SUPPLEMENTAL DRAFT ENVIRONMENTAL IMPACT STATEMENT
and SECTION 4(F) EVALUATION
SR 520 BRIDGE REPLACEMENT AND HOV PROGRAM

DECEMBER 2009

# SR 520: I-5 to Medina Bridge Replacement and HOV Project

# Geology and Soils Discipline Report

Washington State
Department of Transportation

U.S. Department of Transportation
Federal Highway
Administration

# SR 520: I-5 to Medina Bridge Replacement and HOV Project Supplemental Draft EIS

# Geology and Soils Discipline Report

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December 2009

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# Acronyms and Abbreviations

| | |
|---|---|
| BMP | best management practice |
| CTC | Concrete Technology Corporation |
| Ecology | Washington State Department of Ecology |
| EIS | environmental impact statement |
| FHWA | Federal Highway Administration |
| GIS | geographic information system |
| HCT | high-capacity transit |
| HOV | high-occupancy vehicle |
| I-5 | Interstate 5 |
| NAVD88 | North American Vertical Datum of 1988 |
| NRCS | Natural Resources Conservation Service |
| SDEIS | Supplemental Draft Environmental Impact Statement |
| SEM | sequential excavation method |
| SPUI | single-point urban interchange |
| SPT | standard penetration test |
| SR | State Route |
| USGS | U.S. Geological Survey |
| WDNR | Washington State Department of Natural Resources |
| WSDOT | Washington State Department of Transportation |

# Introduction

## Why are geology and soils considered in an environmental impact statement?

The geology and soils within a proposed project site are considered in an environmental impact statement (EIS) for three main reasons:

1. They influence the type and size of foundation required for structures, which, in turn, affect the project cost, footprint, noise level, and amount of ground disturbance created by construction equipment, and they determine the volume of excavated soils.
2. The composition, location relative to the water table, and density of soils that would be excavated determine the suitability of the soils for reuse as fill on the project. The suitability of soil for reuse affects truck traffic beyond the project boundaries and space available for placement of waste or excess fill.
3. The presence of geologic hazards (such as active seismicity and the potential for liquefaction) increases the mitigation costs for the project. Unmitigated hazards may pose risks to the users of the facility, adjacent landowners, and the aquatic environment.

## What are the key points of this discipline report?

The proposed project would have the following geology and soil effects:

- Option K could use up to 320,000 cubic yards of soil and rock materials, which would contribute to aggregate (that is, crushed stone) depletion from aggregate quarries in the Puget Sound region and western Washington.
- An abundance of compressible and low-strength soils in a region with high seismicity greatly increases the cost of a project. The greatest effect of the soils and geology on the I-5 to Medina: Bridge Replacement and High-Occupancy Vehicle (HOV) Project would be that deep foundations would be required to support many of the proposed structures in deep, weak, and compressible soils. The cost and time required to construct the structures is further increased by

the high seismicity of the region and the difficulties of constructing over water or weak soils.

- The 6-Lane Alternative would be designed to withstand an earthquake with a 1,000-year recurrence interval (that is, a 7 percent probability of exceedance over the 75-year design life of the structure). With the No Build Alternative, the existing Portage Bay Bridge and western approach structures and ramps for the Evergreen Point Bridge could fail during a seismic event with a 210-year recurrence interval (WSDOT 2002). The already limited remaining design life of these existing bridges could be shortened by smaller events.
- The landslide hazards, soft soils of Portage Bay and Lake Washington, and active seismicity of the region could add substantially to the cost and complexity for constructing the 6-Lane Alternative. Increased complexity often translates to increased construction duration and more or larger construction machinery. While the geologic conditions could be challenging, modern engineering and construction techniques have been developed to deal with these challenges. For example, landslide failure during construction is a noted risk, and there are engineering practices to mitigate that risk. The risk of triggering landslides or inducing unwanted settlement during construction and over the design life of the facility would be relatively small.
- The affected environment for geology and soils and the construction and operational effects on geology and soils for the Phased Implementation scenario would be the same as for the full-build 6-Lane Alternative.

# What is the I-5 to Medina: Bridge Replacement and HOV Project?

The Interstate 5 (I-5) to Medina: Bridge Replacement and High-Occupancy Vehicle (HOV) Project is part of the State Route (SR) 520 Bridge Replacement and HOV Program (SR 520 Program) (detailed in the text box below) and encompasses parts of three main geographic areas—Seattle, Lake Washington, and the Eastside. The project area includes the following:

- Seattle communities: Portage Bay/Roanoke, North Capitol Hill, Montlake, University District, Laurelhurst, and Madison Park

- Eastside communities: Medina, Hunts Point, Clyde Hill, and Yarrow Point
- The Lake Washington ecosystem and associated wetlands
- Usual and accustomed fishing areas of tribal nations that have historically used the area's aquatic resources and have treaty rights

The SR 520 Bridge Replacement and HOV Project Draft Environmental Impact Statement (EIS), published in August 2006, evaluated a 4-Lane Alternative, a 6-Lane Alternative, and a No Build Alternative. Since the Draft EIS was published, circumstances surrounding the SR 520 corridor have changed in several ways. These changes have resulted in decisions to forward advance planning for potential catastrophic failure of the Evergreen Point Bridge, respond to increased demand for transit service on the Eastside, and evaluate a new set of community-based designs for the Montlake area in Seattle.

To respond to these changes, the Washington State Department of Transportation (WSDOT) and the Federal Highway Administration (FHWA) initiated new projects to be evaluated in separate environmental documents. Improvements to the western portion of the SR 520 corridor—known as the I-5 to Medina: Bridge Replacement and HOV Project (the *I-5 to Medina project*)—are being evaluated in a Supplemental Draft EIS (SDEIS); this discipline report is a part of that SDEIS. Project limits for this project extend from I-5 in Seattle to 92nd Avenue NE in Yarrow Point, where it transitions into the Medina to

What is the SR 520 Program?

The SR 520 Bridge Replacement and HOV Program will enhance safety by replacing the aging floating bridge and keep the region moving with vital transit and roadway improvements throughout the corridor. The 12.8-mile program area begins at I-5 in Seattle and extends to SR 202 in Redmond.

In 2006, WSDOT prepared a Draft EIS—published formally as the SR 520 Bridge Replacement and HOV Project—that addressed corridor construction from the I-5 interchange in Seattle to just west of I-405 in Bellevue. Growing transit demand on the Eastside and structure vulnerability in Seattle and Lake Washington, however, led WSDOT to identify new projects, each with a separate purpose and need, that would provide benefit even if the others were not built. These four independent projects were identified after the Draft EIS was published in 2006, and these now fall under the umbrella of the entire SR 520 Bridge Replacement and HOV Program:

- I-5 to Medina: Bridge Replacement and HOV Project replaces the SR 520 roadway, floating bridge approaches, and floating bridge between I-5 and the eastern shore of Lake Washington. This project spans 5.2 miles of the SR 520 corridor.
- Medina to SR 202: Eastside Transit and HOV Project completes and improves the transit and HOV system from Evergreen Point Road to the SR 202 interchange in Redmond. This project spans 8.6 miles of the SR 520 corridor.
- Pontoon Construction Project involves constructing the pontoons needed to restore the Evergreen Point Bridge in the event of a catastrophic failure and storing those pontoons until needed.
- Lake Washington Congestion Management Project, through a grant from the U.S. Department of Transportation, improves traffic using tolling, technology and traffic management, transit, and telecommuting.

SR 202: Eastside Transit and HOV Project (the *Medina to SR 202 project*). Exhibit 1 shows the project vicinity.

Exhibit 1. Project Vicinity Map

# What are the project alternatives?

As noted above, the Draft EIS evaluated a 4-Lane Alternative, a 6-Lane Alternative (including three design options in Seattle), and a No Build Alternative. In 2006, following Draft EIS publication, Governor Gregoire identified the 6-Lane Alternative as the state's preference for the SR 520 corridor, but urged that the affected communities in Seattle develop a common vision for the western portion of the corridor. Accordingly, a mediation group convened at the direction of the state legislature to evaluate the corridor alignment for SR 520 through Seattle. The mediation group identified three 6-lane design options for SR 520 between I-5 and the floating span of the Evergreen Point Bridge; these options were documented in a Project Impact Plan (WSDOT 2008). The SDEIS evaluates the following:

- No Build Alternative
- 6-Lane Alternative
  - Option A
  - Option K
  - Option L

These alternatives and options are summarized below. The 4-Lane Alternative and the Draft EIS 6-lane design options have been eliminated from further consideration. More information on how the project has evolved since the Draft EIS was published in 2006, as well as more detailed information on the design options, is provided in the Description of Alternatives Discipline Report (WSDOT 2009b).

## What is the No Build Alternative?

Under the No Build Alternative, SR 520 would continue to operate between I-5 and Medina as it does today: as a 4-lane highway with nonstandard shoulders and without a bicycle/pedestrian path. (Exhibit 2 depicts a cross section of the No Build Alternative.) No new facilities would

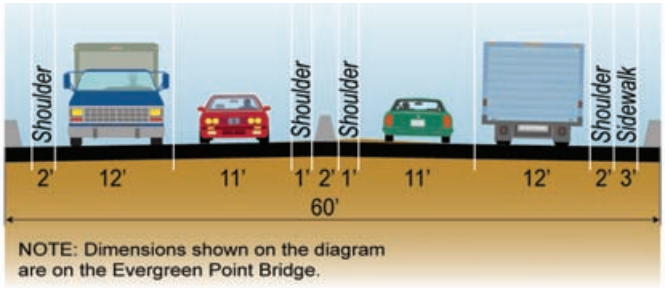



Exhibit 2. No Build Alternative Cross Section

be added to SR 520 between I-5 and Medina, and none would be removed, including the unused R.H. Thomson Expressway ramps near the Washington Park Arboretum. WSDOT would continue to manage traffic using its existing transportation demand management and intelligent transportation system strategies.

The No Build Alternative assumes that the Portage Bay and Evergreen Point bridges would remain standing and functional through 2030 and that no catastrophic events, such as earthquakes or extreme storms, would cause major damage to the bridges. The No Build Alternative also assumes completion of the Medina to SR 202 project as well as other regionally planned and programmed transportation projects. The No Build Alternative provides a baseline against which project analysts can measure and compare the effects of each 6-Lane Alternative build option.

## What is the 6-Lane Alternative?

The 6-Lane Alternative would complete the regional HOV connection (3+ HOV occupancy) across SR 520. This alternative would include six lanes (two 11-foot-wide outer general-purpose lanes and one 12-foot-wide inside HOV lane in each direction), with 4-foot-wide inside and 10-foot-wide outside shoulders (Exhibit 3). The proposed width of the roadway would be approximately 18 feet narrower than the one described in the Draft EIS, reflecting public comment from local communities and the City of Seattle.

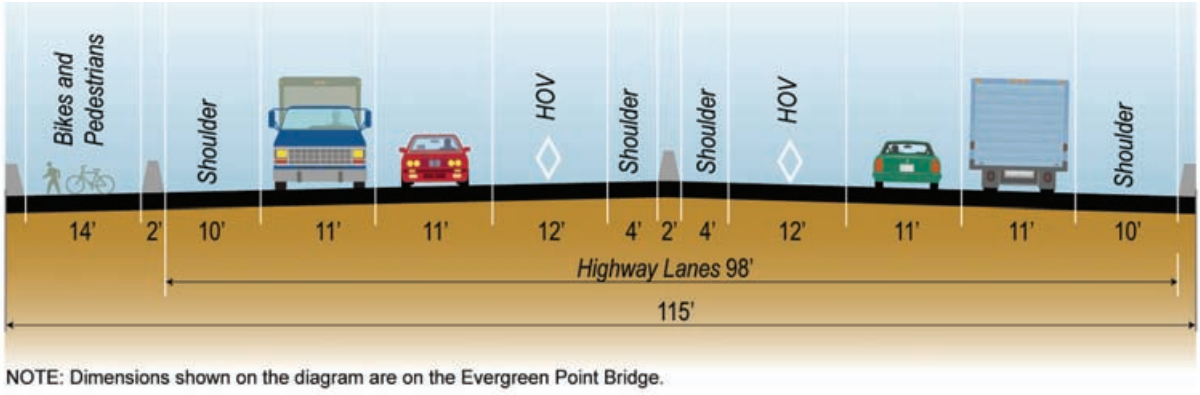



Exhibit 3. 6-Lane Alternative Cross Section

SR 520 would be rebuilt from I-5 to Evergreen Point Road in Medina and restriped and reconfigured from Evergreen Point Road to 92nd Avenue NE in Yarrow Point. A 14-foot-wide bicycle/pedestrian path

would be built along the north side of SR 520 through the Montlake area and across the Evergreen Point Bridge, connecting to the regional path on the Eastside. A bridge maintenance facility and dock would be built underneath the east approach to the Evergreen Point Bridge.

The sections below describe the 6-Lane Alternative and design options in each of the three geographical areas the project would encompass.

