakes

Crustal earthquakes cause damage to roadway and bridge structures by strong ground shaking, and by the secondary effects of ground failures (ground surface ruptures, landslides, liquefaction), or by seismic induced water waves (tsunamis and seiches).

Madin (1994) indicates that several shallow crustal faults are mapped within the vicinity of the project area. Fault locations are mapped northeast of the project area near Camas and Yacolt, Washington (Phillips 1987). In Oregon, the Portland Hills Fault is mapped southwest of the project area. The East Bank Fault is mapped within the secondary API along Greeley Road (Beeson et al. 1991). The Portland Hills and East Bank faults are included on Exhibit 4-4.

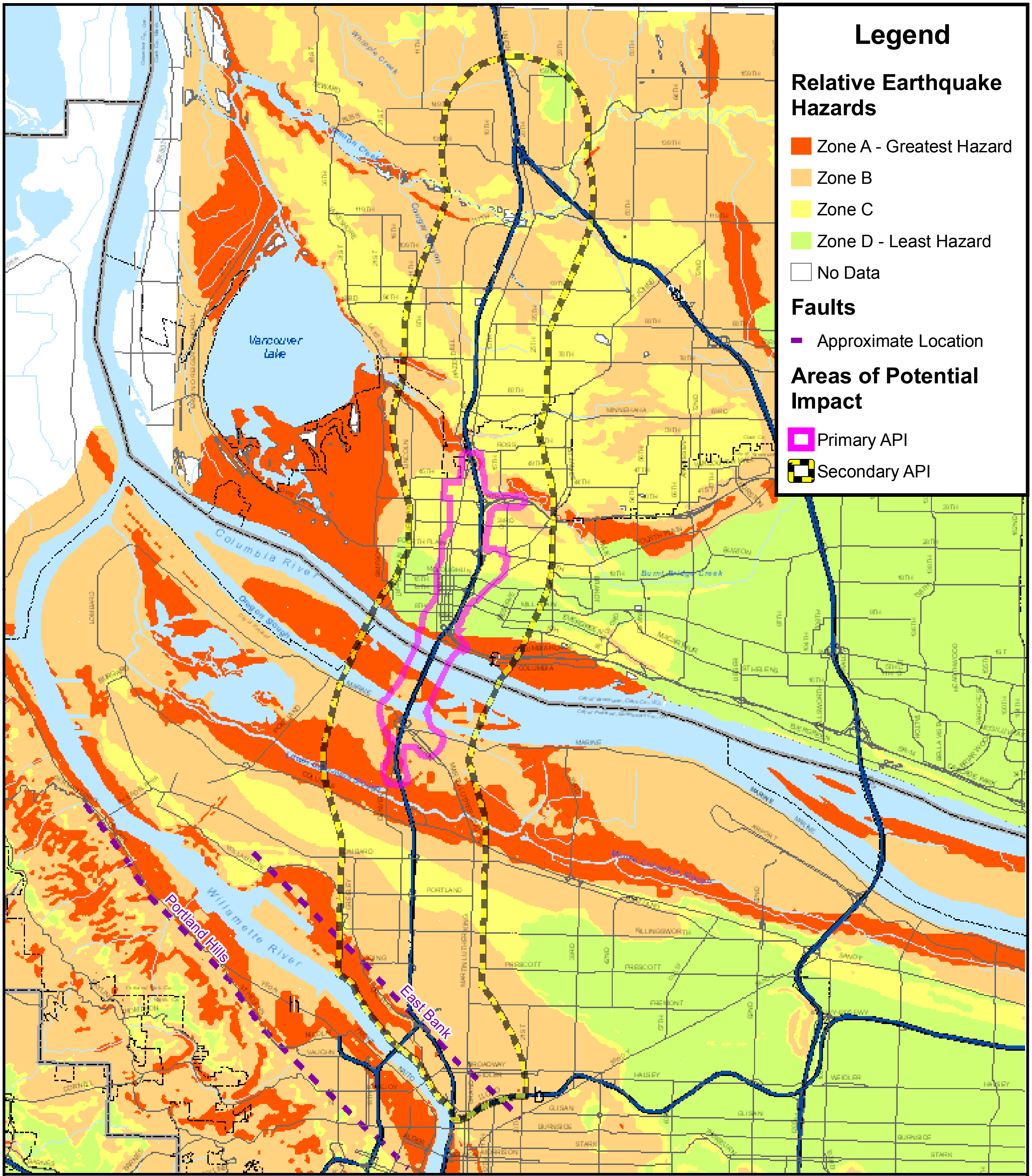

Exhibit 4-4: Seismic Hazards

Columbia River CROSSING

Analysis by C. Hainey; Analysis Date: Jul-2007; Plot Date: Jul-2007; File Name: Ex_3_Seismic.mxd

It is theorized that the maximum plausible magnitude for local shallow crustal earthquakes is no greater than M6.5 (Mabey et al. 1993). Madin (1994) suggests that faulting in this region occurred primarily during the Pleistocene and that there has been no late Pleistocene or Holocene faulting within the project area. Mabey et al. (1993) indicate that the few moderate earthquakes that have originated near the project area during the brief recorded history have been crustal earthquakes. The recurrence rate of maximum plausible magnitude crustal earthquakes within the project area is approximately 1,000 to 2,000 years (Bott and Wong 1993). Displacement at these faults may occur at the ground surface.

