ENVIRONMENTAL ASSESSMENT
SR 520 BRIDGE REPLACEMENT AND HOV PROGRAM

DECEMBER 2009

SR 520, Medina to SR 202: Eastside Transit and HOV Project

Appendix I

Geology and Soils Technical Memorandum

Washington State Department of Transportation

U.S. Department of Transportation
Federal Highway Administration

SR 520, Medina to SR 202: Eastside Transit and HOV Project Environmental Assessment

Geology and Soils

Technical Memorandum

Prepared for

Washington State Department of Transportation
Federal Highway Administration

Lead Author

CH2M HILL

Consultant Team

HDR Engineering, Inc.
Parametrix, Inc.
CH2M HILL
Parsons Brinckerhoff
Michael Minor and Associates
Pacific Rim Resources

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Acronyms and Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
AgB	Alderwood gravelly sandy loam
AgC	Alderwood gravelly sandy loam
AgD	Alderwood gravelly sandy loam
AkF	Alderwood and Kitsap soils
AmC	Arents, Alderwood material
ASTM	American Society for Testing Materials
Bh	Bellingham silt loam
BMPs	best management practices
cm/s	centimeters per second
CSZ	Cascadia subduction zone
EvC	Everett gravelly sandy loam
FHWA	Federal Highway Administration
FS	factor of safety
g	acceleration in gravitational units
GIS	geographic information system
GMA	Growth Management Act
HOV	high-occupancy vehicle
ICC	International Code Council
KpB	Kitsap silt loam
KpD	Kitsap silt loam
LIDAR	light detection and ranging
lf	linear foot
LRFD	load and resistance factor design
No	Norma sandy loam
PNSN	Pacific Northwest Seismic Network

Qtb	Lawton clay
Qva	Vashon advance outwash
Qvr	Vashon recessional outwash
Qvt	Vashon till
RCW	Revised Code of Washington
SCS	Soil Conservation Service
sf	square foot
Sk	Seattle muck
SR	State Route
TESC	Temporary Erosion and Sedimentation Control (plan)
Tu	Tukwila muck
USGS	U.S. Geological Survey
WDNR	Washington State Department of Natural Resources
WSDOT	Washington State Department of Transportation
yd^3	cubic yard

1. Introduction

Why are geology and soils considered in an environmental assessment?

Geology and soils are considered in an environmental assessment for three main reasons:

1. Geology and soils influence the type of foundation required for bridges and walls, which in turn affect the project cost, footprint size, volumes of excavated and imported soils, and possibly the noise level of construction equipment.
2. The composition, location relative to the water table, and density of excavated soils determine whether the soils are suitable for reuse as fill on the project. Soil reuse affects truck traffic beyond the project boundaries; if the onsite soils cannot be reused, it might be necessary to transport suitable fill to the site. In addition, the demand on sand and gravel resources within the Puget Sound area could be affected by soil reuse on this project.
3. The presence of geologic hazards, such as active seismicity (i.e., the frequency or magnitude of earthquake activity) and landsliding or erosion, increases construction costs through mitigation measures for the project. Unmitigated hazards could pose risks to the traveling public, adjacent landowners, and the aquatic environment.

What are the key points of this technical memorandum?

The proposed project would have a minimal effect on the geology and soils in the study area. The greatest effect would be the use of soil and rock material for the Build Alternative. If potential hazards (i.e., slope instability, liquefaction, and landslides) were properly mitigated, the project would improve the geology and soils within the project footprint.

> What is liquefaction?
>
> Liquefaction is a phenomenon in which the strength and stiffness of a soil is reduced by earthquake shaking or other rapid loading.
>
> Liquefaction occurs in saturated soils, that is, soils in which the space between individual particles is completely filled with water. "Liquefiable" soils are relatively loose. Soils that have become denser as a result of the weight of glacial ice are usually not liquefiable.

The project would have some effects during construction, as described below:

- The project would use roughly 400,000 net tons of soil and rock materials, which would reduce geology and soils resources outside the project limits because these materials would be imported to meet construction needs.
- Project development would result in new loads or reductions in loads on local soils as embankments were placed and as areas were excavated.
- The project would result in changes in soil layers as materials were removed to accommodate project elements (e.g., retaining walls) or as soils were removed or placed to improve performance of project elements.

Construction activities on steep slopes and through areas with known or suspected past landsliding would use modern engineering and construction techniques developed to minimize landsliding hazards.

What is the project?

The Washington State Department of Transportation (WSDOT) is proposing to construct the SR 520, Medina to SR 202: Eastside Transit and HOV Project to reduce transit and high-occupancy vehicle (HOV) travel times and to enhance travel time reliability, mobility, access, and safety for transit and HOVs in rapidly growing areas along the State Route (SR) 520 corridor east of Lake Washington. Exhibit 1 shows the project vicinity. Some of the improvements included in this project were originally part of the SR 520 Bridge and HOV Project. On June 18, 2008, the Federal Highway Administration (FHWA) authorized WSDOT to develop the SR 520, Medina to SR 202: Eastside Transit and HOV Project as an independent project. The project includes building a complete HOV system between Lake Washington and 108th Avenue NE and restriping the existing HOV lanes from the outside lanes to the inside lanes between the 108th Avenue NE interchange and SR 202 in Redmond.

The portion of the project between Evergreen Point Road and 108th Avenue NE was previously part of the SR 520 Bridge Replacement and HOV Project. The SR 520, Medina to SR 202: Eastside Transit and HOV Project has been an independent project to address needs specific to the portion of SR 520 east of Lake Washington. The project limits extend approximately 8.8 miles along SR 520 from the east shore of Lake Washington (vicinity of Evergreen Point Road) to the interchange with SR 202 in Redmond.

WSDOT is considering two alternatives for the project: the Build Alternative and the No Build Alternative.

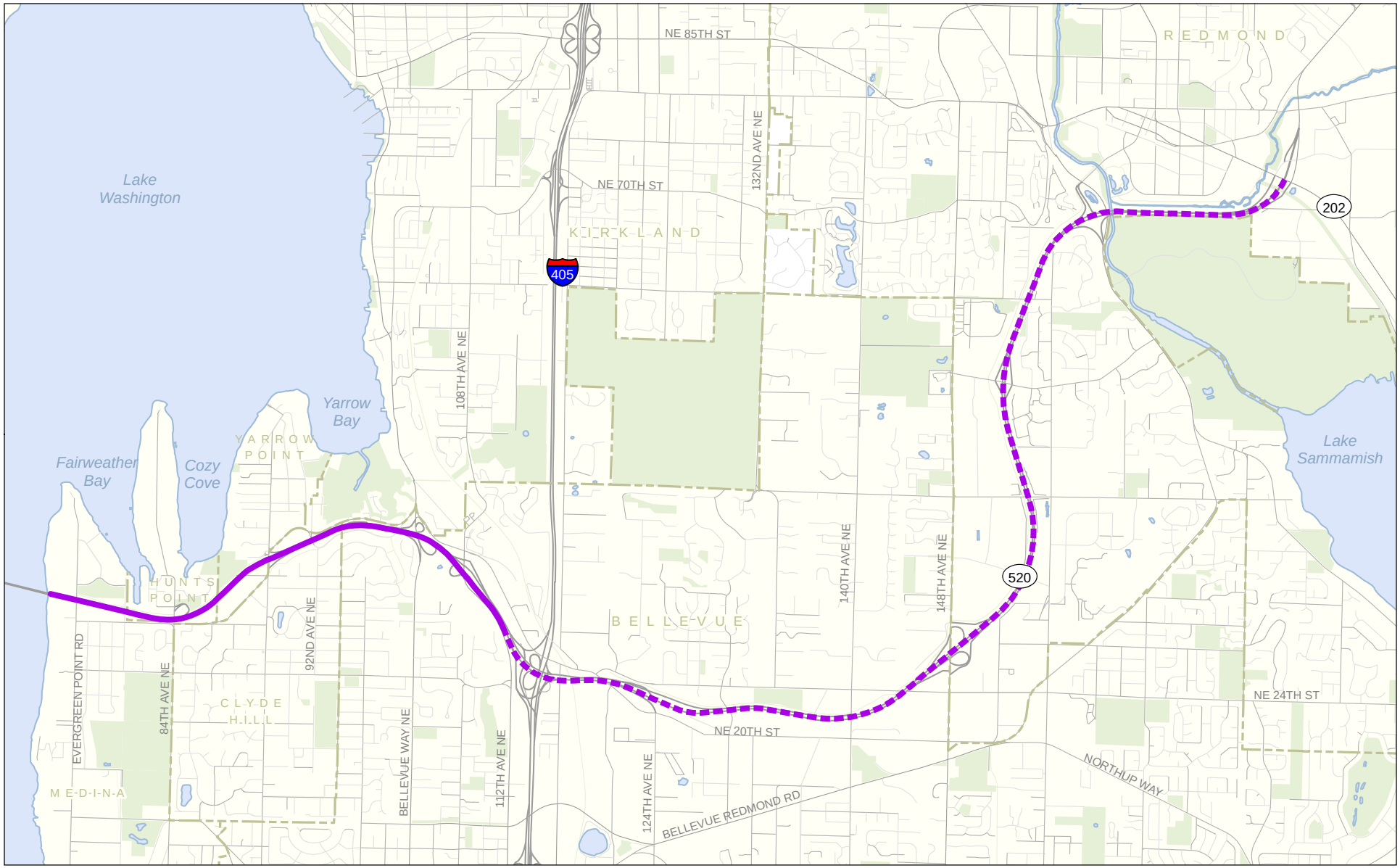
Build Alternative

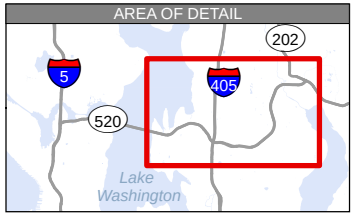
Under the Build Alternative, the proposed project would include the improvements described below.

SR 520 Improvements from Lake Washington to I-405

The proposed project would reconstruct SR 520 from just west of Evergreen Point Road to just east of 108th Avenue NE. Elements constructed as part of this section include the following:

- Construct a new eastbound HOV lane from Lake Washington to the existing eastbound HOV lane west of the I-405 interchange. This improvement would complete the currently discontinuous HOV network on the Eastside and improve travel time reliability for buses and carpools.
- Relocate the existing westbound HOV lane from the outside lane to the inside lane from Lake Washington to I-405. This change would enhance safety by eliminating the need for merging vehicles to weave across the faster-moving HOV lanes to reach the general-purpose lanes.





Construction Extent

Restriping Extent

Park

City Limits

N

0 0.5 1 Miles

Source: King County (2005) GIS Data (Streets), King County (2007) GIS Data (Waterbody) and CH2M HILL (2008) GIS Data (Parks and Streams). Horizontal datum for all layers is NAD83(91); vertical datum for layers is NAVD88.

Exhibit 1. **Project Vicinity**

Medina to SR 202: Eastside Transit and HOV Project

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- Construct a lid with inside transit stop over SR 520 at Evergreen Point Road.
- Construct a new lid and modify the existing half-diamond interchange at 84th Avenue NE.
- Construct a new lid with inside transit stop over SR 520 at 92nd Avenue NE and modify the existing interchange.
- Reconfigure the existing interchange at Bellevue Way NE.
- Construct new HOV direct access ramps at 108th Avenue NE. This improvement would create a more efficient connection for transit and HOV from SR 520 to the South Kirkland Park-and-Ride via local streets.
- Add a bike/pedestrian path from Lake Washington to approximately 108th Avenue NE. This improvement would facilitate nonmotorized use of SR 520, provide transit connections for bikes and pedestrians, and complement the existing nonmotorized transportation network on the Eastside.