## Seattle

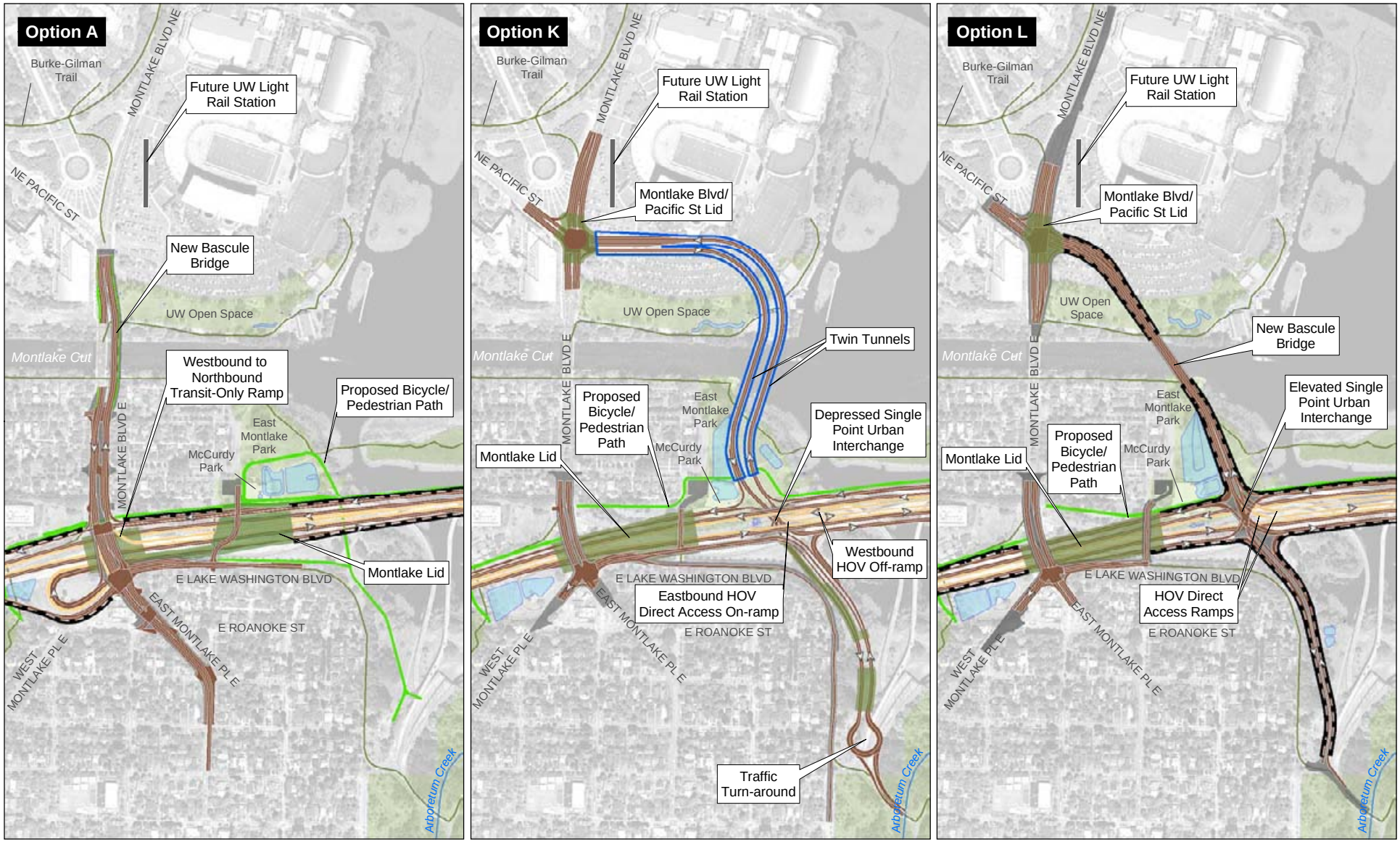
### Elements Common to the 6-Lane Alternative Options

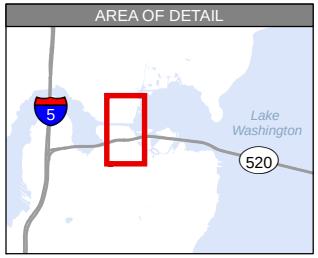
SR 520 would connect to I-5 in a configuration similar to the way it connects today. Improvements to the I-5/SR 520 interchange would include a new reversible HOV ramp connecting the new SR 520 HOV lanes to existing I-5 reversible express lanes. WSDOT would replace the Portage Bay Bridge and the Evergreen Point Bridge (including the west approach and floating span), as well as the existing local street bridges across SR 520. New stormwater facilities would be constructed for the project to provide stormwater retention and treatment. The project would include landscaped lids across SR 520 at I-5, 10th Avenue East and Delmar Drive East, and in the Montlake area to help reconnect the communities on either side of the roadway. The project would also remove the Montlake freeway transit station.

The most substantial differences among the three options are the interchange configurations in the Montlake and University of Washington areas. Exhibit 4 depicts these key differences in interchange configurations, and the following text describes elements unique to each option.

### Option A

Option A would replace the Portage Bay Bridge with a new bridge that would include six lanes (four general-purpose lanes, two HOV lanes) plus a westbound auxiliary lane. WSDOT would replace the existing interchange at Montlake Boulevard East with a new, similarly configured interchange that would include a transit-only off-ramp from westbound SR 520 to northbound Montlake Boulevard. The Lake Washington Boulevard ramps and the median freeway transit stop near Montlake Boulevard East would be removed, and a new bascule bridge (i.e., drawbridge) would be added to Montlake Boulevard NE, parallel to the existing Montlake Bridge. SR 520 would maintain a low profile through the Washington Park Arboretum and flatten out east of Foster Island, before rising to the west transition span of the Evergreen Point




- Potential Sound Wall
- Existing Regional Bicycle/Pedestrian Path
- Tunnel
- Lid or Landscape Feature
- Proposed Bicycle/Pedestrian Path
- Stormwater Facility
- General Purpose Lane
- HOV, Direct Access, and/or Transit-Only Lane
- Future UW Light Rail Station
- Park

N

0 250 500 1,000 Feet

Source: King County (2006) Aerial Photo, King County (2005) GIS Data (Streams), City of Seattle (1994) GIS Data (Bike/Ped Trail), Seattle Bicycle Map (2008) GIS Data (Bike/Ped Trail) CH2M HILL (2008) GIS Data (Park). Horizontal datum for all layers is NAD83(91); vertical datum for layers is NAVD88.

Exhibit 4. **Options A, K, and L: Montlake and University of Washington Areas**

I-5 to Medina: Bridge Replacement and HOV Project

Bridge. Citizen recommendations made during the mediation process defined this option to include sound walls and/or quieter pavement, subject to neighborhood approval and WSDOT's reasonability and feasibility determinations.

Suboptions for Option A would include adding an eastbound SR 520 on-ramp and a westbound SR 520 off-ramp to Lake Washington Boulevard, creating an intersection similar to the one that exists today but relocated northwest of its current location. The suboption would also include adding an eastbound direct access on-ramp for transit and HOV from Montlake Boulevard East, and providing a constant slope profile from 24th Avenue East to the west transition span.

Is it a highrise or a transition span?

A transition span is a bridge span that connects the fixed approach bridge to the floating portion of the bridge. The Evergreen Point Bridge has two transition spans, one at the west end of the floating bridge transitioning traffic on and off of the west approach, and one on the east end of the floating bridge transitioning traffic on and off of the east approach. These spans are often referred to as the "west highrise" (shown) and the "east highrise" during the daily traffic report, and the west highrise even has a traffic camera mounted on it.

Today's highrises have two characteristics—large overhead steel trusses and navigation channels below the spans where boat traffic can pass underneath the Evergreen Point Bridge. The new design for the floating bridge would not include overhead steel trusses on the transition spans, which would change the visual character of the highrise. For the SDEIS, highrise and transition span are often used interchangeably to refer to the area along the bridge where the east and west approach bridges transition to the floating bridge.

### Option K

Option K would also replace the Portage Bay Bridge, but the new bridge would include four general-purpose lanes and two HOV lanes with no westbound auxiliary lane. In the Montlake area, Option K would remove the existing Montlake Boulevard East interchange and the Lake Washington Boulevard ramps and replace their functions with a depressed, single-point urban interchange (SPUI) at the Montlake shoreline. Two HOV direct-access ramps would serve the new interchange, and a tunnel under the Montlake Cut would move traffic from the new interchange north to the intersection of Montlake Boulevard NE and NE Pacific Street. SR 520 would maintain a low profile through Union Bay, make landfall at Foster Island, and remain flat before rising to the west transition span of the Evergreen Point Bridge. A land bridge would be constructed over SR 520 at Foster Island. Citizen recommendations made during the mediation process defined this option to include only quieter pavement for noise abatement, rather than the sound walls that were included in the 2006 Draft EIS. However, because quieter pavement has not been demonstrated to meet all FHWA and WSDOT avoidance and

minimization requirements in tests performed in Washington State, it cannot be considered as noise mitigation under WSDOT and FHWA criteria. As a result, sound walls could be included in Option K. The decision to build sound walls depends on neighborhood interest, the findings of the Noise Discipline Report (WSDOT 2009b), and WSDOT's reasonability and feasibility determinations.

A suboption for Option K would include constructing an eastbound off-ramp to Montlake Boulevard East configured for right turns only.

### Option L

Under Option L, the Montlake Boulevard East interchange and the Lake Washington Boulevard ramps would be replaced with a new, elevated SPUI at the Montlake shoreline. A bascule bridge (drawbridge) would span the east end of the Montlake Cut, from the new interchange to the intersection of Montlake Boulevard NE and NE Pacific Street. This option would also include a ramp connection to Lake Washington Boulevard and two HOV direct-access ramps providing service to and from the new interchange. SR 520 would maintain a low, constant slope profile from 24th Avenue East to just west of the west transition span of the floating bridge. Noise mitigation identified for this option would include sound walls as defined in the Draft EIS.

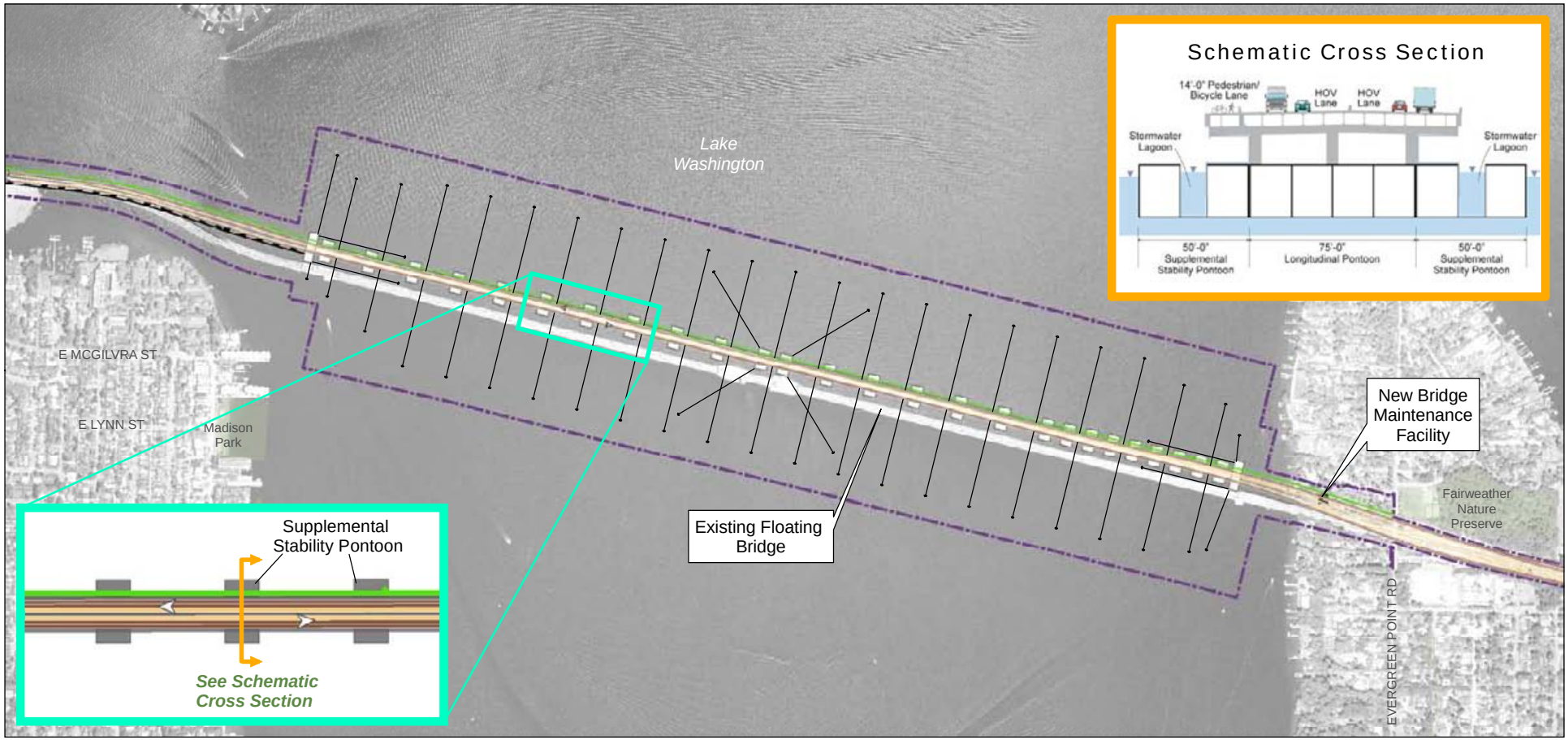
Suboptions for Option L would include adding a left-turn movement from Lake Washington Boulevard for direct access to SR 520 and adding capacity on northbound Montlake Boulevard NE to NE 45th Street.

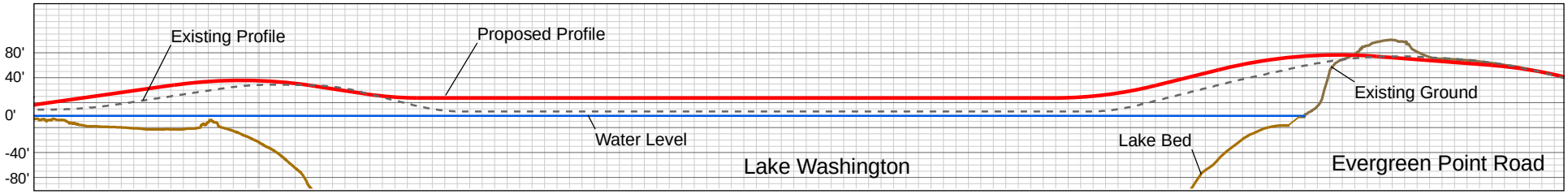
## Lake Washington

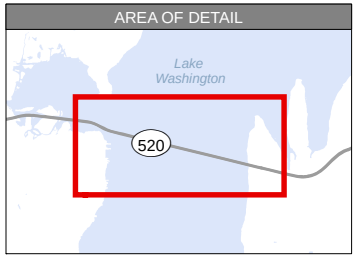
### Floating Bridge

The floating span would be located approximately 190 feet north of the existing bridge at the west end and 160 feet north at the east end (Exhibit 5). Rows of three 10-foot-tall concrete columns would support the roadway above the pontoons, and the new spans would be approximately 22 feet higher than the existing bridge. A 14-foot-wide bicycle/pedestrian path would be located on the north side of the bridge.

The design for the new 6-lane floating bridge includes 21 longitudinal pontoons, two cross pontoons, and 54 supplemental stability pontoons. A single row of 75-foot-wide by 360-foot-long longitudinal pontoons would support the new floating bridge. One 240-foot-long by




- Anchor and Cable
- Pontoons
- Limits of Construction
- Proposed Bicycle/Pedestrian Path
- General Purpose Lanes
- HOV, Direct Access, and/or Transit-Only Lane
- Park

N

0 250 500 1,000 Feet

Source: King County (2006) Aerial Photo, CH2M HILL (2008) GIS Data (Park). Horizontal datum for all layers is NAD83(91); vertical datum for layers is NAVD88.