4.4.3.4 Ground Motion

Ground motion during an earthquake creates potential for building and bridge collapse as well as road failure. Certain soil types, typically soft unconsolidated fine-grained soils, may amplify ground motion through low impedance and resonance effects from reflection and trapping of surface waves (Pratt et al. 2001). Severe ground motion disrupts building and bridge load balances, causing unequal weight distribution that can result in structure collapse.

Much of the project area is underlain by soft, unconsolidated fine-grained soils that may amplify ground motion during an earthquake. The likely relative amplification of peak ground motion acceleration in the Oregon portion of the project area is greatest along the banks of the Columbia Slough (Mabey et al. 1993). In the Washington portion of the project area, the greatest likely relative amplification of peak ground motion acceleration occurs along the banks of the Columbia River and in areas within Burnt Bridge Creek and Salmon Creek (Mabey et al. 1994). Other areas within the secondary API have a lower hazard of relative amplification of peak ground motion acceleration.

4.4.3.5 Soil Liquefaction

Soil liquefaction occurs when ground shaking breaks grain-to-grain contact in saturated unconsolidated deposits causing the material to rapidly change its physical properties and behave more like a liquid than a solid. Liquefiable soils tend to be fairly young, loose granular soils (as opposed to clay) that are saturated with water (NRCS 2004). Unsaturated soils do not liquefy, but they may settle (Mabey et. al. 1993) during an earthquake. Consequently, structures such as roads, buildings, and bridges may be subjected to foundation settlement due to loss of effective stress. These structures may sink into the subsurface or collapse as a result of soil liquefaction.

Liquefiable soils typically occur in saturated sediments where the groundwater table is no deeper than 30 feet (Mabey et al. 1993). The greatest thickness of liquefiable soils in the project area is encountered in the alluvial unit (Qal). Catastrophic flood deposits (Qff and Qfc) typically lie above the water table or are too dense to be considered liquefiable soils. However, Qff may be liquefiable if a seasonal or abnormally high groundwater table saturates this unit. The relative soil liquefaction hazard is greatest within mapped Quaternary alluvial unit (Qal) areas from Columbia Boulevard in Oregon north to approximately Fourth Street, Burnt Bridge Creek, and Salmon Creek in Washington.

4.4.3.6 Liquefaction-Induced Lateral Spreading

Lateral spreading occurs as large, surficial blocks of soil move horizontally in response to earthquake ground motion and liquefaction. Ground displacement generally occurs on slopes of less than 3 degrees and moves toward unsupported banks such as a river and stream channels. Lateral spreading can compress or buckle building foundations, bridge footings, roadways, pipelines, and other utilities built on or across the failure (Youd 1993). Localized lateral spreading may also occur around of in-water bridge piers where severe scour has created oversteepened slopes. Failure of these slopes during a seismic event will induce large lateral forces on in-water bridge piers. This is currently a problem for the existing in-water bridge piers and is a potential long-term problem for new in-water bridge piers. Liquefaction-induced lateral spreading could potentially occur along the north and south banks of the Columbia River and Columbia Slough, Burnt Bridge Creek, Salmon Creek, the Mocks Bottom area, and near in-water piers.

4.4.3.7 Relative Earthquake Hazards

The earthquake hazards discussed in Section 4.4.3 have been given a quantitative rating scale by Mabey et al. (1993, 1994). Each hazard is given a value of A to D (A for areas with the greatest hazard and D for areas with the least hazard). This relative hazard categorization is based on the greatest or least likelihood for damage by any combination of earthquake hazards. Relative earthquake hazards are shown on Exhibit 4-4 and are categorized according to the methodology described in Mabey et al. (1994). Relative earthquake hazard analysis for CRC was conducted with maps published for the Vancouver 1:24,000 quadrangle by Mabey et al. 1994 and for the Portland 1:24,000 quadrangle by Mabey et al. 1993.

An updated earthquake hazard map has been published for Clark County at a scale of 1:100,000 (Palmer 2004). The City of Vancouver uses this map for land use planning. However, the 2004 Clark County map was not used for this alternative analysis. The 2004 Clark County Site Class map employs a different hazard evaluation method than the 1993 and 1994 maps. An updated map for the Portland area using hazard evaluation similar to the 2004 Clark County map has not been published. As a result a consistent comparison could not be made of the alternatives using these different map sets. In addition, the use of the 1993 and 1994 maps are more useful for analysis because the maps have a higher resolution.