> What is a lid?
>
> The term "lid" is short for "lidded highway". Lids are long bridges that cover a length of highway. Lid surface areas can carry paths and trails to connect communities across the highway, landscaping to create open space and places for passive recreation, and items such as pergolas, seating, and transit waiting areas.

SR 520 Improvements from I-405 to SR 202

- Restripe existing eastbound and westbound HOV lanes from the outside to the inside lane. This change would enhance safety by eliminating the need for merging vehicles to weave across the faster-moving HOV lanes to reach the general-purpose lanes.

Other Improvements

- Provide noise walls between Evergreen Point Road and Bellevue Way NE.
- Provide retaining walls and stormwater management system improvements.
- Improve stream habitat by realigning portions of the Yarrow Creek channel and shortening some culverts.
- Improve fish passage culvert crossings to restore fish passage and open up habitat that was previously inaccessible to salmon and other fish species.
- Mitigate the project’s effects on wetlands and streams at a site or sites as determined through future negotiations with permitting agencies.

No Build Alternative

Under the No Build Alternative, the project would not be built. Only routine maintenance, repair, and minor safety improvements would take place on SR 520 in the study area over the next 20 years. The No Build Alternative would not improve transit reliability and transit and HOV travel times on SR 520. Also included in the No Build Alternative for traffic modeling purposes is the assumption that the SR 520, Bridge Replacement and HOV Project would not be built until this project is complete.

WSDOT is evaluating the No Build Alternative to provide a reference point for comparing the effects, both positive and negative, associated with the proposed project.

2. Methodology

This section summarizes the methodology used for identifying the affected environment for geology and soils, evaluating potential effects, and developing mitigation measures.

What guiding plans and policies were used for this analysis?

Policies and guidance relevant to the geology and soils analysis include the following:

- King County Critical Areas Ordinance (King County Code Chapter 21A.24)
- Land use codes and sensitive/critical areas overlays for Medina, Hunts Point, Clyde Hill, Yarrow Point, Kirkland, and Bellevue (King County 2003)
- International Building Code, 2006, for structures requiring human occupancy (ICC 2006)
- WSDOT *Environmental Procedures Manual*, Section 420, October 2008 (WSDOT 2008)
- WSDOT *Geotechnical Design Manual*, December 2006 (WSDOT 2006)
- American Association of State Highway and Transportation Officials (AASHTO) *Load and Resistance Factor Design (LRFD) Bridge Design Specifications*, 4th Edition, 2008 Interim Revisions (AASHTO 2008)
- Shannon & Wilson, Inc. 2006. *Existing Geotechnical Report*. Prepared for WSDOT Urban Corridors Office. Vol. 8. December 19, 2006 (Shannon & Wilson 2006)

How did the team coordinate information gathering?

The project team interviewed geotechnical staff from jurisdictions along the Eastside SR 520 corridor to gather information on excavation support in the overconsolidated clay and silt materials present in the corridor, such as Lawton clay, which has a relatively high potential for instability when excavated.

The team gathered information regarding wall design, slope stabilization, subsurface information, plan and profile drawings, mapping overlay work, and mitigation measures.

How was the affected environment identified?

Team members searched various archives and databases to find documents and maps containing geologic and geotechnical information for the study area. Pertinent documents were collected from the following resources:

- Internal resources such as the CH2M HILL library in Bellevue, Washington
- University of Washington archives in Seattle, Washington
- Washington State Department of Natural Resources (WDNR) on-line references database
- WSDOT archives in Tumwater, Washington

- U.S. Geological Survey (USGS) on-line references database

How were the environmental effects evaluated?

The team assessed the potential effects of the project on adjacent properties and downstream areas. General effects of construction through various subsurface conditions are described qualitatively. The team quantified earthwork volumes provided by the design team and distances through geologic hazard areas; relative effects can be associated with these quantitative measures.

The team evaluated ways that geology and soils can directly affect construction in areas such as waste-soil disposal and use of fill, backfill, and aggregate resources.

How were mitigation measures developed?

The team developed feasible mitigation measures to address the potential adverse effects of the project, and measures that, implemented with agency consultation, could reduce the effect on areas inside and/or outside the study area.

What data sources were used for the analysis?

The team used the following data sources for the geology and soils analysis:

- USGS geologic maps
- WDNR geologic maps and geologic hazard maps for King County
- City of Bellevue critical areas maps, available from the City of Bellevue Planning Department
- Washington state earthquake hazard maps, available from WDNR
- As-built foundation plans for the existing walls and structures
- Subsurface exploration logs, subsurface profiles, and geotechnical reports available from the WSDOT Geotechnical Division files at the State Materials Laboratory, Tumwater
- Existing field reconnaissance information provided in WSDOT reports
- A literature review for new geology or geotechnical reports and maps published since 2002, including geophysical work
- Roadway plan, profile, and cross sections at 200-foot intervals, available from the SR 520 project office

3. Affected Environment

This section describes regional geology and seismicity, surficial soils, geologic units, and geologic hazards in the study area. It also discusses the relative permeability and general occurrence of groundwater within the various geologic units. Groundwater is discussed in detail in the Water Resources Discipline Report (WSDOT 2009a).

What created the topography and geology of the Puget Sound area and project corridor?

The soils and land types found within the SR 520 corridor are heavily influenced by multiple Pleistocene (the period from approximately 10,000 to 2,000,000 years ago) glaciations that resulted in a series of north–south trending ridges of glacial drift separated by deep troughs. The troughs are now occupied by streams and lakes and their associated alluvial and lacustrine deposits.

The Puget Sound region was overridden by ice during the most recent period of glaciation, the Vashon stade, which occurred between roughly 10,000 and 20,000 years ago. The study area was covered by ice about 2,000 feet thick, resulting in the very dense and highly overconsolidated glacial till, advance outwash, and transitional bed or lacustrine deposits that are described in this report. The depth from the surface through the glacially overconsolidated till to bedrock is generally 500 feet or more.

Large quantities of meltwater were discharged as the Vashon glacier receded. The meltwater sorted material in its path and left behind very gravelly and sandy sediments ranging from 5 to 100 feet thick. These deposits, called recessional outwash, exist in various densities and are quite porous.

Alluvial materials have been deposited in streams and river valleys since the recession of the Vashon glacier. These alluvial materials are generally much looser or softer than the glacially overridden materials.

Organic and peat material accumulations can be found along the project corridor. These soft soils consist of plant material and woody debris and are commonly interbedded with silt and clay.

Is the study area prone to seismic activity?

The study area is located in the seismically active Puget Sound region. Seismicity in this region is caused by the Juan de Fuca oceanic plate sinking beneath the North American continental plate and by northwest movement of the tectonic block occupied by western Oregon and northern California. These mechanisms are shown conceptually in Exhibit 2. Detailed discussions of these movements are provided by Wells et al. 1998, Miller et al. 2001, and Hyndman et al. 2003. The convergence of these plates has resulted in three source mechanisms for seismic activity in the Puget Sound area. These source mechanisms are:

1. The Cascadia subduction zone (CSZ) interplate source off the coast of Washington
2. The deep intraslab subduction zone located approximately 20 to 40 miles below the area
3. Shallow crustal faults

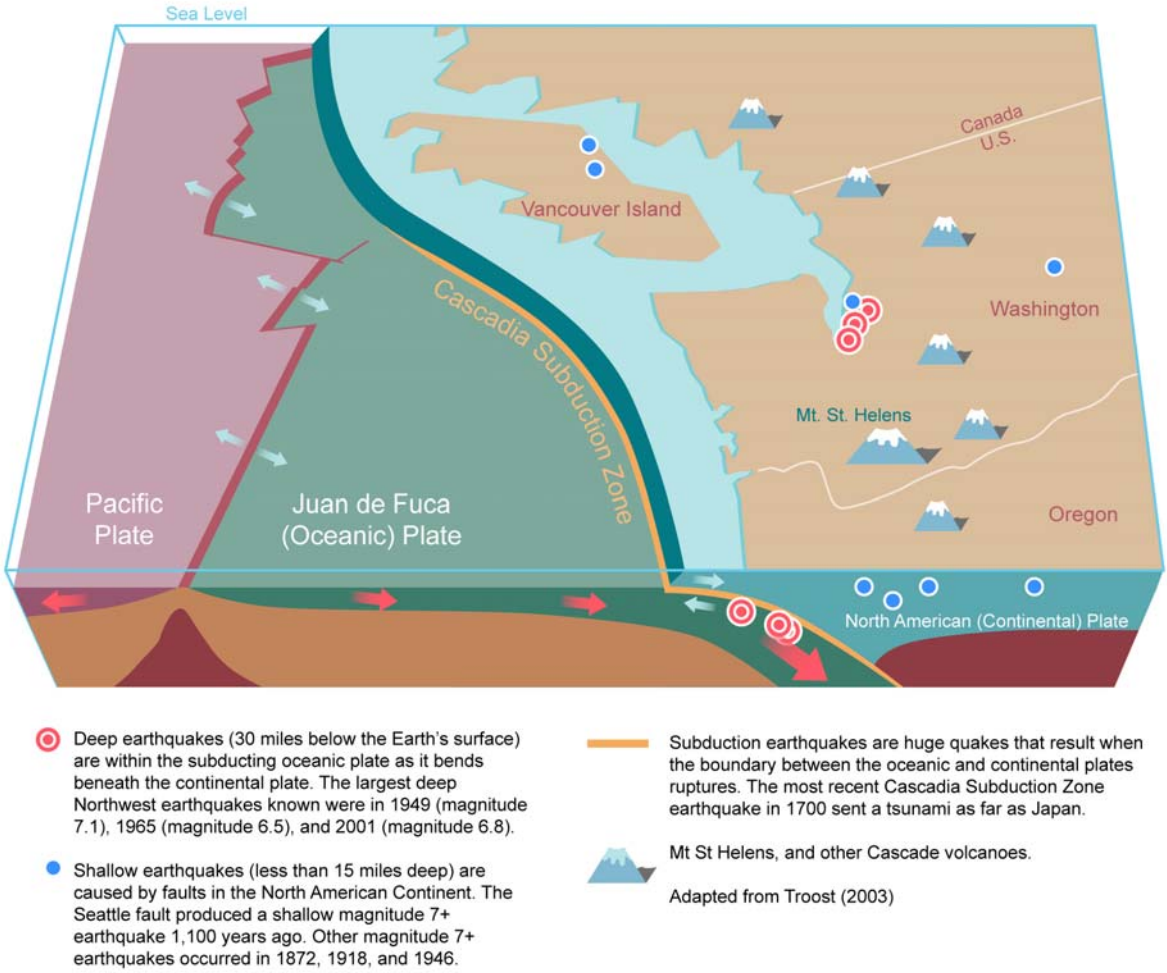


Exhibit 2. Sources of Earthquakes in the Puget Sound Region

An earthquake with one of these source mechanisms could result in large vibratory ground motions in the study area. The most recent large earthquakes in the area include the 1949 Olympia earthquake with a magnitude of 7.1, the 1965 Sea-Tac earthquake with a magnitude of 6.5, and the 2001 Nisqually earthquake with a magnitude of 6.8. All of these are examples of the deep intraslab subduction zone.