Exhibit 5. **6-Lane Alternative at the Evergreen Point Bridge (Common to All Options)**

I-5 to Medina: Bridge Replacement and HOV Project

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75-foot-wide cross-pontoon at each end of the bridge would be set perpendicularly to the longitudinal pontoons. The longitudinal pontoons would be bolstered by the smaller supplemental stability pontoons on each side for stability and buoyancy. The longitudinal pontoons would not be sized to carry future high-capacity transit (HCT), but would be equipped with connections for additional supplemental stability pontoons to support HCT in the future. As with the existing floating bridge, the floating pontoons for the new bridge would be anchored to the lake bottom to hold the bridge in place.

Near the east approach bridge, the roadway would be widened to accommodate transit ramps to the Evergreen Point Road transit stop. Exhibit 5 shows the alignment of the floating bridge, the west and east approaches, and the connection to the east shore of Lake Washington.

### Bridge Maintenance Facility

Routine access, maintenance, monitoring, inspections, and emergency response for the floating bridge would be based out of a new bridge maintenance facility located underneath SR 520 between the east shore of Lake Washington and Evergreen Point Road in Medina. This bridge maintenance facility would include a working dock, an approximately 7,200-square-foot maintenance building, and a parking area.

## Eastside Transition Area

The I-5 to Medina project and the Medina to SR 202 project overlap between Evergreen Point Road and 92nd Avenue NE in Yarrow Point. Work planned as part of the I-5 to Medina project between Evergreen Point Road and 92nd Avenue NE would include moving the Evergreen Point Road transit stop west to the lid (part of the Medina to SR 202 project) at Evergreen Point Road, adding new lane and ramp striping from the Evergreen Point lid to 92nd Avenue NE, and moving and realigning traffic barriers as a result of the new lane striping. The restriping would transition the I-5 to Medina project improvements into the improvements to be completed as part of the Medina to SR 202 project.

## Pontoon Construction and Transport

If the floating portion of the Evergreen Point Bridge does not fail before its planned replacement, WSDOT would use the pontoons constructed and stored as part of the Pontoon Construction Project in the I-5 to Medina project. Up to 11 longitudinal pontoons built and stored in Grays Harbor as part of the Pontoon Construction Project would be

towed from a moorage location in Grays Harbor to Puget Sound for outfitting (see the sidebar to the right for an explanation of pontoon *outfitting*). All outfitted pontoons, as well as the remaining pontoons stored at Grays Harbor would be towed to Lake Washington for incorporation into the floating bridge. Towing would occur as weather permits during the months of March through October. Exhibit 6 illustrates the general towing route from Grays Harbor to Lake Washington, and identifies potential outfitting locations.

**What is Outfitting?**

Pontoon outfitting is a process by which the columns and elevated roadway of the bridge are built directly on the surface of the pontoon.

Exhibit 6. Possible Towing Route and Pontoon Outfitting Locations

The I-5 to Medina project would build an additional 44 pontoons needed to complete the new 6-lane floating bridge. The additional pontoons could be constructed at the existing Concrete Technology Corporation facility in Tacoma, and/or at a new facility in Grays Harbor that is also being developed as part of the Pontoon Construction Project. The new supplemental stability pontoons would be towed from the construction location to Lake Washington for incorporation into the floating bridge. For additional information about pontoon construction, please see the Construction Techniques Discipline Report (WSDOT 2009c).

## Would the project be built all at once or in phases?

Revenue sources for the I-5 to Medina project would include allocations from various state and federal sources and from future tolling, but there remains a gap between the estimated cost of the project and the revenue available to build it. Because of these funding limitations, there is a strong possibility that WSDOT would construct the project in phases over time.

If the project is phased, WSDOT would first complete one or more of those project components that are vulnerable to earthquakes and windstorms; these components include the following:

- The floating portion of the Evergreen Point Bridge, which is vulnerable to windstorms. This is the highest priority in the corridor because of the frequency of severe storms and the high associated risk of catastrophic failure.
- The Portage Bay Bridge, which is vulnerable to earthquakes. This is a slightly lower priority than the floating bridge because the frequency of severe earthquakes is significantly less than that of severe storms.
- The west approach of the Evergreen Point Bridge, which is vulnerable to earthquakes (see comments above for the Portage Bay Bridge).

Exhibit 7 shows the vulnerable portions of the project that would be prioritized, as well as the portions that would be constructed later. The vulnerable structures are collectively referred to in the SDEIS as the Phased Implementation scenario. It is important to note that, while the new bridge(s) might be the only part of the project in place for a certain period of time, WSDOT's intent is to build a complete project that meets all aspects of the purpose and need.

The Phased Implementation scenario would provide new structures to replace the vulnerable bridges in the SR 520 corridor, as well as limited transitional sections to connect the new bridges to existing facilities. This scenario would include stormwater facilities, noise mitigation, and the regional bicycle/pedestrian path, but lids would be deferred until a subsequent phase. WSDOT would develop and implement all mitigation needed to satisfy regulatory requirements.

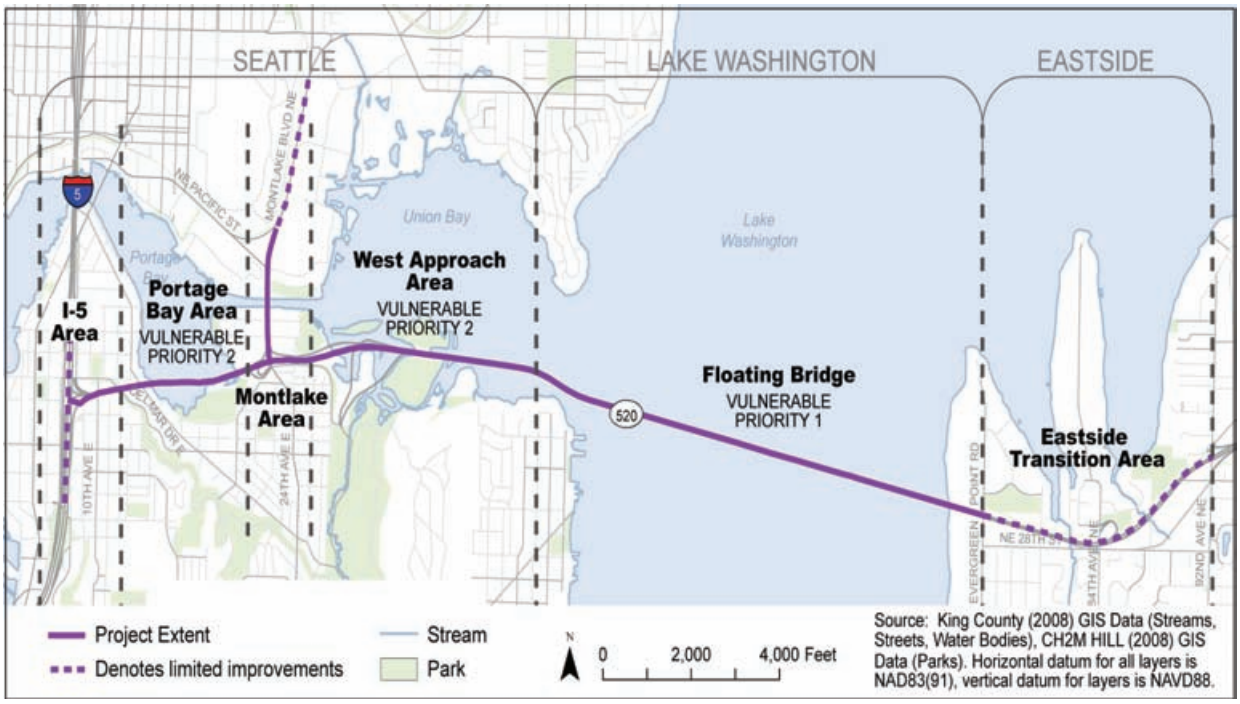



Exhibit 7. Geographic Areas along SR 520 and Project Phasing

To address the potential for phased project implementation, the SDEIS evaluates the Phased Implementation scenario separately as a subset of the "full build" analysis. The evaluation focuses on how the effects of phased implementation would differ from those of full build and on how constructing the project in phases might have different effects from constructing it all at one time. Impact calculations for the physical effects of phased implementation (for example, acres of wetlands and parks affected) are presented alongside those for full build where applicable.

# Affected Environment

This discipline report discusses the Affected Environment for the I-5 to Medina: Bridge Replacement and HOV Project. The geology and soils study area is shown as the area of construction on Exhibit 4, and the project limits are shown on Exhibit 5. Geologic conditions in the Puget Sound area are also described to provide a regional context.

Additional pontoons and anchors might be constructed at the existing Concrete Technology Corporation (CTC) facility in Tacoma and at a new casting basin facility located in Grays Harbor. The CTC facility is an operating industrial site located in a large industrial park. WSDOT's proposed use of this site to build pontoons is consistent with its current industrial purpose and location and, therefore, would not produce substantial, unavoidable effects on the geology and soils that would warrant analysis or mitigation measures. Maintenance activities during pontoon construction at the Grays Harbor casting basin facility sites may result in effects on geology and soils. These effects are discussed under the *Potential Effects of the Project* section below.

## How was the information collected?

The geology and soil analysts defined the topography, surficial soils, regional and site geology, soil characteristics, and potential geologic hazards within the study area based on published maps and reports, existing geotechnical information, and a field reconnaissance.

Analysts collected maps and reports published by governmental agencies from the Internet and from the CH2M HILL library in Bellevue, Washington. Key Web sites that were used to collect published maps and reports included the following:

- Surficial soils maps from the Natural Resources Conservation Service (NRCS 2009)
- Geologic maps from GeoMapNW (Pacific Northwest Center for Geologic Mapping Studies, University of Washington 2009)
- Geologic maps from the U.S. Geological Survey (USGS) on-line National Geologic Map Database (USGS 2009a)
- Publications from the USGS on-line publications database (USGS 2009b)

- Groundwater information from the Washington State Department of Ecology (Ecology 2009a)
- Seismic hazard maps from the USGS Earthquake Hazards Program Web site (USGS 2009c)
- Fault and fold maps from the USGS fault and fold map database (USGS 2009d)
- Maps from the City of Seattle, Washington Web site (City of Seattle 2009)
- Topographic maps from the King County, Washington, King County Geographic Information System Center Web site (King County 2009)
- City of Seattle Department of Planning and Development Environmentally Critical Areas Update Web site (City of Seattle Department of Planning and Development 2007)

Geotechnical reports published by consultants and governmental agencies were collected from the GeoMapNW archives (Pacific Northwest Center for Geologic Mapping Studies, University of Washington), City of Seattle Public Utilities Department geotechnical archives, the geotechnical archives at WSDOT in Tumwater, Washington, and from the WSDOT project office. The geotechnical information collected from these sources is listed in Attachment 1. Additional existing geotechnical information was collected from the Ecology Well Logs Web site (Ecology 2009b), which provides a database of driller's well reports.

The geology and soil analysts reviewed the following key reports when preparing this SDEIS:

- *SR 520 Bridge Replacement and HOV Project, Westside Conceptual Structures Recommendations Technical Memorandum* (HDR Inc. et al. 2009a)
- *SR 520 Westside Construction Techniques Technical Memorandum* (HDR Inc. et al et al. 2009b)
- *Draft Preliminary 10-Percent Design Geotechnical Report* (Shannon and Wilson 2007)

# What are the existing geology and soil characteristics of the study area?

The geology and soil analysts collected and reviewed information from the sources listed in the previous section and visited the project site to develop a description of geological conditions within the study area. The general geology and soil conditions interpreted from these reviews are described in the following subsections, which include topography, surficial soils, geology, soil characteristics, groundwater conditions, and existing and potential aggregate sources. The locations of possibly contaminated soils and contaminated groundwater are discussed in the Hazardous Materials Discipline Report (WSDOT 2009d).

The **study area** consists of areas in which project-related activities would result in ground disturbance

## Topography

The regional topography consists of a series of north-south trending ridges separated by deep troughs. Streams, lakes, and the waterways of Puget Sound occupy the troughs. Glaciations that moved back and forth across the region thousands of years ago shaped this regional topography. More recently, erosion processes and landform changes made by development of the area have shaped the topography.

The study area transects two north-south trending ridges, two generally flat-lying areas, and the relatively deep trough now filled by Lake Washington. Elevations range between 200 feet (North American Vertical Datum of 1988 [NAVD88]) at the southwestern end of the study area and 5 feet (NAVD88) at the eastern end of the study area, but drop to as low as elevation -200 feet beneath the floating bridge on Lake Washington. As discussed in the subsequent *Geology* subsection, much of the present topography resulted from multiple glaciations and subsequent human modifications.

**Surficial soils:** The soils from 0 to 5 feet below the ground surface, described using different criteria than surficial geology. Soils are described using criteria and terms by the NRCS.

**Surficial geology:** The geologic deposits exposed at the surface. Described using the criteria and terms by the American Society of Testing and Materials. The geology is the parent material to the surficial soils.

**Parent material:** The underlying geological material (generally bedrock or a superficial or drift deposit) in which soil horizons form. Soils typically get a great deal of structure and minerals from their parent material. Parent materials are made up of consolidated or unconsolidated mineral material that has undergone some degree of physical or chemical weathering.

## Surficial Soils

The NRCS has mapped surficial soils in rural and agricultural areas and has not mapped the surficial soils within the City of Seattle city limits. Surficial soils have been mapped by the NRCS for the study area east of Lake Washington to 92nd Avenue NE.

NRCS field personnel map the surficial soils; they dig shallow (typically 1- to 5-foot-deep) test holes and observe material in roadway and streambed cuts. The maps reflect only the material

present in the upper few feet at the time of testing. Although the surficial soils along the project alignment have been modified by development, these soils typically provide an indication of the underlying geologic unit.

Exhibit 8 summarizes typical characteristics and engineering properties of the surficial soils mapped underlying the study area as described by the NRCS. In general, topsoil is removed from beneath roadway embankments and foundations, so the descriptions apply only to "undisturbed" soils adjacent to the roadway.