None of these maps should be used to make construction design decisions for the CRC project area. Only a site-specific geotechnical investigation performed by a qualified geologist or engineer can adequately assess the potential for damage from soil liquefaction, ground motion amplification, or earthquake induced landslides. The 1993 and 1994 relative earthquake hazard maps are intended to provide a source of comparable information used in the alternative selection process for CRC.

4.5 Soil Type Properties

The Natural Resources Conservation Service (NRCS 2004) has identified 26 different types of soil hazards that typically impact construction projects because they affect the design, installation, and maintenance of many built structures. Two soil hazard types have been identified in the project area, high shrink-swell soils and wet soils. These soil hazard types and locations within the project area are shown on Exhibit 4-5.

4.5.1 High Shrink-Swell Soils

High shrink-swell soils are primarily clay soils that swell when moisture is absorbed. These soils typically occur in poorly drained bottomland found within the project area. High shrink-swell soils can exert pressures on solid structures and cause severe damage. Sauvie Silt Loam has a moderate shrink-swell potential, and is located south of the Columbia River and Columbia Slough within the project area.

4.5.2 Hydric Soils

Hydric soils or wet soils are described as having a groundwater table that occurs within 1.5 feet of the ground surface. This condition likely occurs during the wetter months of the year. The high water table creates areas of standing water and can fill excavation sites with water. These soils are mapped throughout much of the project area. Hydric soils in Oregon occur from the Columbia River south to the southern bank of the Columbia Slough. In Washington, hydric soils have been identified between Burnt Bridge Creek and Salmon Creek, as shown on Exhibit 4-5. Hydric soils have been identified west of the primary API just north of the Columbia River.