The most well known faults within the study are the Seattle Fault and South Whidbey Island Fault. These faults are crustal faults. It is assumed that these sources are capable of causing magnitude 7.0 to 7.3 events and are estimated to have a recurrence interval of approximately 1,000 to 3,000 years (Frankel et al. 2002). The Seattle Fault is approximately 4 miles south of the study area, while recent aeromagnetic and light detection and ranging (LIDAR) surveys by the USGS (Blakely et al. 2004) suggest that the onshore projection of the South Whidbey Island Fault is 9 to 10 miles northeast of the study area's east end. However, more recent studies of the South Whidbey Island Fault place the fault within 6 miles of the study area (Shannon & Wilson Inc. 2008). The published locations of the Seattle Fault and South Whidbey Island Fault are shown on Exhibit 3.

What are the potential consequences of seismic activity in the study area?

The consequences of seismic activity are vibratory motion of the ground and, in some cases, permanent ground displacement. The effects of these ground movements on the project elements depend on the magnitude and duration of vibratory motions, the permanent ground displacement, and the ability of current design methods to accommodate these transitory or permanent movements.

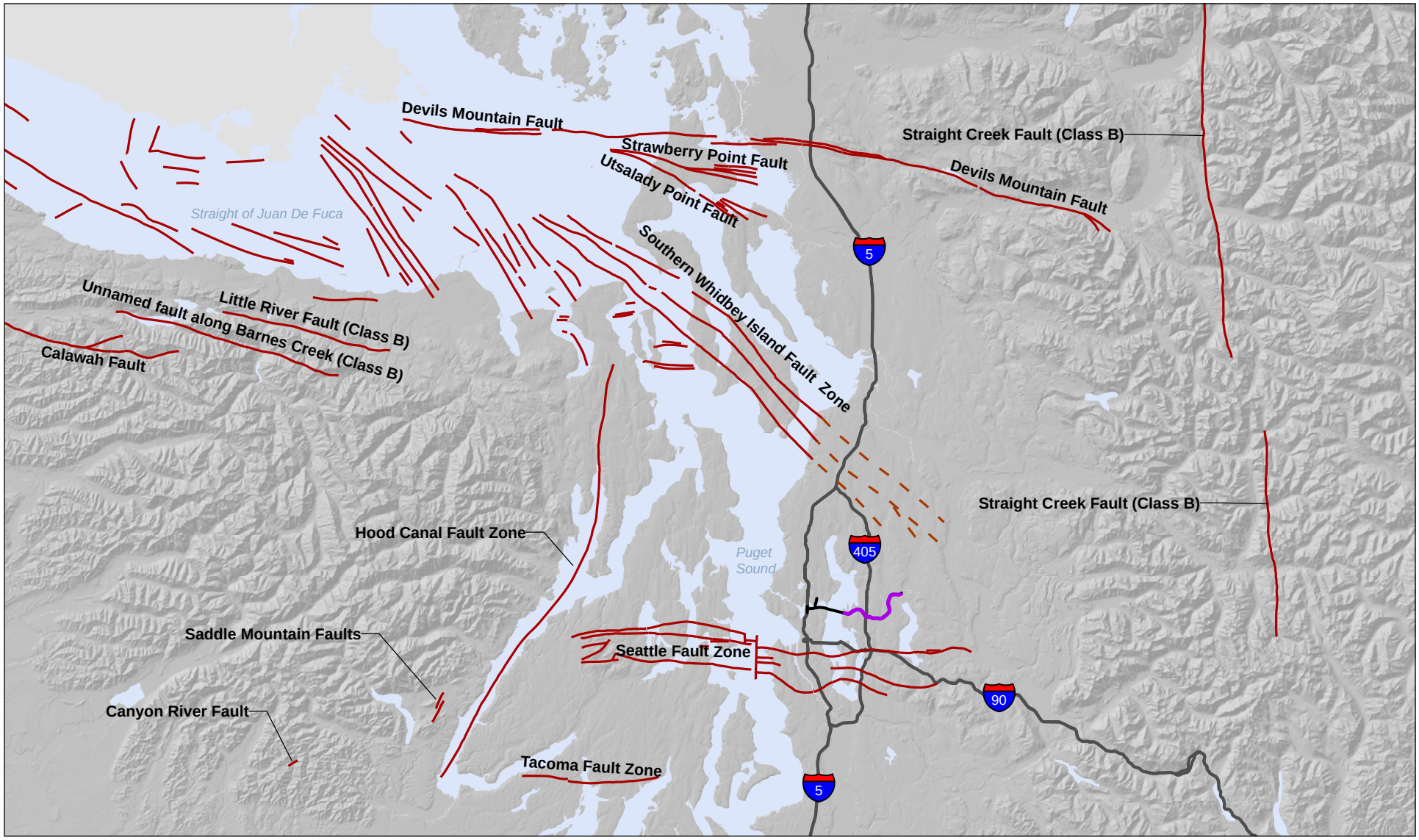
Vibratory Ground Motions

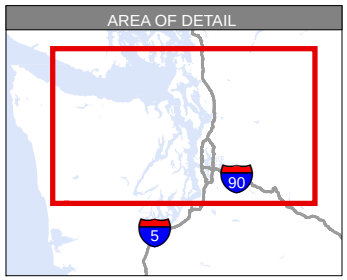
Seismic waves moving through the earth cause vibratory movement of the ground. The level of vibratory ground movement is determined by the specific location of the earthquake source and the soil conditions at the site. These vibratory movements are measured in terms of amplitude and duration of shaking. The amplitude can range from barely noticeable to accelerations that are damaging to structures. The duration of noticeable ground movement varies from a few seconds to over a minute.

> Ground Motions
>
> A common measure of ground movement amplitude is acceleration in gravitational units (e.g., 1 g = 32.2 ft/sec^2). Ground accelerations less than 0.05 g are barely felt, while accelerations in excess of 0.5 g can be damaging to poorly designed structures or cause soil liquefaction and other disturbances of the earth.

In view of the seismic activity in the Puget Sound area, the project team would conduct detailed studies during design to confirm that the project elements were able to withstand the vibratory ground motions resulting from seismic events. Preliminary assessments of the likely ground shaking assume that gravitational units could be in excess of 0.4 g along the project corridor for a 7-percent chance or probability of occurrence over 75 years (1,000-year return period). However, recently published studies by the USGS accounting for effects specific to the Puget Sound area (such as basin effects) may increase the ground motions for this project. The shaking level is based on seismic hazard studies conducted by the USGS for the Puget Sound area (Frankel et al. 2002). This chance (or probability) of occurrence is consistent with the basis of bridge design identified in 2008 by AASHTO, and is the minimum level considered by WSDOT for bridge projects.

The minimum levels of ground motion used during the project design, referred to as the design acceleration, would be based on USGS probabilistic modeling of earthquakes from all three source mechanisms that have a 7-percent chance of occurring over a 75-year period, or a 1,000-year return period.





Source: USGS (1999) 30 Meter DEM; USGS (2004) GIS Data (Faults), WSDOT (2004) GIS Data (State Route), and Ecology (2001) GIS Data (Waterbody). Horizontal datum for all layers is NAD83(91); vertical datum for layers is NAVD88.

Project Area

Fault

On-Land Projection of Fault as postulated by Blakely, et al. (2004)

N

0 10 20 Miles

Exhibit 3. **Published Locations of Faults**

Medina to SR 202: Eastside Transit and HOV Project

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Permanent Ground Displacements

Permanent ground displacement could result from either fault movement or the indirect effects of ground shaking. Movement associated with faulting is usually the result of displacement of crustal faults. These movements could be horizontal, vertical, or a combination of the two, depending on the type of fault (Wells and Coppersmith 1994). The amount of movement could vary from less than an inch to several feet.

Movement resulting from the indirect effects of ground shaking could involve densification of loose granular soils (i.e., sands, gravels, and sometimes silts), resulting in settlement of the ground surface; lateral movement of the ground resulting from liquefaction, often referred to as lateral spread or flow; and slope movements due to added forces of earthquake shaking (Youd et al. 2001).

The proposed project alignment does not cross any active faults, according to current faulting maps. Based on current information, permanent ground movement along the project alignment resulting from fault movement would be unlikely. However, the ground motions associated with a design earthquake could result in permanent vertical or horizontal ground movement from densification, liquefaction-induced lateral spreading or flow, and slope instability. The potential for these groundshaking-related hazards is reviewed in the *What are geologic hazards and are there geologic hazards in the study area?* section.

What are the geologic units in the study area?

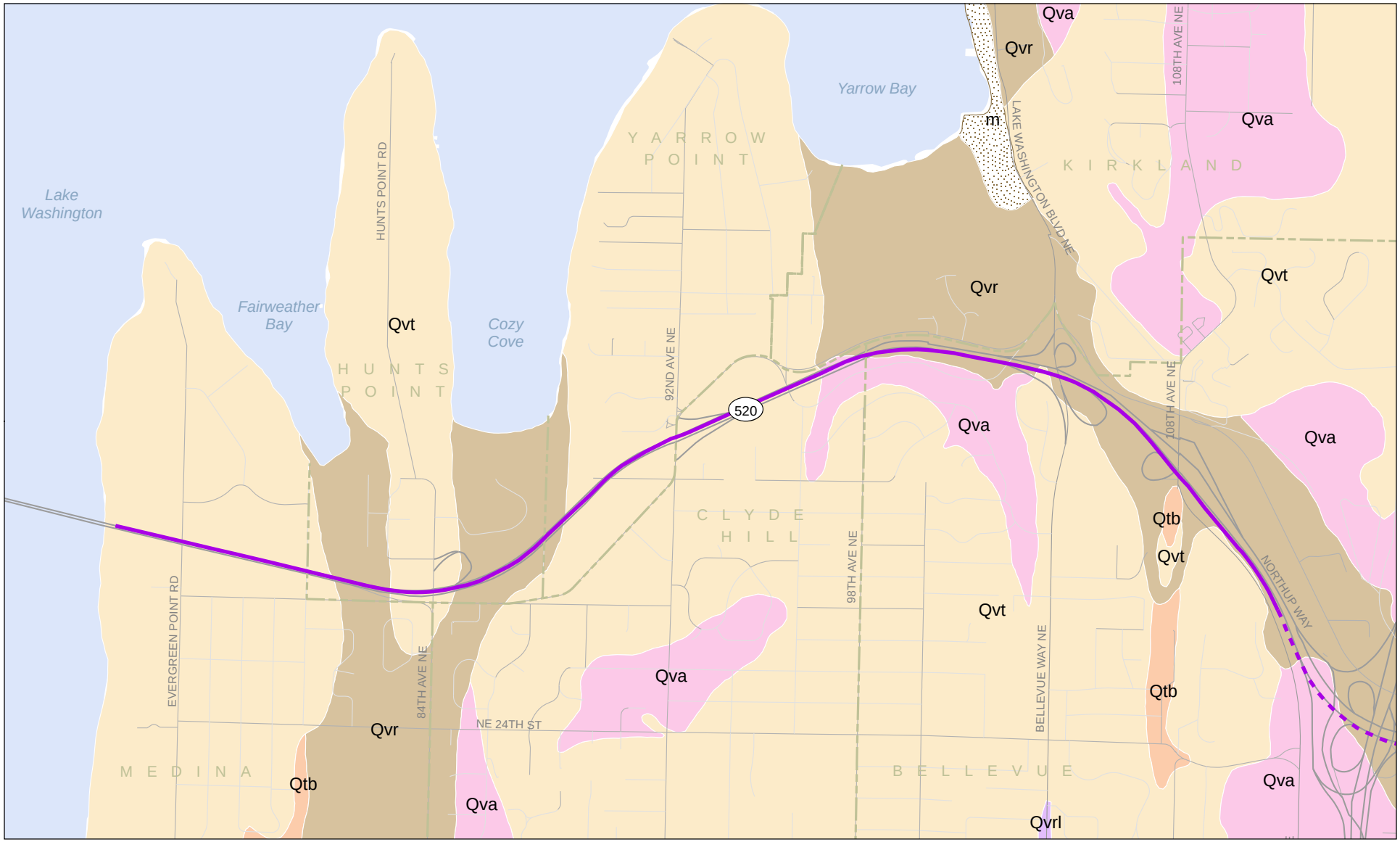
Several mapped geologic units exist within the study area (Minard 1983, Galster and Laprade 1991, Yount et al. 1993, Booth et al. 2002). Exhibit 4 shows approximate surface exposures of the various units.