### Alderwood Series

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

### 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) is a part of the Kitsap series.

### Urban Land

Urban land (Ur) consists of 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.

## Geology

This section describes how the geology in the region formed then summarizes the geologic information within and near the study area that was used to perform the geology review. Existing information was used to determine the geologic units and soil characteristics encountered within the study area.

Exhibit 8. Summary of Surficial Soil Properties as Classified by the NRCS

| 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** | | | | | | | | | |
| 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-foot 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 |
| **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; high frost-action potential | Moderate; seasonal high water table, low shear strength | Moderate; seasonal high water table, moderately well-drained | 1.5- to 3-foot depth to seasonal high water table |
| **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 NRCS (2009) based on specific criteria determined by NRCS.

Source: NRCS (2009).

## Regional Geology

The geomorphology in the Puget Sound region, including the study area, is primarily the result of multiple glaciations that occurred from 2 million to 10,000 years ago. (Geologists refer to this period as the Pleistocene Epoch.) Each advance and retreat of the glaciers during the Pleistocene Epoch modified the land through erosion and deposition of soils.

Geomorphology: The study of the evolution of landforms.

The repeated glaciation left a deposit of soil in the region that includes the study area. These glacial deposits overlie bedrock. Bedrock is located approximately 1,500 feet below the ground surface (Jones 1996).

## Study Area Geology

The geologic units and soil characteristics within the study area were defined using geotechnical information available in public archives and Web sites. The *References and Bibliography* chapter lists pertinent sources that were collected and used as a basis for preparing this discipline report. The available information consisted of the following:

- Published maps, such as topographic maps, geologic maps, and geologic hazard areas maps
- Collected geotechnical reports, including summaries of existing geological conditions, site plans, boring logs, cross sections of subsurface soil profiles, geotechnical recommendations, and soil index testing results
- Driller's well logs that included soil descriptions and groundwater information

In addition to the project-specific subsurface exploration (Shannon and Wilson 2007), three of the most important sources of information were the geotechnical archives at WSDOT, the City of Seattle Public Utilities Department, and the GeoMapNW archives (Pacific Northwest Center for Geologic Mapping Studies, University of Washington 2009). These sources included geotechnical data in over 360 boring logs from borings that were drilled within or adjacent to the study area. The test holes provided information about soil types and consistency to depths of up to 280 feet. Test-hole information included visual descriptions of the soil, results from standard penetration tests, and the engineering classifications of the soil. Exhibit 1-1 in Attachment 1 includes a list of collected geotechnical information. The project geotechnical engineers have

The standard penetration test (SPT) is conducted to obtain a measure of the resistance of the soil and to retrieve a disturbed soil sample. Results of the SPT are presented as the SPT blowcount, "N." Values of N provide a means for evaluating the relative density of granular (coarse-grained) soils and the consistency of cohesive (fine-grained) soils. Low N-values indicate soft or loose deposits, while high N-values are evidence of hard or dense materials.

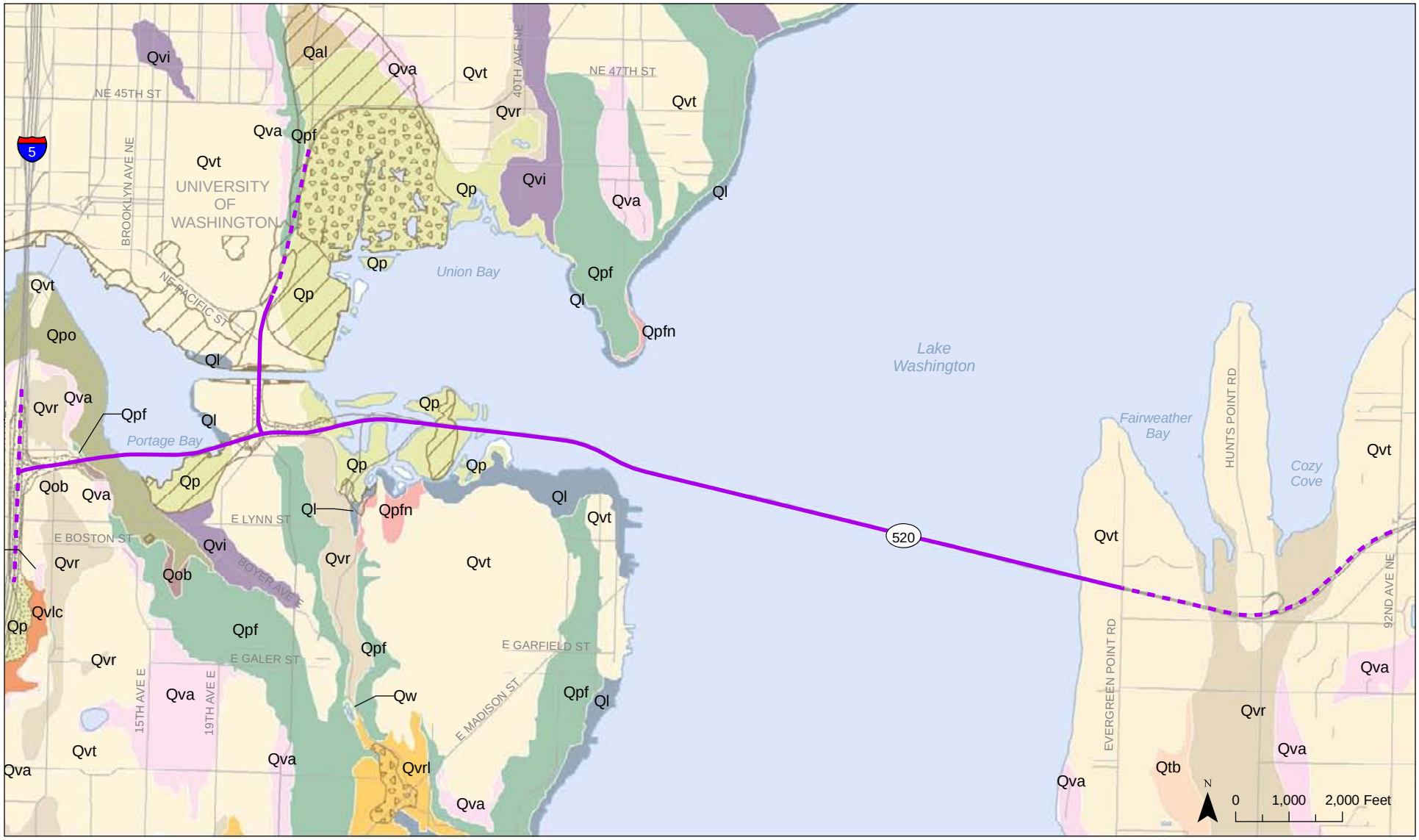
combined the most pertinent data into the *Draft Preliminary 10-Percent Design Geotechnical Report* (Shannon and Wilson 2007) and the *SR 520 Bridge Replacement and HOV Project, Existing Geotechnical Data Report* (Shannon and Wilson 2006). In these reports, Shannon and Wilson have developed preliminary subsurface profiles and conceptual-level geotechnical design recommendations. Additional subsurface information will continue to be collected to support the detailed design of the selected option.

The geology and soil analysts also reviewed over 300 Ecology (2009b) well logs for borings and wells up to 775 feet deep within and adjacent to the study area. The well logs provided general visual soil descriptions, depths where groundwater was encountered, and groundwater well construction details.

### Geologic Units Overview

A description of the geologic units that underlie the study area was developed from geologic maps (Booth et al. 2002 and Troost et al. 2005) and a geotechnical report by Shannon and Wilson (2007). The geologic maps show the geologic units that are encountered at the surface. These maps are generally considered the most recent, authoritative discussion of geology for the Seattle and King County area. More detailed descriptions of the soils underlying the site based on the collected existing geotechnical reports, specifically the Shannon and Wilson (2007) report, are provided in the *Geologic Deposits Characteristics Overview* subsection on the following page. The Shannon and Wilson (2007) report describes geologic units that are not shown on the surficial geologic maps because the report is based on deposits encountered underlying the site during drilling, not just the surficial geology. The deposits were interpreted to be specific geologic units by Shannon and Wilson (2007).

The surficial geology within the study area is mapped by Booth et al. (2002) and Troost et al. (2005) as modified land, artificial fill, peat, lake deposits, recessional outwash deposits, Vashon till, deposits of pre-Fraser glaciation age, Olympia beds, and deposits of pre-Olympia age, as shown on Exhibit 9. Other surficial geologic units are shown on Exhibit 9 but are not mapped within the study area; therefore, those geologic units are not discussed in this report.




| | | | | | |
|---|---|---|---|---|---|
| Qw | Wetland Deposits | Qva | Advance Outwash Deposits | | Regraded Land |
| Qp | Peat | Qtb | Transitional Beds and Older Glacial Deposits | | Artificial Fill |
| Ql | Lake Deposit | Qpf | Deposits of Glaciation Age | | Landfill Debris |
| Qvr | Recessional Outwash Deposits | Qpfn | Nonglacial Deposits Pre-Fraser Glaciation | | Modified Land |
| Qvrl | Vashon Recessional Lacustrine Deposits | Qob | Olympia Bed | | Project Extent |
| Qvi | Ice-Contact Deposits | Qpo | Deposits of Pre-Olympia Age | | Limited Improvements |
| Qvt | Vashon Till | Qvlc | Lawton Clay Member of Vashon Drift | | |

Source: Troost et al (2005) GIS Data (Surficial Geology), Surficial Geology Map: King County (2003) GIS Data (Surfcial Geology) based on Booth et al. (2002) and King County (2005) GIS Data (Streets) King County (2007) GIS Data (Water Bodies). Horizontal datum for all layers is NAD83(91); vertical datum for layers is NAVD88.

Exhibit 9. **Surficial Geology**

I-5 to Medina: Bridge Replacement and HOV Project

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Loose and soft surficial deposits are typically underlain by dense to very dense glacial deposits. The top of the dense to very dense deposits are encountered at varying depths within the study area, ranging from 0 to 125 feet below the existing ground surface or mud line (that is, lake bottom).

The project-specific subsurface profiles prepared by Shannon and Wilson (2007) indicate that the study area is generally underlain by artificial fill, colluvium, landslide deposits, peat, lake deposits, recessional outwash deposits, recessional lacustrine deposits, Vashon till, advance outwash deposits, glaciolacustrine deposits (including transitional beds and Lawton clay), and pre-Vashon units (including nonglacial fluvial deposits, nonglacial lacustrine deposits, glacial outwash, glaciolacustrine deposits, glacial till, and glaciomarine deposits). The profiles are included as Attachment 2 to this document.

Exhibit 10 provides a general description of these geologic units, based on mapping and commentary according to Troost et al. (2005) and Shannon and Wilson (2007). Exhibit 11 summarizes typical engineering properties and hazard susceptibilities of the geologic units that are potentially within the project footprint. Geologic hazards are further discussed below in the *Do the existing geology and soils conditions pose any geologic hazards for the study area?* section.

A more detailed description of the soil characteristics based on available geotechnical reports (specifically the Shannon and Wilson [2007] report), is provided in the *Geologic Deposits Characteristics Overview* below and subsequent subsections.

### Geologic Deposits Characteristics Overview

The characteristics of deposits underlying the study area determine, to a large extent, the methods of design and construction that would be used and the long-term operational issues that must be considered.

In summary, the subsurface conditions encountered during drilling are both cohesive and granular soils that have been glacially overridden. These deposits are at or within several feet of the ground surface beneath topographically elevated areas (Shannon and Wilson 2007). In the intervening swales west of Lake Washington, deposits of predominantly very soft to soft peat and cohesive silt and clay are present. Exhibit 12 describes the general suitability of various deposit types for support of embankments and structures.

Exhibit 10. Summary of Geologic Units Potentially Underlying the Study Area

| Geologic Unit (Map Symbol)[a] | Description | Density/Hardness |
|---|---|---|
| **Quaternary Deposits—Deposited after the last glacial retreat, within the last 13,500 years** | | |
| Modified land (shown as speckled pattern on Exhibit 9) | Fill and/or graded natural deposits that obscure or alter the original deposit. | Varies |
| Artificial fill (Hf) (shown as hatching pattern on Exhibit 9) | Placed by humans, both engineered and nonengineered. Various materials including debris; cobbles and boulders may be common. | Dense to stiff if engineered, but loose to dense or very soft to stiff if nonengineered |
| Colluvium (Hc) | Disturbed heterogeneous mixture of more than one soil type, including organic debris. Hillside slope accumulations. | Loose or soft |
| Landslide deposits (Hls) | Disturbed, heterogeneous mixture of one or more soil types; may contain wood or other organics. Normally located at and adjacent to the toe of slopes. | Loose or soft, with random dense or hard pockets |
| Peat (Qp/Hp) | Predominantly organic matter consisting of plant material and woody debris accumulated in bodies greater than about 3 feet in thickness of mappable extent. Accumulations greatest in floor of recessional-outwash channels and where lowering of Lake Washington has exposed extensive lake-floor deposits. Commonly interbedded with silt and clay. | Very soft to medium stiff or very loose to medium dense |
| Lake deposits (Ql/Hl) | Silt and clay with local sand layers, peat, and other organic sediments deposited in slow-flowing water. Most mapped areas are lake-bottom sediments exposed by the lowering of Lake Washington in 1916. | Very soft to medium stiff or very loose to medium dense |
| **Deposits of the Vashon Glaciation—the most recent glacial advance and retreat** | | |
| Recessional outwash deposits (Qvr/Qvro) | Layered sand and gravel. Cobbles and boulders common. Discontinuous. May include thin layer on glacial till uplands, although deposits less than 3 feet thick are not shown on Exhibit 9. | Loose to dense; deposited as the glacial ice retreated and glacially overridden |
| Recessional lacustrine deposits (Qvrl) | Fine sand, silt, and clay. Glaciolacustrine sediment deposited as glacial ice retreated. | Dense to very dense or soft to hard; not glacially overconsolidated |
| Vashon till (Qvt) | Compact diamict of silt, sand, and subrounded to well-rounded gravel. Cobbles and boulders common. Glacially transported and deposited under ice. Commonly fractured and has intercalated lenses. Upper 3 feet of unit generally weathered and only medium dense to dense. | Very dense; overconsolidated by the glacial ice |