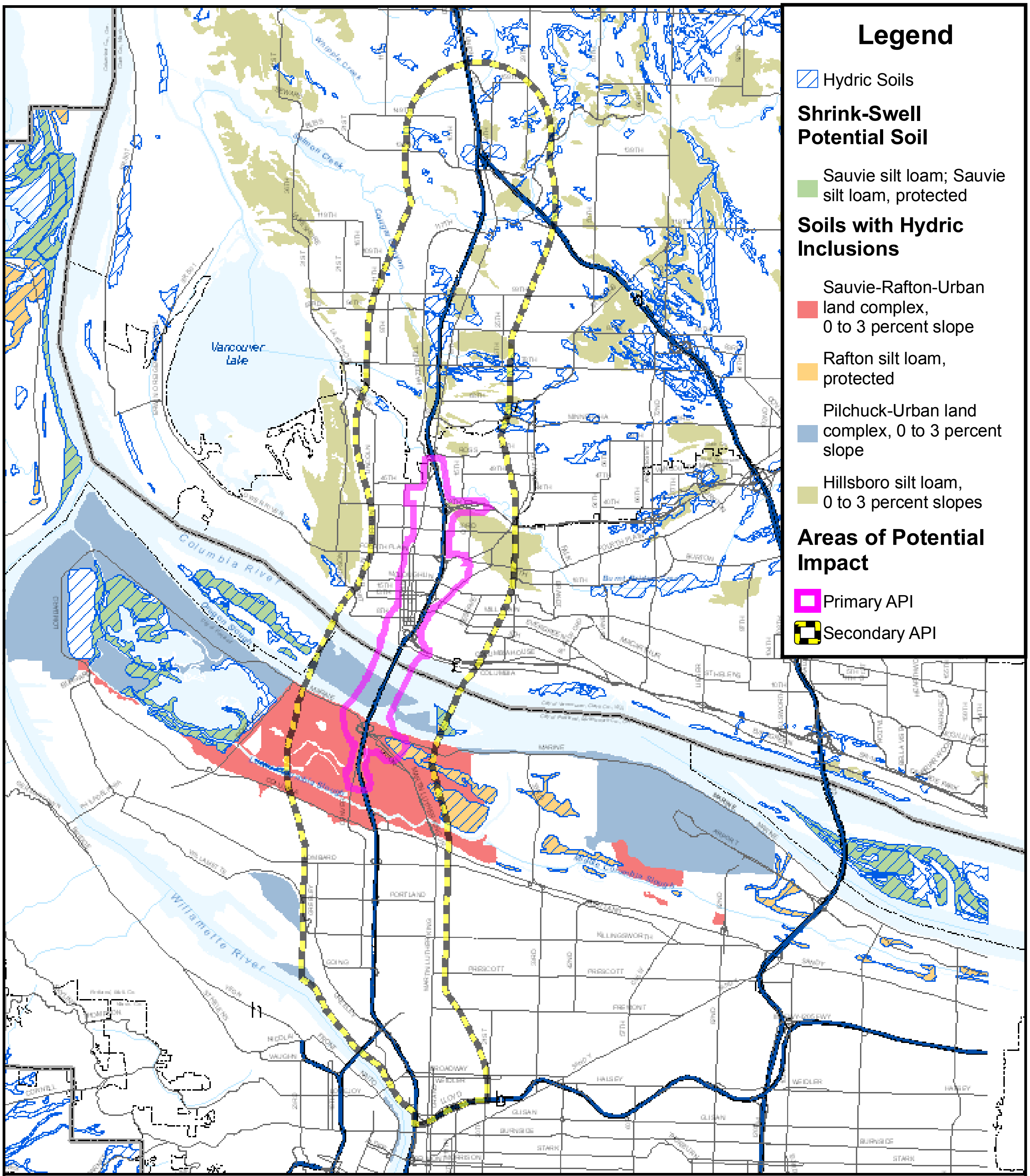

Exhibit 4-5: Hazardous Soil Types

Columbia River CROSSING

Analysis by C. Hainey; Analysis Date: Jul-2007; Plot Date: Jul-2007; File Name: Ex_4_Haz_Soil.mxd

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5. Long-Term Effects

5.1 How is this section organized?

This section describes the long-term effects that would be expected from the I-5 CRC alternatives and options. The section is separated into three parts which provide comprehensive descriptions and comparisons. The first part describes effects from the four full alternatives and the No-Build Alternative. This discussion focuses on how these alternatives would affect resources in the corridor and region. It then focuses on effects that would occur with various design options at the segment level. Lastly it provides a comparative and synthesized summary of the effects associated with the system-level choices.

5.2 Impacts from Full Alternatives

This section describes the impacts from four full alternatives and the No-Build Alternative. These are combinations of highway, river crossing, transit and pedestrian/bicycle alternatives and options covering all of the CRC segments. They represent the range of system-level choices that most affect overall performance, impacts and costs. The full alternatives are most useful for understanding the regional impacts, performance and total costs associated with the CRC project. Details on the project elements compared below are discussed in detail in the following sections on segments and system-level options.

5.2.1 No-Build Alternative

The No-Build Alternative would not affect geologic resources or disturb steep slopes. The current I-5 alignment is in substantially the same position as it would be under the build alternatives. Both No-Build and build alternatives are underlain by soils with a relatively high earthquake hazard rating and are susceptible to a major seismic event. The primary difference between the No-Build and build alternatives is that the No-Build Alternative would not include upgrades to or retrofitting of the existing bridge; where the build alternatives would have seismic upgrades included. As such, the build alternatives would likely better withstand a major seismic event.

5.2.2 Replacement Crossings with BRT/LRT, Tolling, and TSM/TDM Options

The full replacement alternatives would utilize the full-length I-5 transit alignment, but differ in transit modes and tolling and TSM/TDM options. The elements of interest in these alternatives are the length and location of the transit alignment. Potential effects to steep slopes occur near Burnt Bridge Creek and could affect the northern portion of the I-5 alignment. However, there would be no difference in effects between the replacement and supplemental alternatives with respect to steep slopes.

Relative earthquake hazards mapping data suggests that soils along the northern portion of the I-5 alignment are susceptible to liquefaction. There would be no difference in effects between the replacement and supplemental alternatives with respect to liquefaction along the I-5 alignment. The replacement alternatives would likely provide a greater safety factor during a major seismic event due to needing to retrofit current engineering controls under the supplemental alternatives.

5.2.3 Supplemental Crossing with BRT/LRT and I-5 Higher Toll

The supplemental alternatives would utilize the full-length I-5 transit alignment, but differ in transit modes and tolling options. The elements of interest in these alternatives are the length and transit alignment. Potential effects to steep slopes occur near Burnt Bridge Creek and could affect the northern portions of the I-5 alignment. However, there would be no difference in effects between the replacement and supplemental alternatives with respect to steep slopes.

Relative earthquake hazards mapping data suggest that soils along the northern portion of the I-5 alignment are susceptible to liquefaction. There would be no difference in effects between the replacement and supplemental alternatives with respect to liquefaction along the I-5 alignment. The replacement alternatives would likely provide a larger safety factor during a major seismic event than the existing bridge under the No-Build Alternative.

5.3 Long-Term Effects from Segment-level Options

This section describes and compares the effects associated with specific highway alignment and interchange options and specific transit alignments and options. They are organized by Segment.

- Segment A: Delta Park to Mill Plain District
- Segment B: Mill Plain District to North Vancouver

Effects from highway alignment options are described separately from impacts from transit options. The purpose of this organization is to present relevant information for similar alignment choices. A comprehensive discussion is provided in cases where the traffic and transit choices would have a substantial effect on each other.

For highway alignments, Segment A has a design option of either a replacement bridge or supplemental bridge.