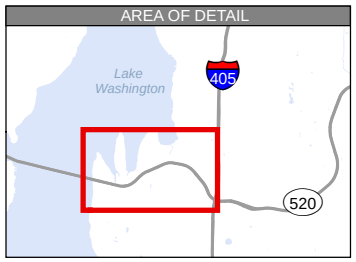
Exhibit 5 summarizes typical engineering properties and susceptibility to pertinent geologic hazards for each geologic unit. Geologic hazards are discussed in the *What are geologic hazards and are there geologic hazards in the study area?* section. The following subsections briefly describe the general characteristics of the geologic units in the study area.

Vashon Recessional Outwash – Qvr

Vashon recessional outwash is sediment deposited by the meltwaters of the last recession of glacial ice. Recessional outwash is typically a medium- to coarse-grained sand and gravel deposit that frequently has little silt or clay and is generally very permeable. Because it has not been glacially overridden, recessional outwash is loose to medium dense, and is typically easy to excavate with backhoes or dozers.

The ability of recessional outwash soils to support structure foundations is low to moderate for transportation structures. Bridges commonly require large spread footings or are founded on piles that penetrate to denser underlying materials. Walls retaining fill materials typically do not require deep foundation support; the spread footings or reinforced soil can usually be supported adequately by the recessional outwash.





Qvr	Recessional Outwash
Qvrl	Recessional Lacustrine Sediments
Qtb	Glacial Till
Qva	Advance Outwash *(silt dominated lowland lacustrine deposits)*
Qvt	Transitional Beds and Older Glacial Deposits
m	Modified Land

Construction Extent

Restriping Extent

City Limits

N

0 500 1,000 2,000 Feet

Source: Surficial Geology Map: King County GIS Data (2003) based on Booth et al. (2002), WSDOT (2004) GIS Data (State Route), and King County (2007) GIS Data (Waterbody). Horizontal datum for all layers is NAD83(91); vertical datum for layers is NAVD88.

Exhibit 4. **Surficial Geology**

Medina to SR 202: Eastside Transit and HOV Project

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Vashon Till – Qvt

Vashon till is a compact, unsorted mixture of silt, clay, sand, gravel, cobbles, and occasional boulders. It covers the ground surface over the higher elevations in the study area and ranges from a few feet to over 100 feet thick. The till can vary locally; some zones of primarily coarse-grained (sand or larger) or fine-grained (silt or smaller) soils are present. It has been overridden by the glacial ice and is generally very dense and of very low permeability. This is the predominant near-surface material throughout the study area.

Exhibit 5. Summary of Typical Engineering Properties and Hazard Susceptibility of Geologic Units

Geologic Unit	Where Unit May be Found in Study Area	Strength	Permeability	Liquefaction Potential[a]	Erosion Hazard on Steep (>15%) Slope[b]	Landslide Hazard on Steep (>15%) Slope[b]
Vashon Recessional Outwash (Qvr)	Troughs or valleys	Medium	Medium to High	Low to Medium	High	Medium
Vashon Till (Qvt)	Majority of the study area in higher elevations	High	Low	Low	Low	Low
Vashon Advance Outwash (Qva)	Underlying till	High	Low to Medium	Low	Low to Medium	Low to Medium
Transitional Beds (Qtb) and older glacial deposits	Lower elevations of hill areas	High[c]	Low	Low	Low to Medium	Low to Medium[d]

Note: The terms low, medium, and high were determined based on professional opinion from experience with the soil types. The hazard susceptibility was determined based on criteria in city and county codes and professional opinion. Codes include King County Code 21A.24 and City of Bellevue Land Use Code LUC 20.25H and 20.50.

[a]Liquefaction requires saturated soil; this exhibit assumes a shallow groundwater condition. Liquefaction is also limited to relatively free-draining soils; this exhibit assumes that the soils are not primarily silt or clay.

[b]Based on city and/or county codes and regulations.

[c]For some materials, like the Lawton clay, there may be pre-existing planes of weakness with low strength; excessive deformation may also reduce strength to very low residual levels.

[d]Landslide hazards in transitional beds are high if they have been cut into. If left in place and not disturbed, the landslide hazard is low.

Strength – For the purpose of this document, values of low, medium, and high strength were defined by the typical relative density or consistency, and determined by the corrected standard penetration test (ASTM D 4633-86) blow count, or N_{60} value. (Cohesionless soils are soils such as sands and gravels. Cohesive soils are soils such as clays and silts.)

Low: cohesionless soils, N_{60} <10; cohesive soils, N_{60} <9

Medium: cohesionless soils, N_{60} = 11-50; cohesive soils, N_{60} = 9-30

High: cohesionless soils, N_{60}>50; cohesive soils, N_{60} >30

Permeability – Rate of fluid flow through a porous material under standard conditions of area, thickness, and pressure. Units are in centimeters/second (cm/s).

Low: 10^{-5} or less

Medium: 10^{-4} to 10^{-2}

High: 10^{-2} or greater

Undisturbed Vashon till is generally excellent for foundation support; structures can typically be built on shallow spread footings. It is difficult to drive pilings more than a few feet into Vashon till because it is so dense and frequently contains cobbles and boulders. Commonly, the undisturbed till is stable at relatively steep temporary and permanent slopes. Vashon till from excavations can be reused as embankment and backfill. However, because of its high silt and clay content, Vashon till cannot be compacted easily if it becomes wet. Therefore, Vashon till slated for reuse on the project must be protected from rain and runoff during excavating, transport, stockpiling, and placement.

Within till areas, groundwater is commonly present in the upper weathered portion of the till and in any topsoil that may have formed within a few feet of the ground surface. Groundwater tends to perch on the underlying unweathered till. Although the groundwater surface is high, the normal flow of groundwater through till is very slow because of its low permeability.

Vashon Advance Outwash – Qva

The Vashon advance outwash unit consists of mainly sand and gravel, with occasional boulders and cobbles that were pushed ahead of the Vashon glaciation. Although permeability varies, advance outwash is generally at least two to four orders of magnitude more permeable than till. Advance outwash is typically very dense or hard and of relatively high strength.

Advance outwash generally has high allowable weight-bearing, stands firm at relatively steep slopes, and makes excellent embankment material. Depending on the clay and silt content, it may be difficult to compact if exposed to moisture, but advance outwash is typically less weather-sensitive than till.

Transitional Beds – Qtb

Transitional beds are glacially overconsolidated clay and silt deposits (including the Lawton clay) that are sometimes interbedded with sand layers. This unit is found throughout the study area and is found at the location of pre-existing landslides. These deposits have a relatively high potential for instability when excavated. Lawton clay, in particular, is generally hard and relatively strong in its undisturbed state. However, it tends to lose strength upon deformation, such as might occur during temporary excavations or when soil pressures are applied in retaining wall construction.

Lawton clay deposits can contain fissures that formed due to stress relief during deglaciation. Grading changes, such as removal of an overlying low-permeability layer, could introduce water to these fissures which, combined with stress relief from regrading, could result in substantial loss of strength. When interbedded with sands or gravels, these low-permeability materials might confine groundwater, locally eroding the surface materials and resulting in instability where the water intersects the ground surface on slopes.

What are geologic hazards and are there geologic hazards in the study area?

Geologically hazardous areas might not be suited for development because of public health and safety concerns. Within the project vicinity, these are areas susceptible to erosion, landslides, and excessive deformation during earthquakes. Washington's Growth Management Act (GMA) (RCW 36.70A) requires all cities and counties to identify critical areas, including geologic hazard areas, within their jurisdictions and formulate development regulations for critical area protection.

Geologic hazards analyzed in the study area were erosion, landslides, and seismicity. Mine and volcanic hazards also fall under the GMA, but these hazards are not present along the SR 520 corridor. Steep slopes typically have a higher risk of erosion and landsliding; therefore, some jurisdictions (such as King County) have regulations governing steep slope hazards.

Exhibit 6 shows the approximate locations of erosion, landslide, and seismic hazard areas as mapped by King County (2003) and the City of Bellevue (2004). The definitions of geologic hazards in ordinances from other cities within the study area are similar enough to King County's definitions to allow the King County maps to be used for the hazard analyses. The following sections describe the different kinds of hazard areas.

Erosion Hazards

Erosion hazard areas are typically defined as (1) soils that form on fine-grained geologic units, or (2) till that is steeper than 15 percent, or (3) soils that form on coarse-grained soils that are sloped at 40 percent or more. Exhibit 6 shows the mapped erosion hazard locations in the study area.

Landslide Hazards

Jurisdictions in the study area generally define landslide hazards as any slopes steeper than 40 percent, or slopes of 15 percent or more that also have interbedded sand and silt or clay, springs or seeps, landslide deposits or other indications of past landsliding, or that show signs of rapid stream downcutting or wave or bank erosion. Exhibit 6 shows the mapped landslide hazard locations in the study area.

Seismic Hazards

Seismic hazards are generally considered to be areas with a severe risk of ground shaking or deformation during an earthquake. Secondary earthquake effects include soil liquefaction and ground motion amplification. Exhibit 6 shows the mapped potential liquefaction hazard areas.

Liquefaction occurs when saturated, cohesionless soils, such as sand, are transformed into a liquid state, commonly as a result of earthquake-induced ground shaking. Predictions of amplified ground shaking or liquefaction and associated deformation that could damage buildings or engineered structures require detailed knowledge of soil composition, stratigraphy, groundwater, and ground slope—information that is too detailed for large-scale mapping of hazards. Therefore, local jurisdictions have taken a conservative approach, generally classifying all post-glacial deposits in low-lying areas as seismic hazards. If the Build

Alternative were selected, liquefaction potential would be determined from site-specific subsurface information during design.

What are the surficial soil units in the study area?

Surficial soil units mapped by the Soil Conservation Service (SCS) are shown in Exhibit 7 (SCS 1972). Surficial soils are typically mapped by field personnel who dig shallow (typically 1- to 5-foot-deep) test holes and observe the soil profiles and material; the maps reflect only the material present in the upper few feet at the time of testing. Although the surficial soils along the proposed project alignment have been modified by construction, the surface soils typically provide an indication of the underlying geologic unit.