Exhibit 10. Summary of Geologic Units Potentially Underlying the Study Area

| Geologic Unit (Map Symbol)[a] | Description | Density/Hardness |
|---|---|---|
| Advance outwash deposits (Qva) | Well-sorted sand and gravel. May grade upward into till. Silt lenses locally present in upper part and are common in lower part. Grades downward into Qvgl with increasing silt content. | Dense to very dense; deposited in advance of the Vashon glaciation and overridden by ice |
| Glaciolacustrine deposits (Qvgl) includes transitional beds (Qtb) and Lawton clay (Qvlc) | Very fine-grained flour deposit. Silty clay, clayey silt, with interbeds of silt and fine sand. Scattered organic fragments locally. Includes transitional beds and Lawton clay. | Hard or dense to very dense; deposited in advance of the Vashon glaciation and overridden by ice |
| **Pre-Vashon Units—Overconsolidated by glacial ice** | | |
| Deposits of pre-Fraser glaciation age (Qpf) | Interbedded sand, gravel, silt, and diamicts of indeterminate age and origin. | Very dense and hard |
| Nonglacial deposits of pre-Fraser glaciation age (Qpfn) | Sand, gravel, silt, clay, and organic deposits of inferred nonglacial origin based on the presence of peat, paleosols, and tephra layers. | Very dense and hard |
| Nonglacial fluvial deposits (Qpnf) | Clean to silty sand, gravelly sand, sandy gravel. Alluvial deposits of rivers and creeks. | Very dense |
| Nonglacial lacustrine deposits (Qpnl) | Fine sandy silt, silty find sand, clayey silt; scattered to abundant fine organics. Lake deposits in depressions. | Dense to very dense or very stiff to hard |
| Glacial outwash (Qpgo) | Clean to silty sand, gravelly sand, sandy gravel. Glaciofluvial sediment deposited as glacial ice advanced or retreated. | Very dense |
| Glaciolacustrine deposits (Qpgl) | Silty clay, clayey silt, with interbeds of silt and fine sand. | Very stiff to hard or very dense |
| Olympia beds (Qob) | Sand, silt (locally organic-rich), gravel, and peat, discontinuously and thinly interbedded; may contain tephra and/or diatomaceous layers. | Very dense and hard |
| Deposits of pre-Olympia age (Qpo) | Interbedded sand, gravel, silt, and diamicts of indeterminate age and origin. | Very dense and hard |
| Glacial till (Qpgt) | Gravelly silty sand, silty gravelly sand, cobbles, and boulders common. | Very dense |
| Glaciomarine deposits (Qpgm) | Till-like deposit with clayey matrix. Variable mixture of clay, silt, sand, and gravel; scattered shells locally; cobbles and boulders common. | Very dense or hard |

Source: Booth et. al (2002), Troost et al. (2005), and Shannon and Wilson (2007)

[a] Map symbol is either that of Troost (2005) or of Shannon and Wilson (2007). Shannon and Wilson uses different geologic map symbols than Troost.

Exhibit 11. Summary of Typical Engineering Properties and Hazard Susceptibility of Geologic Units

| Geologic Unit | Strength | Permeability | Liquefaction Potential[a] | Erosion Hazard on Steep (>15%) Slope[b] | Landslide Hazard on Steep (>15%) Slope[b] |
|---|---|---|---|---|---|
| **Quaternary Deposits** | | | | | |
| Artificial fill (Hf) | Varies | Varies | Varies | Varies | Varies |
| Colluvium (Hc) | Low | Varies | Varies | High | High |
| Landslide deposits (Hls) | Low | Varies | Varies | High | High |
| Peat (Qp/Hp) | Low | Saturated | N/A[f] | High | High |
| Lake deposits (Ql/Hl) | Low | Low to Medium | Low to Medium | High | High |
| **Deposits of the Vashon Glaciation** | | | | | |
| Recessional outwash deposits (Qvr/Qvro) | Medium | Medium to High | Medium | High | High |
| Recessional lacustrine deposits (Qvrl) | Varies | Varies | Low | Low to Medium | Medium |
| Vashon till (Qvt) | High | Low | Low | Low | Low |
| Advance outwash deposits (Qva) | High[c] | Low to Medium | Low | Low to Medium | Low to Medium |
| Glaciolacustrine deposits (Qvgl) includes transitional beds (Qtb) and Lawton clay (Qvlc) | High[d, e] | Low | Low | Low | Medium[d, e] |
| **Pre-Vashon Units** | | | | | |
| Deposits of pre-Fraser glaciation age (Qpf) | High | Low to High | Low | Low | Low |
| Nonglacial deposits of pre-Fraser glaciation age (Qpfn) | High | Low | Low | Low | Low |
| Nonglacial fluvial deposits(Qpnf) | High | High | Low | Low | Low |
| Nonglacial lacustrine deposits (Qpnl) | High | Low | Low | Low | Low |
| Glacial outwash (Qpgo) | High | High | Low | Low | Low |
| Glaciolacustrine deposits (Qpgl) | High | Low | Low | Low | Low |

Exhibit 11. Summary of Typical Engineering Properties and Hazard Susceptibility of Geologic Units

| Geologic Unit | Strength | Permeability | Liquefaction Potential[a] | Erosion Hazard on Steep (>15%) Slope[b] | Landslide Hazard on Steep (>15%) Slope[b] |
|---|---|---|---|---|---|
| Olympia beds (Qob) | High | Low | Low | Low | Low |
| Deposits of pre-Olympia age (Qpo) | High | Low to High | Low | Low | Low |
| Glacial till (Qpgt) | High | Low | Low | Low | Low |
| Glaciomarine deposits (Qpgm) | High | Low | Low | Low | Low |

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 of Seattle Municipal Code 25.09.020, City of Medina Municipal Code 18.12.330, and professional opinion.

[a]Liquefaction depends in part on density of the material and the groundwater table elevation. These ratings assume groundwater within 5 to 10 feet of the ground surface.

[b]Based on City codes and regulations.

[c]High strength unless cut vertically below the water table, then potentially low to medium strength.

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

[e]Landslide hazards in Lawton clay are high if they have been cut into. If left in place and not disturbed, then the landslide hazard is low.

[f]Peat is not liquefiable but could experience some strength loss following seismic shaking.

Exhibit 12. General Suitability of Deposit Types for Support of Embankments and Structures

| Soil Type | Description |
|---|---|
| Artificial fill | Highly variable depending on material type and placement method. Generally unsuitable for bridge spread footings. |
| Colluvium | Properties range from poor to good. Typically acceptable for support of embankments and structural earth walls but poor for bridge support. |
| Landslide deposits | Require special attention during design. Frequently have zones of low strength and poor drainage. May be subject to differential settlement. |
| Peat | Requires deep foundations for bridge support. Subject to high short-term and long-term settlement under embankments. Weak. |
| Lake deposits | Require deep foundations for bridge support. Can be highly compressible and weak. |
| Colluvium, peat, and lake deposits | Require deep foundations. In saturated conditions, these soils have the potential to lose strength and undergo settlement and/or lateral movement during a design-level earthquake. Excavations often require dewatering and shoring or relatively flat slopes for temporary support. |

Exhibit 12. General Suitability of Deposit Types for Support of Embankments and Structures

| Soil Type | Description |
|---|---|
| Vashon recessional outwash deposits | Generally suitable for spread footing and embankment support. Moderately strong. Excavations may require dewatering if below groundwater. |
| Vashon recessional lacustrine deposits | Require deep foundations. Compressible and weak. |
| Vashon till | Good soils for supporting structures, can be difficult to excavate. Difficult to drive piles in more than a few feet because very compact and frequently contains cobbles and boulders. Stable at relatively steep slopes, makes good embankments and backfill, but highly weather-sensitive due to silt and clay content and cannot be compacted when wet. Glacial till has low permeability. |
| Vashon advance outwash deposits | Glacially compressed with high strength and low compressibility. High allowable weight-bearing, stands firm at relatively steep slopes, makes excellent embankment material. May be difficult to compact if exposed to moisture due to variable silt and clay content, but typically less weather-sensitive than till. Variable permeability. |
| Vashon glaciolacustrine deposits including transitional beds and Lawton clay | Relatively high potential for instability when excavated. Generally hard and relatively strong in its undisturbed state but loses strength upon deformation such that slope instability might occur during temporary excavations. Design of slopes and structures in this material frequently uses residual strength. |
| Deposits deeper than Vashon glaciolacustrine deposits | Glacially compressed with good support characteristics. Typically very strong and incompressible. |
| Soft silt or clay | Poor for structural support. Typically requires consolidation time or other mitigation measure for settlement control. |
| Medium stiff to hard silt or clay | Occasionally suitable for shallow foundations. Typically acceptable for embankment. Weather-sensitive and easily disturbed when exposed. |
| Loose sand | Poor for structural support. Liquefiable if below water. Could require ground improvement near bridge abutments or in embankments behind walls to limit seismic settlement and control lateral deformation. |
| Medium-dense to very dense sand | Can be suitable for spread footing support. Typically suitable for embankment support and behind walls. |

Exhibit 13 summarizes the subsurface deposits and groundwater conditions for specific areas of the project based on information from Shannon and Wilson (2007) and WSDOT et al. (2006). This summary is based on subsurface drilling and geologic interpretation by Shannon and Wilson (2007).

Exhibit 13. Area-specific Subsurface Conditions

| Area | Subsurface Soil Conditions | Groundwater Conditions[a] | Special Notes |
|---|---|---|---|
| I-5 to Portage Bay | Generally underlain by very stiff to hard, silty clay (Qpgl and to a lesser extent Qvgl). Deposits of very stiff to hard, sandy, silty clay to very dense, gravelly, clayey sand (Qpgm) are also present near the ground surface. On the steep hillside above Portage Bay, these deposits are overlain by softer soils consisting of gravelly, sandy, silty clay to silty clay, which represent landslide deposits (Hls) and colluvium (Hc). | 134-foot elevation at Delmar Drive East Undercrossing | The steep hillside between Delmar Drive East and Portage Bay has experienced landsliding in the past. Recent ground cracking was observed as evidence of instability (Shannon and Wilson 2007). Based on previous borings, these landslide deposits and colluvium are typically about 20 feet thick. Near Portage Bay, some of these softer deposits of silty clay likely represent Vashon recessional glacial lacustrine deposits (Qvrl). |
| Portage Bay | Underlain by glacially overridden soils consisting of dense to very dense silt to sandy silt and silty sand (Qpnl). The top of these soils are approximately 90 to 100 feet below the water level of Portage Bay. Under portions of the alignment, the Qpnl is overlain by stiff, silty clay with layers of dense sand (Qvrl). The Qpnl and Qvrl deposits are overlain by 50 to 80 feet of normally consolidated sediments consisting of very soft peat (Hp) and silty clay (Hl). | Generally 19-foot elevation.<br>Artesian conditions in the middle and east end of Portage Bay | |
| Montlake Area | Underlain by very dense or hard soils. The uppermost 30 to 40 feet of soil is very dense, silty, gravelly sand to sand (Qpgt and Qpgo or Qva) with some looser granular soils near Portage Bay and Union Bay. | 38- to 48-foot elevation at Montlake Boulevard East undercrossing | |
| Montlake Area (near Montlake Cut) | South of SR 520, glacially consolidated granular or cohesive soils are likely present within a few feet of the ground surface. | 36- to 39-foot elevation | A buried canal may be located within the proposed widened SR 520. The former canal was up to 30 feet deep near Montlake Boulevard East and may be filled with both engineered and nonengineered fill. |
| Montlake Area (near Union Bay and Pacific Street vicinity) | The area near Husky Stadium is underlain by very dense, gravelly, silty sand to silty, gravelly sand (Qvt). Fill is underlain by very dense, silty, fine sand to fine sandy silt (Qpnf/Qpnl) and hard, silty clay (Qpgl). Fill thickness ranges from 5 feet overlying the till to 20 feet overlying soft peat and clayey silt (Hl) near Union Bay. | 28- to 60-foot elevation | Subsurface conditions are poorly defined (Shannon and Wilson 2007). |

Exhibit 13. Area-specific Subsurface Conditions

| Area | Subsurface Soil Conditions | Groundwater Conditions[a] | Special Notes |
|---|---|---|---|
| West Approach Area (Arboretum vicinity) | West of Foster Island, the alignment is underlain by 25 to 45 feet of very soft peat (Hp), which is typically underlain by 5 to 10 feet of soft to very stiff, silty clay to sandy, silty clay (Hl). Hl is up to 15 feet thick near the existing Lake Washington Boulevard exit overcrossing. East of Foster Island, peat (Hp) has a relative uniform thickness of about 45 feet. Peat is underlain by soft to very stiff, silty clay that is 10 to 35 feet thick. | 19-foot elevation | In the central portion of the Arboretum, 19 feet of landfill debris materials underlying a 2-foot soil cap were observed in a boring. |
| | Peat and clay are underlain by hard silty clay to gravelly, sandy, silty clay and very dense, silty, clayey, gravelly sand (Qpgm) west of Foster Island, and very dense, sandy silt to silty sand and hard, silty clay generally east of Foster Island. The top of the dense to very dense or hard soils is about 40 to 85 feet below the water surface of Union Bay. | | |
| West Approach Area (Arboretum to East end of West Approach) | East of the Arboretum, very soft to soft peat and clay decrease in thickness. Very dense, silty, gravelly sand (Qpgo/Qva) are present within a few feet of the lake bottom and are generally overlain by a thin layer of peat. | 19-foot elevation | |
| Floating Bridge Area (Lake Washington) | Soils underwater in Lake Washington consist of 20 to 40 feet of soft peat (Hp) underlain by soft to stiff clay and silt (Qvrl) to depths of 150 feet below the lake bottom. | | Ground that underlies the water of Lake Washington could be subject to landsliding. Subaqueous deposits of very soft peat and organic silt could move laterally, although there is no evidence that suggests that these soils along the Evergreen Point Bridge are prone to flow (Shannon and Wilson 2007). |

Exhibit 13. Area-specific Subsurface Conditions

| Area | Subsurface Soil Conditions | Groundwater Conditions[a] | Special Notes |
|---|---|---|---|
| Floating Bridge Area (East Approach vicinity) | Soils beneath Lake Washington at the east approach are underlain by very stiff to silt and sandy silt (Qvrl and Qvgl) deposits at the base of the slope and very dense silty gravelly sand (Qvt) and very dense, clayey, silty, gravelly sand (Qpgm) and very dense silt to hard clayey silt (Qvgl) near the top of the slope. | 19-foot elevation | Presence of large underwater block slides up to 150 feet thick in the vicinity of the east approach (Karlin et al. 2004). Collected soil samples did not possess textural features consistent with disturbance in a landslide.<br>The west-facing slope above Lake Washington at the east approach is an area of known or potential instability. There is evidence of slope creep and minor slope movement. Deep-seated instability was not observed (Shannon and Wilson 2007). |
| Floating Bridge Area (Maintenance Facility vicinity) | Looser or softer landslide (Hls) or colluvial (Hc) soils likely mantle the steep slope above the eastern shore of Lake Washington, but not of an appreciable thickness. Much of the alignment is underlain by very dense, silty, gravelly sand to silty sand (Qvt/Qpgt), which is present at or near the ground surface. Till soils are underlain by hard, silty clay to clayey silt and very dense, sandy silt to silt (Qvgl/Qpgl/Qpnl). | 19-foot elevation | Limited subsurface information (Shannon and Wilson 2007). |
| Eastside Transition Area (vicinity between East Approach and 92nd Avenue NE) | Generally underlain by Vashon recessional glacial outwash and till at shallow depths. Very dense, silty, gravelly sand to silty sand (Qvt/Qpgt) is present at or near the ground surface along much of the alignment. These till soils are underlain predominantly by hard, silty clay to clayey silt and very dense, sandy silt to silt (Qvgl/Qpgl/Qpnl). Very dense sand to sandy gravel (Qpgm) and very dense, silty, gravelly sand (Qpgo) was also observed underlying the till. Medium dense, silty sand (Qvro) was encountered to about 8 feet deep at 92nd Avenue NE. Broad swales that the proposed alignment crosses west and east of 84th Avenue NE are likely underlain by less dense or softer recessional soils and peat (Hp). These normally consolidated deposits are underlain by very dense or hard soils at unknown depths. | Not indicated | Limited subsurface information (Shannon and Wilson 2007). |

Sources: Shannon and Wilson (2007), WSDOT et al. (2006).