Segment B has two basic highway alignment options. The I-5 current alignment would widen I-5 without shifting the basic location of I-5 (this can be paired with either the replacement or supplemental alternatives); the other—the I-5 western alignment, would shift the highway to the west in order to accommodate an LRT or BRT alignment on the east side of I-5. In addition, two options are being considered for the SR 500 interchange. One would have a flyover ramp and the other would have a tunnel ramp.

For transit alignments, Segment A is divided into two sub-segments, each with a discrete set of transit choices:

- Sub-segment A1: Delta Park to South Vancouver
- Sub-segment A2: South Vancouver to Mill Plain District

Segment A1 has a design option of either an off-set or adjacent transit alignment for BRT or LRT on Hayden Island.

Segment A2 has a design option of either a two-way Washington Street or a Washington/Broadway couplet for BRT or LRT.

Segment B has transit design options of either Vancouver or I-5 alignments for BRT or LRT. In addition this design option has either a terminus at Lincoln Park and Ride or Clark College Park and Ride, respectively.

5.3.1 Long-Term Effects from Highway Alignments

5.3.1.1 Segment A

Effects to geology, hydrogeology and soil are anticipated to be substantially similar for all of the Segment A highway alignments. The following sections discuss detailed information for impacts associated with these options.

5.3.1.1.1 Geology

Each design option would encounter the same surficial geology. Although details on bridge construction are still preliminary, each of the bridge options is likely to have foundations deeper than mapped surface units. The mapped surface unit for the proposed bridge footprints is Quaternary alluvium. Historic aerial photographs for the area indicate that construction of Columbia River bridge foundations and abutments would likely encounter fill embankments at Hayden Island and in South Vancouver. There are no known aggregate or mining resources within the project area. As such, there is no difference among the design options in regards to effects on geologic resources.

5.3.1.1.2 Hydrogeology

Neither the replacement bridge nor the supplemental bridge crossings will likely have any appreciable effect on hydrogeology or hydrogeologic resources.

5.3.1.1.3 Steep Slopes and Landslides

Steep slopes and landslides have not been identified near the proposed bridge footprints for the replacement or supplemental bridge options. Long-term effects due to steep slopes or landslides are not anticipated for the bridge crossing options.

5.3.1.1.4 Relative Earthquake Hazards

The relative earthquake hazard rating for Hayden Island and where the bridge touches down in South Vancouver is Zone A, the greatest hazard. The proposed bridge which crosses the Oregon slough would also be constructed with relative earthquake hazard Zone A. If a seismic event did occur, the stability of elevated structures and fill embankments could be affected. The upper loose soil deposits at Hayden Island, banks of the North Portland Harbor, and South Vancouver are susceptible to strong ground motion amplification and liquefaction during a seismic event. Ground improvements should be performed in areas beneath abutments and foundations to mitigate the potential adverse effects. The supplemental bridge option would require seismic retrofitting and upgrades to the existing I-5 bridge. As such, a replacement bridge would likely be the preferred design option.

5.3.1.2 Segment B: Mill Plain District to North Vancouver

Effects to geology, hydrogeology and soil are anticipated to be similar for the Segment B highway alignments. The following sections discuss detailed information for impacts associated with these options.

5.3.1.2.1 Geology

Segment B is located on catastrophic flood deposits, coarse-grained facies. Earthwork related to either highway alignment will likely encounter this unit. There are no known aggregate resources in the project area. As such, there is no difference among the design options in regards to effects on geologic resources.

5.3.1.2.2 Hydrogeology

Neither alignment will likely have any appreciable effect on hydrogeology or hydrogeologic resources.

5.3.1.2.3 Steep Slopes and Landslides

Landslides have not been identified near the proposed footprint for the I-5 western alignment. However, slopes greater than 25 percent have been identified near the Kiggins Bowl Terminus. These steep slopes are associated with the Burnt Bridge Creek drainage. Without proper construction techniques, construction near these areas could increase the potential for slope failure and erosion. However, neither highway alignment is in the proximity of these potential hazards. Long-term effects will likely be dependent on geotechnical evaluation of these features.

5.3.1.2.4 Relative Earthquake Hazards

Three relative earthquake hazard zones (A through C) are identified along the Western Alignment. The relative earthquake hazard maps by Mabey et al. (1993 and 1994) were used to compare the entire CRC project area with the same analysis model. These maps are adequate in providing information that will be used in determining a preferred alternative.