Exhibit 8 summarizes typical characteristics and engineering properties of the surficial soils as described by the SCS. Topsoil is typically removed from beneath roadway embankments and foundations, so the descriptions below apply only to “undisturbed” soils adjacent to the roadway.

Alderwood Series

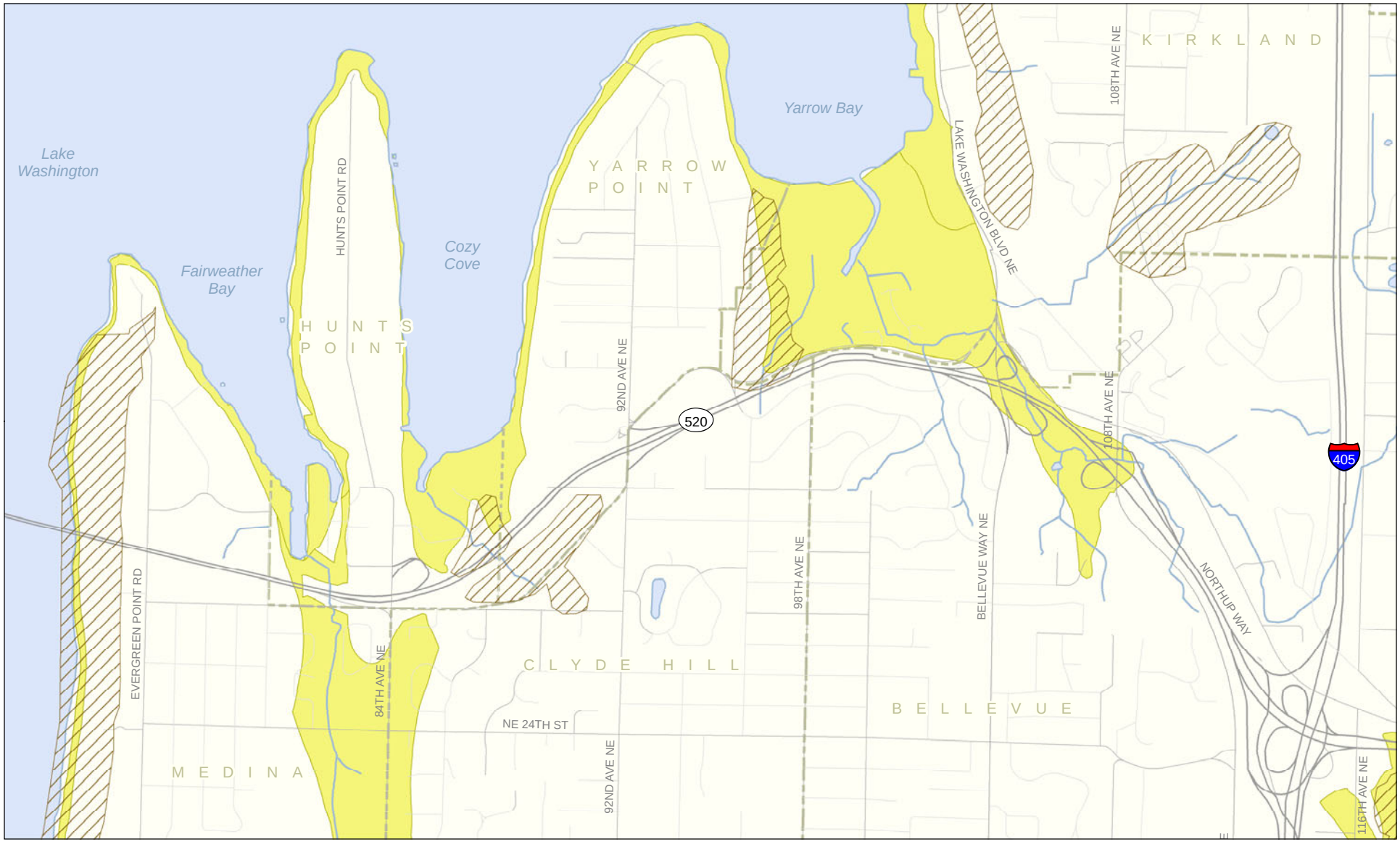
The Alderwood series includes Alderwood gravelly sandy loams (AgB, AgC, and AgD) and Alderwood and Kitsap soils (AkF). The Alderwood series soils are described by SCS (1972) as moderately to well-drained soils that form in uplands in glacial till deposits.

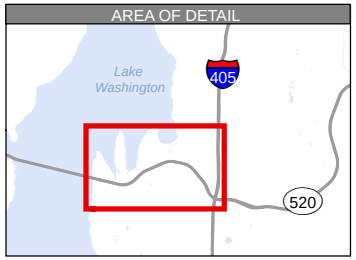
Arents, Alderwood Material

Arents, Alderwood material (AmC) consists of Alderwood soils that have been so disturbed by urbanization that they can no longer be classified with the Alderwood series. The Arents, Alderwood material is described by SCS (1972) as a moderately well-drained soil with features similar to those of the Alderwood series.

Bellingham Series

The Bellingham series includes poorly drained soils that formed in alluvium and are mostly in depressions on the upland glacial till plain. Bellingham silt loam (Bh) is a part of the Bellingham series.





Erosion/Potential Landslide Area
Potential Liquefaction Zone
City Limits
Construction Extent
Restriping Extent
Stream

N
0 500 1,000 1,500 2,000 Feet

Source: King County (1997) GIS Data (Erosion), King County (2003) GIS Data (Potential Landslides), King County (2005) GIS Data (Stream), King County (2007) GIS Data (Street and Waterbody), and WDNR (2002) GIS Data (Liquefaction Zone). Horizontal datum for all layers is NAD83(91); vertical datum for layers is NAVD88.

Exhibit 6. **Geologic Hazards Area**

Medina to SR 202: Eastside Transit and HOV Project

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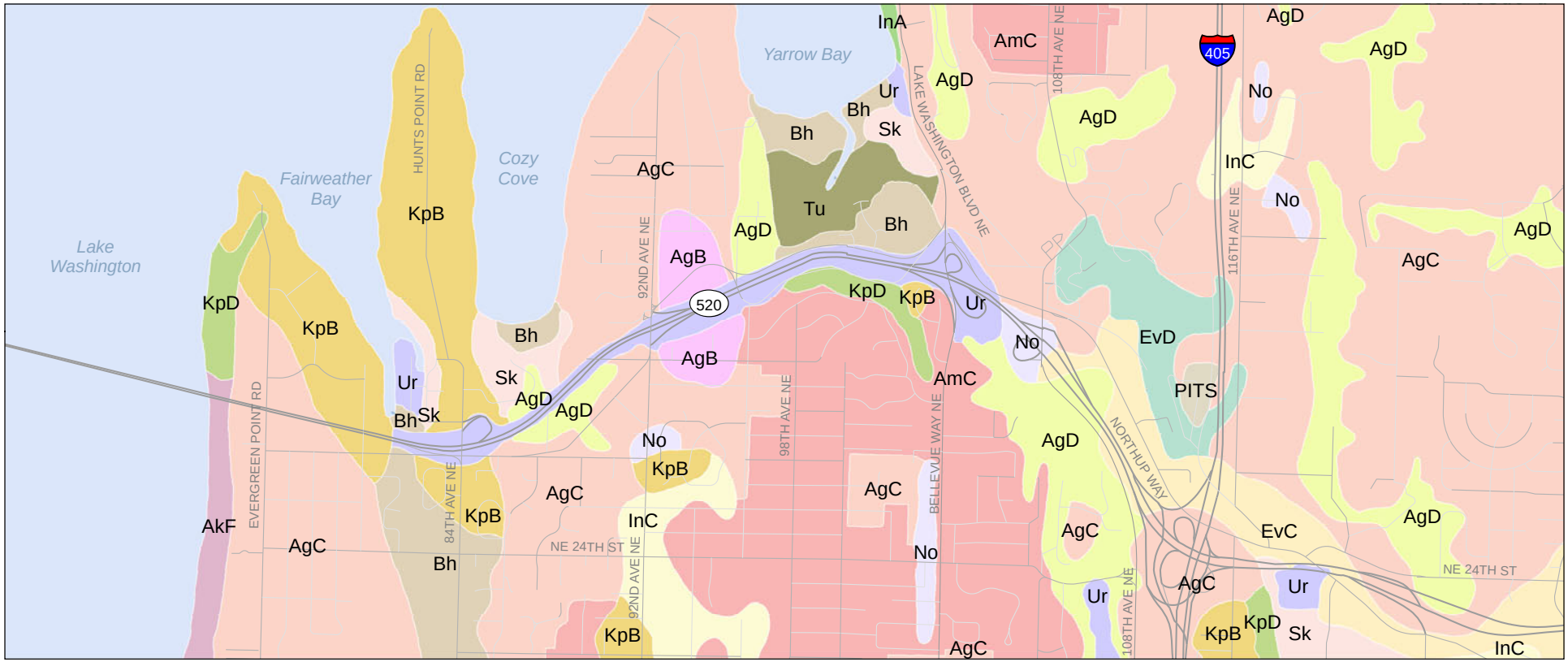


Alderwood Series
(forms in recessional till)

- AgB — Alderwood gravelly, sandy loam, 0-6%
- AgC — Alderwood gravelly, sandy loam, 6-15% slopes
- AgD — Alderwood gravelly, sandy loam, 15-30% slopes
- AkF — Alderwood and Kitsap soils, 25-70% slopes
- AmC — Arents, Alderwood (modified till) material, 6-15% slopes

Indianola Series
(forms in recessional outwash)

- InA — Indianola loamy sand (not included in report because not within project alignment)
- InC — Indianola loamy fine sand (not included in report because not within project alignment)

Bellingham Series
(forms in alluvium)

- Bh — Bellingham silt loam

Everett Series
(forms in glacial till)

- EvC — Everett gravelly sandy loam, 5-15% slopes
- EvD — Everett gravelly sandy loam, 15-30% slopes

Seattle Series
(forms in organic soils)

- Sk — Seattle muck

Tukwila Series
(forms in organic soils)

- Tu — Tukwila muck

Kitsap Series
(forms in glacial lacustrine deposits)

- KpB — Kitsap silt loam, 2-8% slopes
- KpD — Kitsap silt loam, 15-30% slopes

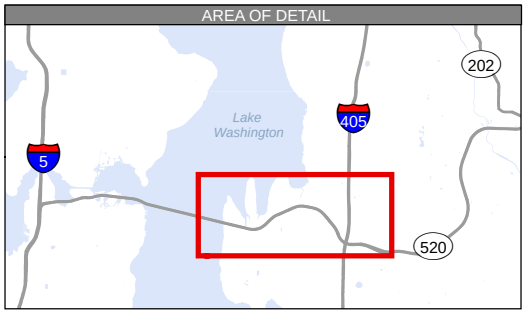
Norma Series
(forms in alluvium)

- No — Norma sandy loam

Urban land
(forms in artificial fill)

- Ur — Modified by urban development
- PITS — Borrow pits

Source: SSURGO (2006) GIS Data (Soils), King County (2005) GIS Data (Street), King County (2007) GIS Data (Waterbody). Horizontal datum for all layers is NAD83(91); vertical datum for layers is NAVD88.