[a] Groundwater information from Shannon and Wilson (2007). Elevation NAVD88 vertical datum.

## Groundwater Conditions

The study area is located in the Seattle Drift Plain topographic unit (Liesch et al. 1963). There are two distinct aquifers—a perched or semi-perched aquifer and a principal aquifer. The perched or semi-perched aquifer is encountered in the Vashon recessional outwash deposits and Vashon till. Wells that tap this aquifer may go dry in the summer. The principal aquifer is encountered in the gravel underlying the Vashon till.

Results of previous explorations within the study area indicate that the groundwater conditions are variable. In some areas, such as adjacent to Lake Washington and Portage Bay, groundwater is located very close to the surface. In other locations, such as along I-5, groundwater may be encountered greater than 95 feet deep, but there may be zones of perched groundwater at shallower depths. Artesian groundwater conditions occur within and adjacent to Portage Bay (Shannon and Wilson 2007).

For further information on groundwater in the study area, please refer to the Water Resources Discipline Report (WSDOT 2009e).

Aquifer: A layer of permeable rock, sand, or gravel through which groundwater flows. Aquifers often supply water to wells and springs.

Aquifer (confined): An aquifer with layers of impermeable material both above and/or below, which confine the water within the aquifer. The water within a confined aquifer is usually referred to as artesian groundwater.

Aquifer (perched or semi-perched): An aquifer that is separated from another water-bearing stratum by an impermeable layer.

Aquifer (principal): The largest aquifer.

Artesian groundwater: Groundwater in a confined aquifer that is under pressure that is higher than the top of the aquifer. When the confined aquifer is tapped by a well, the groundwater is able to rise above the level at which it is first encountered. It may or may not flow out at ground level. The formation containing artesian groundwater is an artesian aquifer or confined aquifer.

## Existing and Potential Aggregate Sources

Most of the soil types located within the study area would not be good sources of aggregate because of the high fines content and wet conditions. Soils with high fines content are more difficult to work with during construction because they are more moisture-sensitive, making them difficult to compact.

Fine-grained Soils

Fine-grained soils are not usually suitable for roadway subgrades or bridge approach fills because it is difficult to compact these materials, particularly during wet-weather periods, and because their strength tends to deteriorate under repeated traffic loads.

Aggregate quantity requirements for the project are expected to range from 52,000 cubic yards for Option L to 320,000 cubic yards for Option K. Imported aggregate would be required as fill for bridge approaches, lid structures and embankments, temporary access roads, temporary and permanent staging areas, and road subgrades. It would also be needed as backfill for utilities, spread-footing foundations, cut and cover tunnels, sequential excavation method (SEM) tunnels, and around footings prior to removal of cofferdams. Aggregate would also be used in concrete to construct structures such as the roadways, retaining walls, lid structures, foundations, tunnel walls, and pontoons and anchors for the floating bridge span. The location of the project is such that trucks could bring the aggregate

Cofferdams

A temporary, water-tight enclosure built in the water and pumped dry to expose the bottom so that construction of piers can be undertaken.

from borrow sources or barges could bring the aggregate from other locations in the Puget Sound region, as well as from the Aberdeen or Hoquiam areas.

## Do the existing geology and soil conditions pose any geologic hazards for the study area?

The geology and soil analysts identified the potential for geologic hazards in the study area by reviewing hazard and critical-area maps published by the City of Seattle, City of Medina, USGS, and Washington State Department of Natural Resources (WDNR) and by interpreting the available geotechnical information.

Geologic hazard areas include areas susceptible to erosion, sliding, earthquakes, or other geologic events. Geologic hazard areas include liquefaction-prone areas, seismic hazard areas, volcanic hazard areas, landslide hazards areas, steep slopes, and erosion hazard areas. Geologic hazard areas pose a threat to the health and safety of citizens when incompatible commercial, residential, or industrial developments are sited in areas of significant hazard.

Sources of hazard mapping include:

- City of Seattle (2003), King County (2003), and WDNR (2002) geographic information system (GIS) maps and other WDNR maps for the study area identified three types of geologic hazards—erosion potential/landslides, steep slopes, and liquefaction potential zone.
- Interpretations of boring logs collected from GeoMapNW (Pacific Northwest Center for Geologic Mapping Studies, University of Washington 2009), WSDOT, and the City of Seattle archives identified potential hazards from settlement or soft-ground conditions.

The following geologic hazard types have been identified within the study area:

- Seismic hazards
- Erosion hazards
- Steep-slope/landslide hazards
- Settlement or soft-ground hazards

The following subsections discuss the ways in which existing geology and soil conditions pose these hazards and the potential locations of these hazards.

## Seismic Hazards

The primary seismic hazards for the study area involve ground-shaking hazards, liquefaction hazards, faulting hazards, and seiche or tsunami hazards. The following sections summarize the extent of these hazards.

### Ground-shaking Hazard

The potential for future earthquake-related ground shaking is relatively high in the study area. Earthquakes in the Puget Sound region can result from any one of three sources:

- The Cascadia subduction zone interplate source off the coast of Washington
- The deep intraslab subduction zone located approximately 20 to 40 miles below the area
- Shallow crustal faults (less than 15 miles deep)

Interplate source: Area between the earth's crustal plates. This area is the source of large earthquakes off the western coast of Washington.

Lithospheric plates: Plates that are located within the lithosphere, which is the outer solid part of the earth. The lithospheric plates include the crust and uppermost mantle.

Subduction zone: The place where two lithospheric plates come together, one riding over the other.

Exhibit 14 conceptually shows the causes of the three types of earthquakes and historical examples of each. The ground shaking used for design of the project will be based on probabilistic modeling that combines the effects of potential earthquakes from all three sources at the location of the project site. The ground accelerations developed for design will consider not only the distances from each of

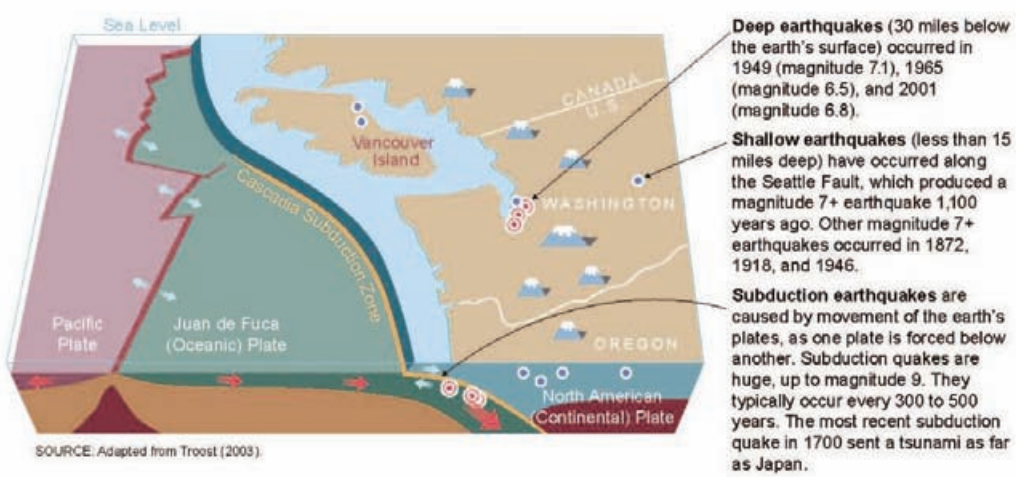



Exhibit 14. Potential Seismic Source Zones in the Pacific Northwest

the potential source mechanisms, but also the ways in which the soils area-wide and at the site would dampen or amplify the earthquake effects.

## Liquefaction Hazard

Soil liquefaction and the accompanying settlement, lateral spreading, or flotation of buried vaults and pipes could occur where areas are underlain by cohesionless soils (for example, fine-grained sand, silt, or sandy silt) of low relative density that are saturated (that is, below the groundwater table). Soft cohesive soils (for example, clay, some silts, and organic or peaty deposits) may experience strength reduction during an earthquake, even though they may not liquefy in the classic sense. The peat (Qp/Hp), lake deposits (Ql/Hl), and some recessional outwash deposits (Qvr/Qvro) that underlie the study area are loose or soft and saturated; therefore, they are potentially susceptible to liquefaction or strength reduction during earthquake shaking. Portions of the study area are mapped as being in liquefaction-prone areas (Exhibit 15). In addition, a Palmer et al. map (2004) indicates that some portions of the study area have a moderate to high potential for liquefaction.

## Faulting Hazard

Two fault zones are located within 20 miles of the study area. The closest fault zone is about 4.5 miles from the study area (Exhibit 16). The USGS refers to these faults as the Seattle Fault Zone (Fault No. 570) and the Southern Whidbey Island Fault Zone (Fault No. 572) and considers them active. A low hazard of surface rupture is anticipated based on the distance (more than 4.5 miles) of the study area from the mapped faults.

## Seiche or Tsunami Hazard

Seiches or tsunamis are a possible secondary effect from seismic events or from an underwater landslide (underwater landslides are further discussed under *Steep-slopes/Landslide Hazards*). Seiches can be induced by earthquakes in lakes, bays, and rivers. The potential magnitude of a seiche event occurring from an earthquake is difficult to predict as the magnitude of the seiche depends on the magnitude of the earthquake, frequency of vibrations, natural period of the water body, sediment thicknesses, presence of thrust faults, and other geologic factors (Barberopoulou 2006).

**Liquefaction**

Liquefaction is when normally solid ground suddenly behaves more like a liquid, usually causing the collapse of any structures supported by it. Relatively loose saturated sands and some silts tend to densify when shaken by a sufficiently strong earthquake. However, the water surrounding the particles cannot escape quickly enough and takes on some or all of the load that was previously taken by soil particle-to-particle contact. The water cannot resist shearing forces, so the frictional resistance, or strength, of the soil is reduced.

**Cohesive soils:** A sticky soil, such as clay or silt.

**Glacially overridden soils:** Soils that have been compressed by glaciers and thus have become dense.

**Compressible soils:** Soft soils that can be compressed such as peat and lake deposits.

**Deformation:** An alteration of shape, as by pressure or stress.

**Dewatering:** Localized lowering of the groundwater table associated with construction.

**Liquefiable**, A loss of strength in saturated, sand-like soils due to earthquake-induced ground shaking. Usually occurs in loose sands and non-plastic silts located below the water table.

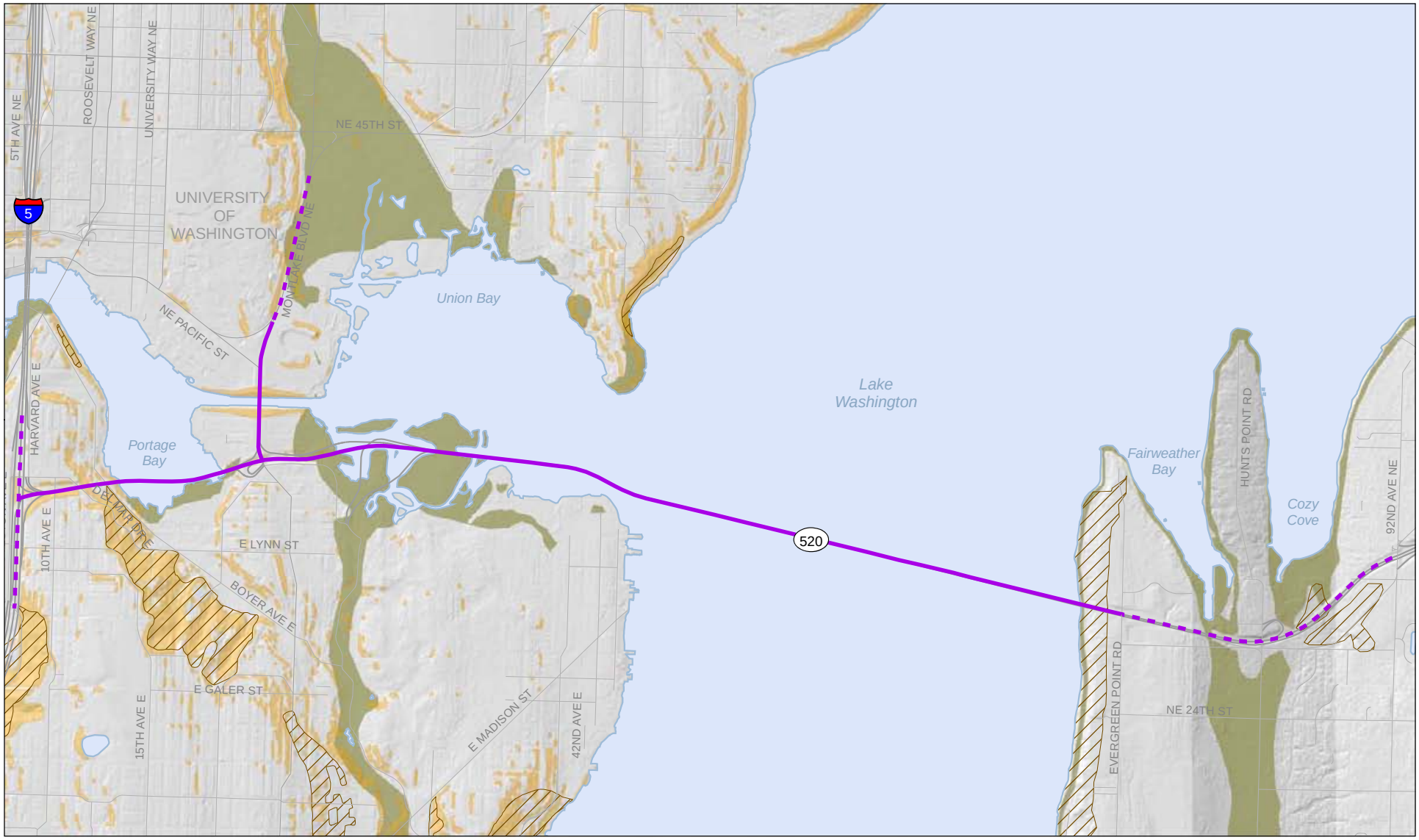
**Permeability:** A measure of the ability of a material (typically, a rock or unconsolidated material) to transmit fluids.