Hazard Zone C has been identified along the current and proposed I-5 alignment from approximately 16th Street to approximately 40th Street. The proposed footprint crosses Hazard Zone B at approximately 41st Street along I-5 and from approximately 39th and O Streets along SR 500 within Burnt Bridge Creek. Proposed highway footprints do not enter Hazard Zone A, however the northern terminus of I-5 comes within 150 feet of a Hazard Zone A area. The hazard ratings in this area are probably due to potential slope instability and liquefaction potential. Liquefaction would be likely to occur in areas of Burnt Bridge Creek where ground improvement will not be performed. Liquefaction-induced lateral spreading may occur within 200–400 feet of the proposed alignment. Lateral spreading and ground shaking could drastically reduce slope stability and affect highway structures in this area. Damage to at-grade pavements could result in cracking and settlement of the roadway. If liquefaction occurs beneath fill embankments, slope instability and excessive settlement could damage the roadway and adjacent facilities.

5.3.2 Long Term Effects from Transit Alignments

The impacts resulting from proposed transit options are similar for all of the build alternatives. The impacts related to LRT or BRT are similar for all options, as are the impacts associated with offset or adjacent Hayden Island alignments.

5.3.2.1 Segment A1: Delta Park to South Vancouver

5.3.2.1.1 Geology

Segment A1 is predominantly located on Quaternary alluvium. A separate geotechnical evaluation is being conducted for the project to address site-specific issues related to geology. There are no known geologic resources in the project area. There is no difference in the impacts associated with geologic resources for any option. Construction and operation would not cause a loss in geologic resources.

5.3.2.1.2 Hydrogeology

Neither alignment will likely have any appreciable effect on hydrogeology or hydrogeologic resources.

5.3.2.1.3 Steep Slopes and Landslides

Steep slopes and landslides have not been identified on Hayden Island, Delta Park, or south Vancouver. Effects related to steep slopes or landslides are not anticipated.

5.3.2.1.4 Relative Earthquake Hazards

Segment A1 is located in Relative Earthquake Hazard Zone A. The rating is due to high susceptibility to liquefaction during intense ground motion in the Quaternary alluvium. Structures may sink and collapse due to liquefaction and liquefaction-induced lateral spreading. Liquefaction-induced lateral spreading could occur along the banks of the North Portland Harbor and along the Columbia River at north Hayden Island and South Vancouver. The lateral spreading and ground shaking could drastically reduce load capacity and damage highway structures in these areas. Damage to bridge approaches and abutments could result in cracking and settlement of the roadway. If liquefaction occurs beneath fill embankments, slope instability and excessive settlement could damage the roadway and adjacent facilities.

5.3.2.2 Segment A2: South Vancouver to Mill Plain District

The impacts from the transit alternatives in Segment A2 are all similar. There is no appreciable difference in the impacts anticipated for the options in this segment.

5.3.2.2.1 Geology

Segment A2 is located on catastrophic flood deposits, coarse-grained facies. All transit options in Segment A2 would have similar impacts. There are no known geologic resources in the project area. There is no difference among the alternatives in the impacts associated with geologic resources. Construction and operation would not cause a loss of geologic resources.

5.3.2.2.2 Hydrogeology

Neither alignment will likely have any appreciable effect on hydrogeology or hydrogeologic resources.

5.3.2.2.3 Steep Slopes and Landslides

Steep slopes and landslides have not been identified in Segment A2. Impacts related to steep slopes or landslides are not anticipated.

5.3.2.2.4 Relative Earthquake Hazards

Segment A2 is located in Relative Earthquake Hazard Zone D, the least hazard. Impacts resulting from significant ground shaking are most likely minor.

5.3.3 Segment B: Mill Plain District to North Vancouver

The impacts of the transit alternatives and options in segment B are all similar. There is one potential difference in impact in Segment B regarding the terminus choice. The alignment options in Segment B are an I-5 transit alignment ending at the Kiggins Bowl Park and Ride and a Vancouver alignment ending at the Lincoln Park and Ride.

5.3.3.1 Vancouver Transit Alignments

The Transit options presented for the Vancouver alignments include a BRT or LRT efficient or increased transit operation on a Broadway two-way or Main-Broadway couplet. The possible impacts of all transit alternatives along a Vancouver alignment in Segment B are similar.

5.3.3.1.1 Geology

Segment B is located on catastrophic flood deposits, coarse-grained facies. Significant earthwork is not anticipated for construction of the majority of the Vancouver alignment. Utility relocations would occur at depths less then 5 to 7 feet below the ground surface. In addition, the Lincoln Park and Ride facility may consist of two levels of subterranean parking, requiring localized excavation. These excavations may encounter the top of the catastrophic flood deposits.

There are no known geologic resources in the project area. There is no difference among the alternatives in the impacts associated with geologic resources. Construction and operation would not cause a loss of geologic resources.

5.3.3.1.2 Hydrogeology

Groundwater will not likely be encountered during construction of any of the Vancouver options. Therefore, impacts to groundwater are not anticipated, unless appreciable subgrade (greater than 20 feet below ground surface) work is conducted for transit or parking structures. Additional geotechnical studies will be performed to further analyze effects to hydrogeology from deep soil disturbance.