N

0 500 1,000 2,000 Feet

Exhibit 7. **Surficial Soils Map**

Medina to SR 202: Eastside Transit and HOV Project

Exhibit 8. Summary of Surficial Soil Properties as Classified by the Soil Conservation Service (1972)

Soil Unit	Associated Geologic Unit	Slopes (%)	Permeability in Surface and Substratum	Erosion Hazard[a]	Suitability as Source of Road Fill[a]	Soil Features Adversely Affecting Freeway Location	Limitations for Foundations for Low Structures	Limitations for Shallow Excavations	Other Notes
Alderwood Series									
AgB	Glacial till	0-6	Very slow in substratum	Slight	Fair	0 to 6% slopes; water moves on top of substratum in winter	Moderate; seasonal high water table	Severe; seasonal high water table	2 to 3.5 feet depth to seasonal high water table
AgC	Glacial till	6-15	Moderately rapid in surface soils and very slow in substratum	Moderate	Fair	6 to 15% slopes; water moves on top of substratum in winter	Moderate; seasonal high water table	Severe; seasonal high water table	2 to 3.5 feet depth to seasonal high water table
AgD	Glacial till	15-30	Very slow in substratum	Severe	Fair	15 to 30% slopes; water moves on top of substratum in winter	Severe steep slopes	Severe steep slopes	Slippage potential is moderate.
AkF	Glacial till	25-70	Varies	Severe to very severe	Fair	25 to 70% slopes; water moves on top of substratum in winter	Severe steep slopes	Severe steep slopes	Slippage potential is severe.
Arents, Alderwood Material									
AmC	Modified glacial till	6-15	Very slow in substratum	Moderate to severe	Fair	0 to 15% slopes; seasonal high water table	Moderate; seasonal high water table	Severe; seasonal high water table	

Exhibit 8. Summary of Surficial Soil Properties as Classified by the Soil Conservation Service (1972)

Soil Unit	Associated Geologic Unit	Slopes (%)	Permeability in Surface and Substratum	Erosion Hazard[a]	Suitability as Source of Road Fill[a]	Soil Features Adversely Affecting Freeway Location	Limitations for Foundations for Low Structures	Limitations for Shallow Excavations	Other Notes
Bellingham Series									
Bh	Alluvium	<2	Slow in both	Slight	Poor	High frost-action potential; moderate shrink-swell potential	Severe; seasonal high water table; water moves on top of substratum in winter	Severe; seasonal high water table	0 to 1 foot depth to seasonal high water table
Everett Series									
EvC	Glacial recessional outwash	5-15	Rapid in both	Slight to moderate	Good	0 to 30% slopes	Slight and moderate: moderate if slope >8%	Severe: very gravelly	No seasonal high water table within a depth of 5 feet
Kitsap Series									
KpB	Lacustrine deposits	2-8	Moderate in surface soils and very slow in substratum	Slight to moderate	Poor	2 to 8% slopes; water moves on top of substratum in winter; moderate shrink-swell potential; high frost-action potential	Moderate; seasonal high water table, low shear strength	Moderate; seasonal high water table, moderately well drained	1.5 to 3 feet depth to seasonal high water table

Exhibit 8. Summary of Surficial Soil Properties as Classified by the Soil Conservation Service (1972)

Soil Unit	Associated Geologic Unit	Slopes (%)	Permeability in Surface and Substratum	Erosion Hazard[a]	Suitability as Source of Road Fill[a]	Soil Features Adversely Affecting Freeway Location	Limitations for Foundations for Low Structures	Limitations for Shallow Excavations	Other Notes
KpD	Lacustrine deposits	15-30	Moderate in surface soils and very slow in substratum	Severe	Poor	15 to 30% slopes, up to 70% slopes; water moves on top of substratum in winter; moderate shrink-swell potential; slippage potential on steeper slopes; high frost-action potential	Severe; seasonal high water table, low shear strength	Severe; seasonal high water table; steep slopes	1.5 to 3 feet depth to seasonal high water table. Slippage potential is severe.
Norma Series									
No	Alluvium	<2	Moderately rapid in both	Slight	Poor	Flood hazard in places; seasonal high water table	Severe; seasonal high water table, flood hazard, low shear strength	Severe; seasonal high water table, flood hazard	0 to 1 foot depth to seasonal high water table. Stream overflow is a severe hazard in places.
Seattle Series									
Sk	Organic soils (peat)	<1	Moderate in both	None	Not suitable	Organic soil; seasonal high water table	Severe; seasonal high water table, organic soil	Severe; seasonal high water table, organic soil	Seasonal high water table at or near surface
Tukwila Series									
Tu	Organic soils (peat)	<1	Moderate in both	None	Not suitable	Organic soil; seasonal high water table	Severe; organic soil	Severe; seasonal high water table, organic soil	Seasonal high water table at or near the surface

Exhibit 8. Summary of Surficial Soil Properties as Classified by the Soil Conservation Service (1972)

Soil Unit	Associated Geologic Unit	Slopes (%)	Permeability in Surface and Substratum	Erosion Hazard[a]	Suitability as Source of Road Fill[a]	Soil Features Adversely Affecting Freeway Location	Limitations for Foundations for Low Structures	Limitations for Shallow Excavations	Other Notes
Urban Land									
Ur	Fill	Varies	Varies	Slight to moderate	Too variable to rate	Too variable to rate	Variable	Variable	Soils and properties are variable

[a] The ratings (slight, fair, moderate, etc.) are as classified by the Soil Conservation Service (1972) based on specific criteria determined by SCS.

Everett Series

The Everett series consists of somewhat excessively drained soils that formed in very gravelly glacial outwash deposits. These soils formed on terraces and terrace fronts. Everett gravelly sandy loam (EvC) is a part of the Everett series.

Kitsap Series

The Kitsap series is made up of moderately well-drained soils that formed in glacial lake deposits. The soils are on terraces and strongly dissected terrace fronts. Kitsap silt loam (KpB and KpD) is a part of the Kitsap series.

Norma Series

The Norma series is made up of poorly drained soils that formed in alluvium in basins on the glaciated uplands and in areas along the stream bottoms. Norma sandy loam (No) is a part of this series.

Seattle Series

The Seattle series is made up of very poorly drained organic soils that formed in material derived from plants. These soils formed in depressions and valleys on the glacial till plain and also in river and stream valleys. Seattle muck (Sk) is part of this series. Seattle muck may contain up to 25 percent wood fragments.

Tukwila Series

The Tukwila series is made up of very poorly drained organic soils that formed from decomposing plants. These soils formed in wet basins of upland depressions and on stream bottoms. Tukwila muck (Tu) is a part of this series.

Urban Land

SCS (1972) classifies Urban land as soils that have been modified by disturbance of the natural layers with additions of fill material several feet thick. Fill materials are used to accommodate large industrial and housing developments.

4. Potential Effects of the Project

What methods were used to evaluate the project's potential effects?

The project's potential effects on geology and soils were evaluated semi-quantitatively by comparing several measurable quantities between the Build Alternative and the No Build Alternative. These potential geology- and soil-related effects, both operational and construction, are listed in Exhibit 9. In the sections that follow, the potential effects are described and the reasons for using these bases of comparison are discussed.

Exhibit 9. Semi-Quantitative Measures of Potential Effects

Potential Effect	Comparative Measure	Comments about Measure
Operational Effects		
Changes in topography	Cut-and-fill volume	Visual effect might be a more noticeable measure. See the Visual Quality and Aesthetics Technical Memorandum (WSDOT 2009b).
Loss of topsoil	Estimated volume of topsoil removed	This is not a complete measure of the potential effect because quality topsoil would probably be reused on the project or sold for use in the region.
Slope stabilizing effects	Length of walls (including lid support walls) and bridge abutments perpendicular to slope contours in landslide hazard areas	The length of a wall or structure is more appropriate than area or other quantitative measures because the slope would need to be stabilized regardless of cut height or volume of soil removed. This is a relatively crude measure because the existing factor of safety against slope movement is unknown.
Stabilizing effects in liquefaction hazard areas	Embankment footprint in liquefaction hazard areas	Length of roadway through mapped liquefaction hazards could also be an appropriate measure. Presumes that the existing condition might liquefy and all liquefied soil might move or otherwise contribute to temporary reduction in water quality.
Groundwater flow or elevation changes	Lane miles of excavation and bridge abutments perpendicular to roadway in moderate to highly permeable geologic units	See the Water Resources Discipline Report (WSDOT 2009a) for additional discussion.
Imported sand and gravel resources for embankment fills	Net embankment, net sand, and gravel for all uses (structures, pavements, and embankments)	Reuse of onsite material potentially reduces some of the need for imported material.
Construction Effects		
Earth-related construction disturbance	Total cut-and-fill volume	These effects potentially include dust, noise, and minor erosion, and represent temporary effects of construction.
Erosion of exposed soil where vegetation has been removed	Main line distance through mapped erosion hazard areas	The product of potentially exposed soil area and duration of exposure might be a better indicator, but it is very difficult to calculate at this stage of design development.

Exhibit 9. Semi-Quantitative Measures of Potential Effects

Potential Effect	Comparative Measure	Comments about Measure
Potential for slope movement during construction	Length of walls in cut and bridge abutments perpendicular to slope contours in landslide hazard areas	Cut volume or wall area within hazard areas might be a slightly better indicator, but it is not possible to calculate at this stage of design development.
Space and disturbance associated with demolition of existing structures	Volume of concrete removed	These effects potentially include dust, noise, and vibration, and represent temporary effects of construction.
Short-term, localized lowering of groundwater table	Length of retaining walls in cuts and bridge abutments in glacial outwash and recent alluvial soils	See the Water Resources Discipline Report (WSDOT 2009a) for additional discussion.

How would operation of the project affect geology and soils?

Build Alternative

Topographic Changes

The Build Alternative would change the topography of the corridor. These changes would be mainly due to the construction of project features. For example, the topography would be raised with the construction of lids and embankments, lowered with the construction of detention ponds and cut walls, and flattened at the existing roadway to accommodate an eastbound HOV lane. The planned locations of these project features are identified in the Description of Alternatives and Construction Techniques Discipline Report (WSDOT 2009d). Earthwork quantities (cut-and-fill volumes) provide a relative measure of the amount of topographic change; total cut-and-fill volumes for the Build Alternative and No Build Alternative are provided in Exhibit 10.

Loss of Topsoil

Although not considered a critical effect, the project team calculated the loss of topsoil as shown in Exhibit 10. Much of the topsoil that would be removed as part of the Build Alternative was disturbed during previous construction. Topsoil would be stripped from the construction limits and might be reused for landscaping on the project. In areas where landscaped lids would be constructed, a net increase in the amount of topsoil could occur.