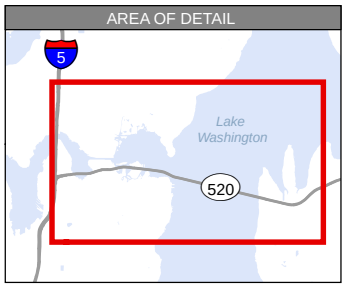
**Saturated:** Within groundwater table.

**Fault zone:** A group of fractures in soil or rock where there has been displacement of the two sides relative to one another. The relative movement can be predominantly horizontal, vertical, or inclined.

**Seiche:** A standing wave in an enclosed or partly enclosed body of water. It is analogous to the sloshing of water that occurs when an adult suddenly sits down in a bathtub (Noson et al. 1988).

**Tsunami:** A series of waves created when a large volume of a body of water, such as an ocean, is rapidly displaced.




Project Extent

Limited Improvements

Erosion/Potential Landslide Area

Steep Slope (Only for Seattle)

Liquefaction Zone

Source: King County (1997) GIS Data (Erosion); King County (2003) GIS Data (Landslides and Hillshade); WADNR (2002) GIS Data (Liquefaction); City of Seattle (2002) GIS Data (Erosion/Potential Landslide and Steep Slopes); City of Seattle (1997) GIS Data (Liquefaction);King County (2005) GIS Data (Streets) King County (2007) GIS Data (Water Bodies), CH2M HILL (2008) GIS Data (Parks). Horizontal datum for all layers is NAD83(91); vertical datum for layers is NAVD88.

N

0 1,500 3,000 Feet

Exhibit 15. **Geological Hazard Areas**

I-5 to Medina: Bridge Replacement and HOV Project

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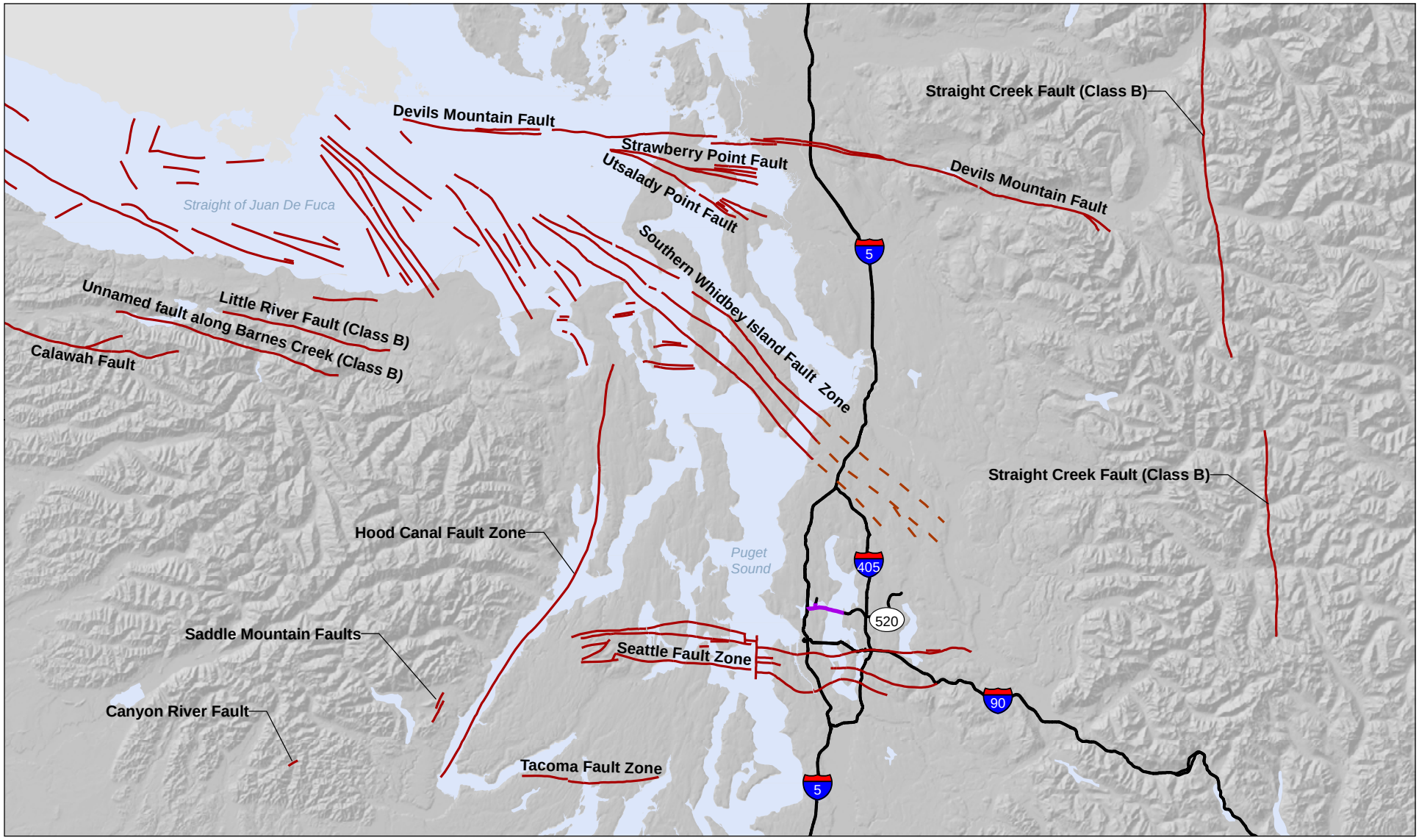


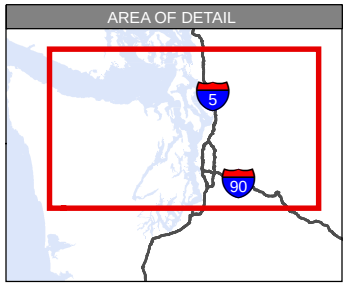


Project Area

Fault

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

N

0 5 10 20 Miles

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

Exhibit 16. **Published Faults**

I-5 to Medina: Bridge Replacement and HOV Project

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In 2002, a seiche damaged houseboats, buckled moorings, and broke water and sewer lines in Lake Union following the Alaskan earthquake with a magnitude of 7.9. Damage was limited to about 20 houseboats. While no historic records are available to document the size of waves produced during this event, Barberopoulou (2006) models estimated maximum wave heights of 1.41 feet (0.43 meter) as a result of this event.

The City of Seattle (under Ordinance 122370) classifies the shoreline and upland areas along Lake Washington within the study area as having an "unknown risk from seiches." The risk of seiche damage to a new floating bridge over its 75-year design life is probably small. The existing bridges have withstood standing waves up to 8 feet tall (King County Office of Emergency Management 2005). According to WSDOT (P. Clarke, Bridge Engineer, WSDOT, Tumwater, Washington. April 21, 2004. Personal communication), the wave forces generated by a seismic event are likely to be less than the design wind waves.

## Erosion Hazards

An erosion hazard is present where soils may experience severe to very severe erosion from construction activity. This hazard typically occurs on a slope of 15 to 40 percent if the soil is erosion-prone. Erosion-prone soils have a high percentage of silt or clay, or they are located above a less permeable soil layer. Erosion hazards occur where steep slopes and landslides are located, as described in the next subsection. Erosion hazards are mapped in the locations shown on Exhibit 15.

## Steep-slope/Landslide Hazards

Steep-slope hazards have a slope of over 40 percent or more within a vertical elevation change of at least 10 feet. The following are examples of areas that are landslide-prone:

- Where there are known landslides
- Where there is evidence of past landslides
- In those areas that are described as potential slide areas in *Seattle Landslide Study* (Shannon and Wilson 2000 and 2003)
- In areas with topographic expression of runout zones, such as fans and colluvial deposition at the toes of hillsides
- In areas at the top of very steep slopes or bluffs, depending on soil conditions

**Colluvial deposition:** Loose bodies of sediment deposited or built up at the bottom of a low-grade slope or against a barrier on that slope, transported by gravity.

**Fans:** A fan-shaped accumulation of debris deposited at the base of a landslide

**Runout zone:** The portion of the landslide where the debris typically comes to rest.

The mapped steep-slope and landslide hazard locations are shown on Exhibit 15. Typically, the potential severity of the hazard increases as the steepness of the slope increases. Areas of known and potential instability include the steep hillside between Delmar Drive East and Portage Bay, the west-facing slope above Lake Washington at the east approach to the Evergreen Point Bridge, and localized areas of steep cuts and fills along the existing SR 520 alignment (Shannon and Wilson 2007).

Works by Golder Associates (2003) and Karlin et al. (2004) identified numerous underwater debris and sand flows, slumps, and large block slides around the margins of Lake Washington that were caused by large earthquakes in the Puget Lowland. The debris and sand flows are relatively thin, but the block slides are as much as 150 feet thick. Karlin et al. (2004) documented a large block slide in the vicinity of the east approach to the Evergreen Point Bridge and a sand flow in the vicinity of the west approach to the Evergreen Point Bridge.

## Settlement or Soft-ground Hazards

Areas underlain by loose compressible sediments, particularly peat and lake deposits, could be subject to ground settlement during and sometimes after construction. The peat deposits and lake deposits shown on Exhibits 9 and 10 can be considered potential settlement or soft-ground hazards. Structures and buried utilities might settle unevenly and become damaged unless they were supported on piles or the ground was improved. These soft soils could also require the use of special construction procedures during placement of fills. If these procedures were not used, bearing or slope failures could occur when fill heights exceeded certain limits. Generally, areas mapped as seismic hazards associated with liquefaction also coincide with areas of settlement hazard.

# 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 among the options of the 6-Lane Alternative. These potential geology- and soil-related effects and the associated measurable quantities are listed in Exhibit 17. The reasons that these methods were used as bases of comparison are discussed in the next subsections, where the construction and operation effects of the project are described.

Exhibit 17. Semi-quantitative Measures of Potential Effects

| Potential Effect | Comparative Measure | Comments about Measure |
|---|---|---|
| **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 | Mainline 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. |
| 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 ground vibration and represent temporary effects of construction. |
| Bridge construction over water | Estimated numbers of new permanent shafts, numbers of temporary piles | These effects potentially include ground vibration, erosion, and the potential for water quality reduction from erosion of soils. They also 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 Water Resources Discipline Report (WSDOT 2009e) for additional discussion. |

Exhibit 17. Semi-quantitative Measures of Potential Effects

| Potential Effect | Comparative Measure | Comments about Measure |
|---|---|---|
| Changes in topography | Cut-and-fill volume | Visual effect might be a more important measure. See Visual Quality and Aesthetics Discipline Report (WSDOT 2009f). |
| 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. |
| **Operational Effects** | | |
| Loss of topsoil | Estimated volume of topsoil removed | 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 | Length of wall or structure is more appropriate than area or other quantitative measure because slope would have to be stabilized regardless of cut height or volume of soil removed. This is a relatively crude measure since the existing factor of safety against slope movement is unknown. |
| Underground facilities located immediately behind retaining walls | Length of walls (including lid support walls) and bridge abutments perpendicular to slope contours in landslide hazard areas | Same as those described for “Slope stabilizing effects” In the row above. |
| Long-term settlement below roadway fill sections | Surface area over areas mapped as peat (Qp) and lake deposits (Ql) where elevation of roadway would be higher than at present | Mapping as lake deposits does not necessarily mean compressible silt, clay, or highly organic material (could be primarily sandy), but peat is compressible highly organic material. |
| Groundwater flow or elevation changes | Covered in Water Resources Discipline Report (WSDOT, 2009e) | See Water Resources Discipline Report (WSDOT 2009e) for additional discussion. |

The project’s potential effects would generally result from the following permanent consequences of the 6-Lane Alternative:

- New loads or reductions in loads on the geology and soils as embankments were placed and as areas were excavated
- Loss of soil layers as materials were removed to accommodate project elements (for example, retaining walls) or as soils were removed or replaced to improve the performance of project elements

- Depletion of geology and soil resources outside the study area as materials were imported to meet the construction needs

In addition to permanent effects, a number of construction effects on geology and soils would result. Some of these effects, such as construction noise or vibration, would occur because construction of the project would require modifying study area geology and soils to meet project development requirements.

The geology and soil analysts reviewed the following key reports:

- *SR 520 Bridge Replacement and HOV Project, Westside Conceptual Structures Recommendations Technical Memorandum* (HDR Inc. et al. 2009a)
- *SR 520 Westside Construction Techniques Technical Memorandum* (HDR Inc. et al. 2009b)

# How would construction of the project affect geology and soils?

Direct effects involving geology and soils that occur during construction of a project are those that result from changes in the geology or soil conditions or those that are determined by geology and soil conditions. The simplest example of a direct effect is the need to change surface soil elevations to meet roadway grade requirements.