5.3.3.1.3 Steep Slopes and Landslides

Steep slopes have been identified in areas along Burnt Bridge Creek. However, the Vancouver alignment options do not extend to Burnt Bridge Creek. Impacts related to steep slopes or landslides are not anticipated.

5.3.3.1.4 Relative Earthquake Hazards

Segment B is located in Relative Earthquake Hazard Zone D, the least hazard. Impacts resulting from significant ground shaking are most likely minor.

5.3.3.2 North I-5 Transit Alignments

In Segment B, the options presented for the I-5 transit alignment include a BRT or LRT efficient or increased transit operation on a McLoughlin/I-5 or 16th Street/I-5 alignment. The possible impacts to the transit alternatives along an I-5 alignment in Segment B are similar for all choices.

5.3.3.2.1 Geology

Segment B is located on catastrophic flood deposits coarse-grained facies. Earthwork for cut-banks, foundations, and grading is planned for the I-5 transit alignment.

There are no known geologic resources in the project area. There is no difference in the impacts associated with geologic resources. Construction and operation would not cause a loss in geologic resources.

5.3.3.2.2 Hydrogeology

Neither alignment will likely have any appreciable effect on hydrogeology or hydrogeologic resources.

5.3.3.2.3 Steep Slopes and Landslides

Steep slopes have been identified in areas along Burnt Bridge Creek. The I-5 alignment terminating at Kiggins Bowl passes within approximately 150 feet of slopes greater than 25 percent. Specific geotechnical methods may need to be employed to shore foundations for the crossing of I-5 to Kiggins Bowl. The direct impacts related to steep slopes will be addressed as part of the geotechnical evaluation.

5.3.3.2.4 Relative Earthquake Hazards

Three relative earthquake hazard zones are identified along the I-5 alignment. Hazard Zone C has been identified along the current and proposed I-5 alignment from approximately 16th Street to approximately 40th Street. The proposed footprint crosses Hazard Zone B at approximately 41st Street along I-5 and from approximately 39th and O Streets along SR 500 within Burnt Bridge Creek. The northern terminus of I-5 transit alignment comes within 150 feet of a Hazard Zone A area. The hazard ratings in this area are probably due to potential slope instability and liquefaction potential. Liquefaction would be likely to occur in areas of Burnt Bridge Creek where ground improvement will not be performed. Liquefaction-induced lateral spreading may occur within 200–400 feet of the proposed alignment. The lateral spreading and ground shaking could drastically reduce slope stability and affect elevated transit structures in this area. Damage to at-grade pavements could result in cracking and settlement of the roadway. If liquefaction occurs beneath fill embankments, slope instability and excessive settlement could damage the transit and parking structures.

5.4 Impacts from Other Project Elements

5.4.1 Minimum Operable Segment (MOS)

Impacts from the MOS would be similar to the full-length transit alternatives extending to the Kiggins Bowl or Lincoln Park and Ride sites, except that it would not include impacts resulting from construction near steep slopes in the Burnt Bridge Creek drainage. Construction in the vicinity of these slopes could increase the potential for slope failure and erosion. The Clark College Park and Ride or the Mill Plain MOS would not be impacted by the potential adverse effects of the Burnt Bridge Creek drainage. Implementation of the MOS element would reduce potential adverse effects resulting from a significant seismic event. The MOS would have less adverse effects than the full-length transit alignments because of the reduced guideway length.

Effects related to steep slopes and relative earthquake hazards for transit and highway alignments would likely not occur with implementation of the MOS element.

5.4.2 Maintenance Base Stations

Additional geologic impacts due to the Ruby Junction or the Vancouver maintenance base station expansions are not anticipated. Both these facilities are located in relative hazard zone D. The Ruby Junction site is not near steep slopes. The Vancouver site is located approximately one-quarter mile from any steep slopes.

5.5 Impacts from System-Level Choices

5.5.1 River Crossing Type and Capacity: How does the supplemental crossing compare to the replacement crossing?

The differences in effects are related to greater seismic risk and seismic upgrading associated with the supplemental crossing. Major seismic retrofitting that is part of the supplemental alternatives would upgrade the existing structures to better withstand the possible effects indicated by a high relative earthquake hazard rating. Without such upgrades, the existing structures would be considerably more vulnerable to damage or collapse in the event of a major earthquake. The replacement crossing would incorporate seismic upgrades within the design and construction. This consideration within the design would likely have a higher degree of integrity than the supplemental crossing retrofits. Impact to geology and soils would be minor.

5.5.2 Transit Mode: How does BRT compare to LRT?

No meaningful difference in impacts is anticipated.

5.5.3 Balance of Transit vs. Highway Investment: Increased Transit System Operations with Aggressive TDM/TSM Measures, and Efficient Transit System Operations with Standard TDM/TSM Measures

No difference in impacts is anticipated.