Exhibit 10. **Potential Operational Effects of Project on Soils and Geology**

Effect	Quantity
Changes in topography, as measured by total volume of soil moved (excavation + embankment):	
No Build	None
Build	317,000 cubic yards (yd^3)
Loss of topsoil[a]:	
No Build	None
Build	22,500 yd^3
Potential stabilizing effects in slope stability hazard areas, as measured by length of cut walls and bridge abutments perpendicular to slope contours in hazard areas (upslope edge only):	
No Build	None
Build	2,300 linear feet (lf)
Potential stabilizing effects in liquefaction hazard areas, as measured by embankment area within mapped hazard areas:	
No Build	None
Build	95,000 square feet (sf)
Net sand and gravel required for embankment[b]:	
No Build	None
Build	3,000 yd^3
Net sand and gravel resources for all uses[c]:	
No Build	None
Build	0.37 Million tons
Potential for permanently lowering groundwater outside right of way, as measured by length of retaining walls in cuts and bridge abutments in glacial outwash and recent alluvial soils:	
No Build	None
Build	6,000 lf

[a] A net value. Topsoil replaced on top of lids subtracts from the net loss.

[b] Assumes 25 percent of all excavation can be reused as embankment and 75 percent of existing concrete structures can be demolished and reused as onsite embankment. A negative value denotes a net export.

[c] Total volume of sand and gravel needed for structures and pavements + total embankment – (25 percent of excavation) + all concrete demolition.

Slope Stabilization

Slopes are located along both sides of the existing project alignment. The roadway also passes through areas of historical landsliding and landslide-prone soils. To accommodate the road widening, extensive use of retaining walls would be required.

During design, there would be an extensive program of subsurface exploration and testing combined with rigorous slope stability analysis. The roadway and supporting structures would be designed to withstand potentially destabilizing forces using WSDOT standard factors of safety (FS) for both global static (minimum FS = 1.5) and seismic (minimum FS = 1.0 to 1.1 or limited earthquake-induced deformations) conditions. In addition to global stability, the project team would factor in pressures resulting from earth, traffic, and seismic loads in the structural design of the retaining structures. It is likely that there are existing slopes that have a factor of safety against sliding less than 1.5 for static loading and possibly less than 1.0 under seismic accelerations. The area was regraded during the initial SR 520 construction and has not been subjected to the design earthquake. Based on the recordings of nearby measuring stations, firm ground at the study area probably experienced horizontal accelerations between 0.05 and 0.11 g during the 2001 Nisqually earthquake with no visible damage (PNSN 2004, USGS 2003). Constructing retaining walls or lids would likely improve the long-term stability of the most potentially unstable slopes.

To obtain the desired slope stability, cylinder pile, tie-back, soil nail, tangent pile, or secant pile walls, and possibly horizontal drains, would be required for all but the shortest walls that retained cuts into the landslide-prone materials. Although these additional structures would increase the stability, they could also preclude the placement of future underground utilities or structures in the immediate vicinity.

The tie-back anchors could be up to 100 feet long, and horizontal drains could be in excess of 100 feet long. The anchors and drains would be located 10 feet or more below the ground surface. In addition to limiting future construction within this zone, easements might be required to allow anchor and drain installation.

Minor amounts of widening into the slope in the area of previous landsliding, between approximately 98th and 102nd Avenues NE, are proposed. After completion of a subsurface exploration and analysis, the walls would be designed to resist the soil loads with an acceptable FS. Additional stabilizing measures, such as subsurface drainage or buttressing, might also be implemented. For example, stormwater would be redirected away from this area farther east along the alignment to another existing outfall location that is more stable. See the Water Resources Discipline Report (WSDOT 2009a) for more detail. Although the existing slope is stable under static conditions, an engineered design might improve the seismic stability.

Potential Stabilizing Effects in Liquefaction Hazards Areas

The subsurface exploration that would be undertaken during design would also define the limits of liquefiable soil. If liquefiable areas were present beneath the land-based roadway, they would be stabilized by one of several methods of soil improvement, thereby increasing the reliability of the SR 520 roadway, and possibly that of existing adjacent areas.

Typical methods of improvement include use of the following:

- Stone columns composed of 3-foot-diameter columns of compacted gravel placed every 10 feet
- Grouted columns of cement and soil that range in diameter from 2 to 3 feet
- Excavation and replacement with non-liquefiable soil

The zone of improvement would extend vertically from the ground surface to the limits of liquefiable soil, which could be 30 feet or more. Horizontally, the improved zone could extend several hundred feet along the length of the alignment, depending on the extent of liquefaction and the amount of loading.

The existing structures were designed without consideration of liquefaction, so the Build Alternative, and potentially some adjacent properties, would have decreased susceptibility to damage from liquefaction compared with the No Build Alternative.

Imported Sand and Gravel Resources

Construction of new roadways would require the use of earth embankments, as well as sand and gravel for pavement and structures. Though sand and gravel pits are required to go through an environmental review process, the need for construction materials adds to an overall depletion of geologic resources.

Most of the native materials that would be excavated along the project alignment contain too much silt and clay to be free-draining. This means that when exposed to rain, runoff, or humid conditions, these soils would be very difficult to re-compact without special processing. Therefore, it is likely that a high percentage of the excavated soil (75 percent was assumed for the results shown in Exhibit 10) would be hauled offsite rather than reused in embankments. The deficit in embankment material would likely be met by importing material that was primarily sand and gravel. Another alternative would be to mix onsite materials with additives such as fly-ash or cement to facilitate reuse. This approach could be costly and would require additional working space and time.

If processing areas were available and work scheduling permitted, the pavements and structures that needed to be demolished could be pulverized onsite and recycled for use on the project. If space was lacking, or if the materials were not needed immediately after demolition, the concrete from the existing structures could be recycled offsite.

The row labeled “Net sand and gravel resources for all uses” in Exhibit 10 includes the estimated aggregate required for structural concrete, paving, and embankments.

Groundwater Flow or Elevation Changes

The project has the potential to change groundwater flow or elevation in three ways:

1. Roadway cuts could lower the groundwater surface at the wall or ditch line.
2. Structures could interrupt lateral groundwater flow.

3. Ground alteration (by settlement under loading or modification to mitigate liquefaction) might change the soil permeability, altering the groundwater flow rate or level.

The potential for substantial groundwater level or flow changes is judged to be low for each of the potential causes, as discussed below.

If the roadway cuts were below the existing groundwater, the groundwater surface would be pulled downward in the immediate vicinity of the cut. This would be true even if the cut were retained by a wall or bridge abutment because drainage material is typically placed behind these structures. The horizontal distance over which this drop in the groundwater surface, or drawdown, would occur is relatively small—on the order of less than 30 feet—for the relatively slow-permeability glacial till and glacial lacustrine materials that are prevalent along the alignment. Many of the alluvial sediments also appear to have a low permeability, limiting the width of lowered groundwater. The only areas where the groundwater would have the potential to be lowered outside of the right of way are where the cuts would be below the existing water table within the moderately to highly permeable glacial outwash soils. Even in these areas, the depth of cuts would probably limit the maximum drop in groundwater beyond the right of way limits to less than 10 feet. Exhibit 10 shows the comparative length of cuts through outwash soils, conservatively assuming that the existing groundwater table was above the proposed cuts in all these locations.

Construction of bridge columns below the water table would replace permeable soil with nearly impermeable concrete. Piles and other deep foundations represent barriers to groundwater flow, but these barriers would be so small, relative to the total area available for flow, that their effect would be negligible.

Compression of soils due to embankment loading could decrease the pore space through which groundwater could flow. However, the effect on overall hydrogeology would be negligible, especially considering the already low permeability of the compressible soils, although there could be localized effects.

There are several methods of ground improvement for liquefaction mitigation; some of them increase the soil permeability, while others decrease the permeability slightly, but the change is relatively small. The potential effect of all these slight changes would be further reduced, because the areas of potentially compressible and liquefiable soils are located at low elevations relative to Lake Washington, where the groundwater flow gradient is also very low.

See the Water Resources Discipline Report (WSDOT 2009a) for more information about potential groundwater effects.

Long-Term Settlement

Boring logs from previous explorations suggest that portions of the Bellevue Way interchange are underlain by soft clay and peat deposits, which could settle under long-term loading and possibly deform excessively during an earthquake. Where settlement or seismic deformation could affect the performance of structures, the structures would be founded on piles or shafts. Embankments would

also be designed to minimize settlement. Despite these commonly employed engineering solutions, constructing in these areas involves a slightly elevated risk compared with the No Build Alternative.

No Build Alternative

The existing bridges crossing over SR 520 between Evergreen Point Road and Bellevue Way have been analyzed by WSDOT and determined to require no seismic retrofit (WSDOT 2001). The existing pedestrian bridge at 80th Avenue NE was retrofitted in 2001. Retrofitting, or the decision that no retrofit would be needed, does not imply that the existing bridges would perform as well as structures designed to the current AASHTO code; it simply means that the obvious seismic structural flaws (i.e., poor joint restraints, inadequate bearing seat length, and lack of stops to prevent spans from pulling away from their supports) common to bridges designed without consideration of seismic loading are not a significant issue.

How would construction of the project affect geology and soils?

Construction effects include those listed in Exhibit 11—the potential for dust, noise, and erosion associated with moving soil; risk of slope movement; space requirements and disturbances associated with demolition of existing structures; disturbances associated with bridge construction; and the possibility of localized changes in groundwater during dewatering. Each of these potential effects is discussed in the paragraphs that follow. Effects from construction of ground improvement are not shown in Exhibit 11 but are discussed below. Exhibit 11 lists the relative severity of the potential temporary effects based on semi-quantitative measures listed in Exhibit 9.

Moving Soil

Moving soil from one location to another requires operation of heavy machinery such as bulldozers, excavators, compactors, and trucks, and would require cut-and-fill of approximately 317,000 cubic yards. There is a certain amount of unavoidable noise associated with operating this equipment, which is discussed in the Noise Technical Memorandum (WSDOT 2009c). Construction within the local jurisdictions would have a relatively low chance of producing much dust or erosion (2,100 linear feet of main line distance mapped through erosion hazard areas) because current erosion and sedimentation control standards require extensive protective measures, as discussed below.

Exhibit 11. Potential Temporary Effects of Project on Soils and Geology During Construction

Effect	Quantity
Relative amount of construction disturbance (e.g., noise, dust, minor erosion) as measured by total cut-and-fill volume:	
No Build	None
Build	317,000 yd^3
Potential for erosion, as measured by the main line distance through mapped erosion hazard areas:	
No Build	None
Build	2,100 lf
Potential for slope movement during construction, as measured by length of cut walls and bridge abutments perpendicular to slope contours in hazard areas (upslope edge only):	
No Build	None
Build	2,300 lf
Potential for disturbance associated with demolition of existing structures, as measured by volume of concrete removed:	
No Build	None
Build	10,000 yd^3
Potential short-term, localized lowering of groundwater, as measured by length of retaining walls in cuts and bridge abutments in glacial outwash and recent alluvial soils:	
No Build	None
Build	6,000 lf

Potential for Initiating Slope Movement

Construction would pass through two areas with landslide-prone soils. The project team would conduct thorough subsurface exploration and analyses to produce design and construction specifications that maintained slope stability. Because two of these areas experienced movement and subsequent additional study during the original construction, the project team has the advantage of a historical full-size laboratory to help understand the soil behavior and avoid past mistakes.

Although a thorough exploration would reduce the risk of slope instability during construction, there would be a small risk of initiating slope movement when constructing in areas of steep slopes through the strain-softening clays and silts. WSDOT could require strict construction specifications to anticipate the potential effects of excavation in these soils. For example, WSDOT could require a geotechnical engineer to evaluate and approve the construction excavation plans. An estimated 2,300 linear feet of cut walls and bridge abutments would be perpendicular to slope contours in hazard areas.

Requirements for Demolition

The existing bridge structures and most walls would be demolished. The exact sequence and methods would be determined during design. The final design would likely be performance-based, with specified limitations on timing, roadway closures, working hours, noise levels, vibrations, and containment of debris and cuttings, as discussed in Description of Alternatives and Construction Techniques Discipline Report (WSDOT 2009d).

WSDOT could provide requirements or incentives to recycle. Crushed concrete would make excellent embankment fill and it is often suitable for structural backfill. Typically, before reinforced concrete could be recycled, it would first need to be broken into smaller chunks so the reinforcing steel could be separated from the concrete, removed from the study area, and possibly sold for scrap. This is commonly accomplished by an excavator-mounted percussion hammer working through the larger chunks of loosened material.

The smaller concrete chunks would be loaded into a crusher. If there was space in the immediate work area and the material was to be reused nearby, a portable crusher could be used.

If there was limited space, or if construction staging requirements would not allow reuse of the recycled material nearby, the concrete chunks would be hauled to a larger processing and stockpile site, either inside or outside the project limits.

Concrete and other types of pavement could also be ground and recycled for reuse either as new pavement or as fill materials. Pavements are typically ground in place and picked up off the roadway bed by a single piece of machinery that loads via a conveyor belt into a truck. In total, the project could generate an estimated 10,000 cubic yards of demolished concrete.

Potential for Changing Groundwater Table

Localized lowering of the groundwater table associated with construction, referred to as dewatering, would likely be required at many excavations for bridge and wall footings, vaults, and piping. For bridge foundations, dewatering would not be anticipated at any of the drilled shaft foundation locations; drilling fluid and possibly water would need to be pumped from the inside of temporary casings, but this would not affect the adjacent groundwater.

From the western limits of the project to approximately 98th Avenue NE, most of the excavations below the existing groundwater table would be through materials of relatively low permeability (primarily till, Qvt, and glacial lacustrine deposits or transitional beds). Because of the low permeability and the low anticipated pumping rates associated with these materials, the dewatering would probably have a negligible effect on the groundwater table outside of the project right of way and no effect on regional aquifers.

Much of the area between approximately 98th Avenue NE and NE 124th Street is underlain by either recessional or advance outwash deposits (Qvr and Qva) (see Exhibit 4). These materials tend to have moderate to high permeability. Excavations for bridge and wall foundations that penetrated the groundwater in these materials would likely require rigorous dewatering methods. These dewatering methods could involve use of shallow well-points or deep wells. If subsequent explorations and

analyses determined that these dewatering methods were required, additional engineering studies would be required to evaluate potential effects of temporary groundwater withdrawal, such as localized settlement. An estimated 6,000 linear feet of retaining walls and bridge abutments are mapped in glacial outwash and recent alluvial soils. Design and analysis have not progressed far enough to define the depth of the groundwater table at every excavation nor the need for alternative dewatering methods.

Ground Improvement

Ground improvement is being considered for the project in certain areas to strengthen the soil, thus minimizing or avoiding seismically-induced liquefaction and settlement. Common ground improvement methods are stone columns, jet grouting, and soil mixing.

All three potential ground improvement methods involve drilling vertical holes, typically spaced from 5 to 10 feet on-center, and adding rock or cement to the ground to improve strength. In the case of stone columns, the stone is vibrated in place and can make the surrounding soil denser. Jet grouting and soil mixing inject or pump cement grout that is mixed with the in-place soil for high strength columns. In all cases, there are considerable amounts of spoils that are overly wet and must be hauled offsite for disposal. With jet grouting and deep soil mixing, the spoils include cement and are therefore high in pH until the cement is completely hydrated. Consistent with local regulations, high pH spoils would be stored onsite until the pH was low enough to allow the spoils to be exported.

No Build Alternative

There would be no construction effects associated with the No Build Alternative.

5. Mitigation

How will adverse effects from construction be avoided or minimized?

Recycling of Existing Pavements and Structures

Recycling of existing pavements and structures could minimize the amount of imported sand and gravel for this project. Scheduling and space requirements might limit the use of recycled materials, but there are many other projects in the Puget Sound area that need aggregates.

Erosion and Sedimentation Control

Where soil is disturbed or exposed in erosion and landslide hazard areas, erosion and sedimentation could be reduced by limiting the work season to the drier months of the year (typically June 1 through October 31). There will be limits on suspended solids contained in the runoff leaving the site. WSDOT could require an approved Temporary Erosion and Sedimentation Control (TESC) plan and the use of best management practices (BMPs), as dictated by guidelines issued by the Washington State Department of Ecology, WSDOT, and the designers.

BMPs may include the following:

- Stabilized pads of quarry spalls, and possibly truck washes, at construction vehicle exits from the site
- Regular sweeping and washing of adjacent roadways
- Silt fences downslope of all exposed soil
- Quarry-spall-lined temporary ditches, with periodic straw bales or other sediment catchment dams
- Temporary covers over soil stockpiles and exposed soil
- Temporary erosion control blankets and mulching to minimize erosion prior to vegetation establishment
- Temporary sedimentation ponds for removal of settleable solids prior to discharge
- Limits on the area exposed to runoff

Compliance with TESC requirements will be monitored by WSDOT and local agency personnel. Monetary fines and withholding of progress payments could be used as enforcement tools.

There could also be requirements for no visible dust. Frequent watering of the site could be used to meet this requirement.

Slope Stability

As noted previously, slopes and earth-retaining structures will be designed to provide a standard factor of safety (FS) against movement during construction and during long-term static and long-term seismic conditions. In areas where the Lawton clay (Qtb) is present such as along NE Points Drive, the major causes of slope instability and potential methods of mitigation that could be implemented, if needed, are as follows:

1. Commonly in retaining wall design, the soil is allowed to deform so that the interparticle friction takes a large portion of the lateral load. This amount of deformation in Lawton clay (or similar materials) can result in the material losing a substantial amount of strength. The local design practice is to design walls for this residual soil strength.
2. Removing upper soil layers can allow surface water infiltration to saturate pre-existing vertical cracks in the top of the Lawton clay; the water reduces the strength of the Lawton clay. Most of the project footprint widening is for construction of walls, rather than cutting, so there will be small risk of changing how water infiltrates. The addition of subsurface drainage in the form of relatively shallow seepage-collection trenches and deep, horizontal drains will be considered to lower the possibility of additional infiltration into the Lawton clay.
3. The Lawton clay is frequently interbedded with sandy zones, which tend to convey groundwater at a much higher rate and are frequently under much higher groundwater pressure heads than the adjacent clay and silt layers. Sometimes when these sandier layers are exposed, internal erosion

(called piping), due to the groundwater pressure, can cause sloughing and destabilization of the face. Drainage blankets, horizontal drains, and confinement of the face could control this type of sloughing.

4. Cyclic weathering deterioration can also reduce the strength of the Lawton clay. As noted above, little change is anticipated to the topography outside of the roadway prism made by retaining walls; however, in some locations, surcharge weights may be considered over exposed Lawton clay to limit this strength loss.

In all cases, whether the widened roadway is cut into or filled on top of these slide-prone deposits, the overall (global) stability of the entire hillside will be considered in design. The boundaries of this stability analysis are natural features that tend to halt the natural progression of slope movement (as illustrated in Exhibit 12), so the design will consider both the right of way and the surrounding property.

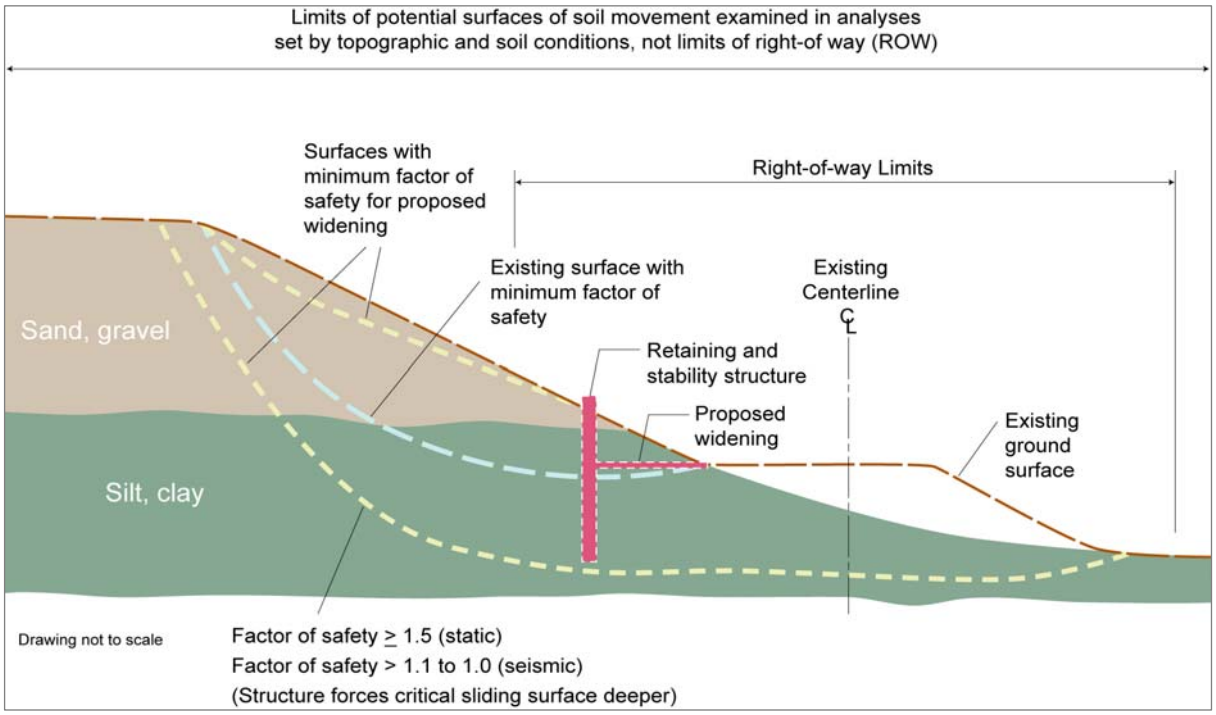


Exhibit 12. Limits of Slope Stability

Demolition Mitigation

Much of the potential disturbance to humans (noise and perceived vibrations) caused by demolition could be mitigated by limiting the work to daytime hours. WSDOT could require no visible dust and limiting vibrations at nearby buildings and other facilities.

Disposal of Dewatering Flow

Water collected from the majority of the construction dewatering systems will be from open sumps and will likely be relatively turbid, both initially and intermittently, as equipment works in proximity to the sumps. Dewatering flows will be routed through temporary sedimentation ponds or Baker tanks to remove settleable solids. Advance treatment to remove very fine suspended clay and silt particles may be considered.

Ground Improvement Mitigation

The need for ground improvement has not yet been identified, so mitigation may not be needed. If ground improvement is proposed, its effects could be mitigated as follows:

- Strictly enforcing the requirements of a spoils containment plan that relies not only on operator care, but has contingency provisions such as physical barriers to contain spoils within the work area.
- Regulating and monitoring runoff and spoils export.

6. Conclusion

The project would have minimal effects on geology and soils. The greatest effect would be the use of soil and rock material for the Build Alternative. If potential hazards (i.e., slope instability, liquefaction, and landslides) were properly mitigated, the project would improve the geology and soils within the project footprint.

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