5.5.4 Major Transit Alignment: How does the Vancouver alignment compare to the I-5 alignment?

Potential steep slope issues may affect the I-5 alignment relative to the Vancouver Alignment. In addition, the I-5 alignment encounters relative Hazard Zone B, where the Vancouver alignment only encounters relative Hazard Zone C. As such the Vancouver alignment is more favorable than the I-5 alignment in regards to limiting geologic hazards.

5.5.5 Tolling: How do the tolling options compare (no toll, standard or higher toll on I-5, toll on both I-5 and I-205)?

No difference in impacts is anticipated.

5.5.6 Transit Project Length: How do the full-length alternatives compare to the shorter length option?

A shorter length would reduce potential adverse effects from steep slopes in the Burnt Bridge Creek drainage and would have less adverse effects due to seismic impacts than the full-length transit alignments because of the reduced length.

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6. Temporary Effects

Temporary effects are potential future effects to resources within the region or locality from the project that occur prior to and during construction of the I-5 CRC project.

6.1 Impacts Common to All Alternatives

Excavations, roadway removal, construction of access roads, staging areas and embankments could result in temporary increases in erosion and sedimentation. Construction operations that have potential to adversely impact slope stability include cut-banks and retaining walls. In addition, temporary effects from stormwater runoff during construction may degrade groundwater quality. Lastly all alternatives may have economic benefits to local quarry and aggregate mining industry.

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7. Mitigation for Long- and Short-Term Effects

7.1 Introduction

Mitigation measures to minimize impacts will be addressed using information obtained during design engineering utilizing standard-of-practice highway construction methods. Mitigation measures will be identified that meet applicable state and federal design and construction codes that govern transportation projects. Construction standards and guidance published by WSDOT, ODOT, FHWA, and AASHTO will be followed to ensure appropriate mitigation measures employed.

The following potential mitigation and minimization measures for long-term and short-term effects were identified:

- Avoidance of steep slopes near Burnt Bridge Creek and Kiggins Bowl, or implementation of engineering controls to minimize impacts.
- Seismic upgrades to existing or newly proposed structures within the API susceptible to earthquake hazards.
- Identification and characterization of geologic hazards.
- Erosion controls through the implementation of erosion control plans and grading permits.
- Protection of groundwater resources through stormwater management and treatment, particularly at excavated piers and park and ride facilities. The project will seek review and approval for any impacts to the Troutdale sole source aquifer.
- Evaluation of groundwater future beneficial use for induced growth.

Site-specific mitigation measures will be considered in subsequent geotechnical evaluations. In cases where avoidance of seismic hazards, steep slopes, and hazardous soil types is not possible due to the distribution of these conditions throughout the project area, effects of these conditions will be minimized through appropriate geotechnical and engineering controls.

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8. Permits and Approvals

8.1 Federal

The U.S. Army Corps of Engineers requires a Section 404 Permit for any activities that place or remove fill in “waters of the U.S.” Exact permit requirements will depend on circumstances and activity. Permits generally issued include: Nationwide General, Regional General, Programmatic General, or Individual.

Activities related to geology and soils that may require Regional or Nationwide permits and are likely anticipated for the project include:

- The drilling of exploratory geotechnical holes, installation of piezometers and/or monitoring wells in (or impacting) waterways or wetlands.
- Drilling design borings at pier location and drilling/constructing large diameter piers for bridges that would be in the Columbia River.
- Water body bank protection and/or erosion/scour protection at bridge piers and abutments.

Additional discussion of impacts to waters from the activities listed above is addressed in the Ecosystems Technical Report.

The EPA will review impacts to the Troutdale sole source aquifer from project activities.

8.2 State

The State of Oregon Department of State Lands may require one of three permits issued. These permits include a Statewide Programmatic General Permit (SPGP), a General Authorization permit, and a Removal-Fill Permit.

Activities that may require State permits and are likely anticipated for the project include:

- The drilling geotechnical holes, monitoring wells, and wells.
- Obtain “start cards” for monitoring wells, wells, and/or dewatering systems.

Additional discussion of impacts to waters from the activities listed above is addressed in the Ecosystems Technical Report.

8.3 Local

With the exception of land use and construction permitting, no resource-specific permits or approvals are likely required for this project.

Construction completed in Vancouver must conform to Section 20.740.130, Geologic Hazard Areas, of the Critical Areas Protection Ordinance. The relative earthquake hazard maps used during this assessment should not be used to obtain critical area protection permit from the City of Vancouver. The map produced by Palmer (2004) should be reviewed prior to requesting permits from the City of Vancouver.

The drilling of geotechnical holes and installation of monitoring wells and wells may require approval through Environmental Review or Environmental Plan check. If more than 10 cubic yards are removed, a Site Development permit may be required.

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