## Construction Effects Common to All Project Areas and Options

The geology and soil analysts evaluated potential environmental effects related to geology and soils during construction based on the geology and soil conditions within the study area and the expected types of construction for the project areas and options. The evaluation of environmental effects during construction generally considered the entire study area. Where unique effects would occur for a specific area and option, they are discussed in the next subsection "*Area- and Option-specific Temporary Construction Effects*.

The planned construction could result in a number of short-term direct effects on the environment related to geology and soils, including the following:

- **Erosion hazards.** Clearing protective vegetation, fill placement, grading, and spoils removal or stockpiling during construction

would allow rainfall and runoff to erode soil particles. This would create the potential for loss of soil at the site of disturbance and downslope from the disturbance and a reduction in runoff water quality. The severity of potential erosion would be a function of the Temporary Erosion and Sedimentation Control measures used by the contractor, the quantity of vegetation removed, site topography, rainfall, and the volume and configuration of stockpiled soils.

- **Topographic changes.** The topographic changes to the corridor would be relatively small because the widened roadway would follow the same corridor as the existing roadway. In addition, the footprint would be minimized by using walls to retain most fills and cuts. Earthwork quantities (cut-and-fill volumes) would provide a relative measure of the amount of topographic change. Total cut-and-fill volumes and other semi-quantitative relative soils and geology project effects for each of the areas and options are provided in Exhibit 18.
- **Slope instability and landslides.** Construction of the project would involve grade changes, cuts and fills, and/or installation of bridge and retaining wall structures that have the potential to destabilize landslide-prone hillsides. Slope movement could result in increased erosion and sedimentation, with a possible reduction of surface water quality. Extreme cases of slope instability and landslides could endanger onsite and offsite property. The overall risk of these direct effects is rated low because slope instability is being considered during the design phases of the project.
- **Construction-induced vibrations.** The use of heavy equipment during construction would cause ground vibrations. The direct effects of the vibrations would depend on the type of heavy equipment, the distance between equipment and receptors (for example, people, sensitive structures, or utilities), and the ability of the soil to transmit vibrations. Most construction-related vibrations, with the exception of those related to demolition and pile-driving, should be imperceptible to people outside of the construction zone, especially considering the existing vibrations caused by SR 520 traffic. Demolition, pile installation by vibratory methods, and pile-driving vibrations might be felt a few hundred feet from the source

Exhibit 18. Semi-quantitative Relative Soils and Geology Project Effects

| Project Effect | Seattle Area | | | Lake Washington and Eastside Transition Area | Project Totals (from I-5 to 92nd Ave NE in Yarrow Point) | | |
|---|---|---|---|---|---|---|---|
| | Option A | Option K | Option L | | Option A | Option K | Option L |
| Total estimated excavation (volume of excavation, cy)[a] | 290,000 | 1,250,000 | 400,000 | 48,000 | 340,000 | 1,300,000 | 450,000 |
| Import fill (total volume of embankment, cubic yards)[a] | 66,000 | 300,000 | 32,000 | 20,000 | 86,000 | 320,000 | 52,000 |
| Lane miles of new roadway not on structure | 3.4 | 3.1 | 3.5 | 0.9 | 4.0 | 4.0 | 4.4 |
| Area of new bridges and structures (square feet)[b] | 1,600,000 | 2,200,000 | 2,000,000 | 1,300,000 | 3,000,000 | 3,500,000 | 3,300,000 |
| Area of walls (square feet, includes all wall types and noise barriers)[c] | 82,000 | 86,000 | 78,000 | 31,000 | 110,000 | 120,000 | 110,000 |
| Length of new concrete barrier (linear feet)[d] | 13,000 | 9,000 | 16,000 | 8,900 | 22,000 | 18,000 | 25,000 |
| Number of new columns and shafts supporting structures over water | 309 | 2,900 | 310 | 6 | 315 | 2,900 | 320 |
| Number of temporary piles | 3,000 | 4,000 | 3,000 | 165 | 3,000 | 4,000 | 3,000 |

[a] Total excavation is the sum of estimated roadway excavation quantities and structure excavation quantities.
[b] Area is square footage of the new structures (ramps, bridges, lids, etc.) and does NOT include any temporary structures or demolition.
[c] Area is for all types of walls including SEW, reinforced concrete retaining, soil nail, soldier pile, soldier pile/cylinder pile, and all noise barrier walls.
[d] Linear feet of concrete barrier only. Does NOT include guard rail.

Note: Values have been rounded to two significant digits.

Source: HDR Inc. et al. (2009c) and WSDOT et al. (2009)

and would be perceptible to people living or working in the area and could affect fish or other wildlife. These activities might have the potential to cause the settlement of loose sands and might damage sensitive structures within a few feet of the activity. Noise and vibration are discussed in the Noise Discipline Report (WSDOT, 2009b).

- **Utility and buried structure protection.** Excavations for structure foundations and relocation of utilities, if not supported correctly, could result in lateral and vertical movement of the ground next to the excavations. The direct effect of the movement could be damage to buried utilities and to structures or roadways located adjacent to the excavations. The additional load of stockpiles or temporary haul roads could cause settlement of the soil in which utilities were located, potentially damaging the utilities.
- **Hazardous materials.** Soils excavated during construction could be contaminated if the project were to cross areas identified in the Hazardous Materials Discipline Report (2009d). For example, "garbage dump" material is indicated in a boring drilled within the Arboretum Interchange (Shannon and Wilson 2007). If encountered, these contaminated soils would require special handling, transport, and disposal at offsite locations. The direct effect of the hazardous materials would be the extra time and cost of special handling.
- **Excavation of unsuitable soils.** Existing soils excavated during construction that could not be used as structural fill or for landscape material would require removal from the study area and disposal elsewhere.
- **Accelerated wear of existing infrastructure.** Trucks used to bring equipment or construction materials to the site or to remove excess soils and construction debris could accelerate deterioration of nearby streets and roadways. For example, if the trucks' loads exceeded the strength of the roadway base material, the pavement could crack or develop ruts.
- **Compression of soils**. Fills used for construction or stockpiles of soil used for temporary material storage could compress soils. This might also laterally squeeze existing soils if the soil strength were inadequate. The displacement of the soils could affect facilities constructed on or within the soils.

- **Aggregate depletion**. Aggregate materials would be required for construction. The use of aggregate for construction, including sand and gravel for pavement and structures, could deplete supplies of material that might be used for other purposes. This would be a cumulative effect of construction.

  Most of the native materials that would be excavated along the project alignment would contain too much silt and clay to be free draining. That would make these soils very difficult to recompact if wet and they could not be reused. Exhibit 19 assumes that 100 percent of the native materials would be hauled offsite rather than reused, and that 100 percent of the materials used for construction would be imported aggregate.

- **Topsoil depletion**. Construction would require removal or burial of the upper layer of organic-rich soil, resulting in a potential loss of topsoil. However, this material would normally be removed and stockpiled within the study area. Later, the topsoil could be used during landscaping associated with construction, resulting in minimal net direct effects. In addition, in areas where landscaped lids would be constructed, a net increase in the amount of topsoil could occur relative to existing conditions.

- **Change in groundwater flow.** Construction of seepage-cutoff retaining structures (such as secant pile walls) could result in impermeable barriers in the ground that could change groundwater flow conditions. In addition, the compression of soil beneath new approach fills might eventually change groundwater flow or flushing conditions. A possible consequence of this may be a shift in the location of any groundwater contaminant plumes that may exist near the project.

- **Dewatering**. Dewatering of excavations located below the groundwater table could result in quantities of sediment-laden water that would not meet water-quality disposal requirements and would have the potential to change the adjacent water table. Prior to concrete curing, high pH surface runoff from structures could become mixed with dewatering flows, adding to water quality concerns. The potential would be more substantial near Portage Bay, Union Bay, and Lake Washington, where groundwater elevations are near the surface. Dewatering could also result in the settlement of nearby structures, if proper considerations were not given to the effects of water-level changes.

## Area- and Option-specific Construction Effects

Exhibit 19 provides a qualitative rating of potential construction effects for specific areas and options within the study area. This qualitative review does not replace the detailed geotechnical work that would be required during the design phases. A qualitative rating of the frequency or seriousness of the potential effects related to geology and soils was assigned, as follows.

- A low rating (L) was given to an effect that would have a low potential of occurring or if the effect would only occur in a localized area.
- A moderate rating (M) was given to an effect that would have a moderate potential to occur or if the effect would occur at multiple locations.
- A high rating (H) was given to an effect that would have a high potential to occur or if it could cause major effects; this rating triggers the need for more detailed studies.

Based on the information that was available when performing this evaluation, none of the effects was determined to be a fatal flaw (an undue risk) that would prevent construction of the project.

In all cases, the evaluation determined that the severity or frequency of the hazard or effect could be avoided or minimized using conventional design and construction methods. Where effects are listed as being moderate to high, more effort is necessary during design to evaluate the severity of the effect and to identify an adequate mitigation method.

The following subsections describe some potential area- and option-specific construction effects.

### No Build Alternative

Under the No Build Alternative, the project would not be constructed and the geology and soils would not be affected. The existing geology and soil environment would remain essentially unchanged.

### 6-Lane Alternative

#### Seattle

Construction that is common to all the Seattle options would consist of lid construction, retaining walls, temporary bridges, bridge demolition, excavations, embankments, pier foundations, piers, temporary bridge

Exhibit 19. Summary of Area-specific Effect Potential during Construction

| | Geologic Hazard | | | Engineering Design and Construction | | | | |
|---|---|---|---|---|---|---|---|---|
| **Alignment** | **Erosion** | **Steep Slope/ Landslide** | **Soft Ground or Settlement** | **Ground-water[a]** | **Low Soil-bearing or Lateral Support** | **Construction Vibrations** | **Risk to Utility and Buried Structures** | **Risk to Overall Constructability** |
| Seattle—Overall | M | M | M | M | M | M | M | M |
| Seattle—Option A | L | M | L | M | L | M | M | L-M |
| Seattle—Option K | L | M | M | H | M | M | M | M-H |
| Seattle—Option L | L | M | M | M | L-M | M | M | M |
| Lake Washington | M | M | L | M | L | M | L | L-M |
| Eastside Transition | M | M | L | M | L | L | M | L-M |
| Phased Implementation Scenario | L | M | M | M | L-M | M | M | M |
| No Build | L | L | L | L | L | L | L | N/A |

[a] Within 0 to 10 feet of the ground surface.

**Rating Legend:**

H = High potential of occurring. Could cause major effects and might affect construction costs. Would require detailed studies.

M = Moderate potential of occurring or occurs in multiple locations. Could have some effects. Would require special consideration. Can be addressed using normal design and construction methods.

L = Low potential of occurring or localized occurrence. Does not appear to be a design or construction issue. Only a few locations would require consideration during design.

N/A = not applicable

widening, work bridges, temporary access roads, stormwater and other facilities, pile-driving, and cofferdams. Short-term effects on geology and soils from construction of all the Seattle options might include the following:

- Design and construction of temporary excavations would be complicated by the proximity of adjacent structures and foundations. Installing tie-back anchors, for example, might not be possible if an adjacent structure or foundation limited the tie-back length. Alternative excavation/wall systems might need to be considered.
- The existing infrastructure might affect design or construction methods of structures such as retaining walls, bridges, lids, or overcrossings. For example:
  - Soil nails used for retaining walls might have to be of varying lengths or installed at different angles to avoid underground utilities.
  - The freeway widening and construction of new earth retention and bridge structures might compromise the stability of existing structures such that intermediate wall/bracing might be necessary.
- The eastern end of the bridge over Portage Bay and the western end of the Lake Washington west approach structure cross potentially liquefiable areas. The current design development does not require stabilization of these soils, or ground improvement, to prevent collapse or nonrepairable damage to the facilities. If the need for small amounts of ground improvement is identified as design is refined, the ground improvements could consist of construction of stone columns, compaction grouting, deep soil mixing, or jet grouting. These activities disturb the ground surface and produce spoils (that is, waste excavation, which by some construction methods, is soil mixed with cement), which cannot be reused at the construction site. The volume of spoils typically ranges from about 5 to 30 percent of the gross improved volume. These potential effects are unlikely because ground improvement is not anticipated as of 10-percent design.

Soil mixing: Mixing the soil in place with a substance, such as cement, which causes the soil to become stronger and less permeable. In-place soil mixing is often used to reduce the liquefaction potential for loose, saturated, granular soils.

- Compressible soils might exist beneath the embankments near the abutments on the east side of the Portage Bay Bridge, the west side of the Evergreen Point Bridge, and ramps in the Arboretum area.

Mitigation to prevent damaging settlement could involve lengthening the construction period to allow time for the soils to consolidate before final grading or paving; installing vertical drains to speed consolidation; or reducing the weight of the earth fill by constructing it of closed-cell polystyrene blocks (that is, expanded polystyrene or Geofoam), imported pumice, expanded shale (all three of which are petroleum-intensive), or lightweight cellular concrete.

- Soft soils extend to depths of up to 100 feet in Portage Bay and groundwater is encountered at or within a few feet of the ground surface within and adjacent to Portage Bay, Union Bay, and Lake Washington. These conditions would require deep foundations and construction of temporary work trestles for construction access.
- Construction dewatering could cause ground settlement. The settlement could affect nearby structures or utilities in the zone of influence.
- Construction dewatering could affect water quality. Dewatering systems would need to be located and designed so that groundwater quality would meet discharge requirements before any water was released into stormwater systems or directed to infiltration systems. See Water Resources Discipline Report (WSDOT 2009e) for further discussion of groundwater discharge controls.
- Contaminated material, if present, could affect excavation of soils. Refer to Hazardous Materials Discipline Report (WSDOT 2009d).
- Spread footings are typically founded within 5 to 10 feet of the finished grade elevation. Construction of spread footings would require excavation, temporary dewatering if the excavation is below the water table, and placement of compacted backfill over and around the footing.
- A landslide hazard would exist if temporary slopes or excavations were made without sufficient stabilization or bracing. Extra care in supporting temporary cuts would be required for all options in the locations of past slides and the geologic conditions in which these slides occurred.

- Demolition of bridges would require cutting of piles at or just below the mudline, which would cause some soil disturbance on the water-body floor.
- Artesian groundwater conditions within and adjacent to Portage Bay would affect the type of foundations used for the elevated roadway. Special construction methods could be required to control or offset the high groundwater pressures and the potential for groundwater flow.
- Sand and gravel deposits (such as Vashon recessional outwash deposits) tend to be of moderate to high permeability. If excavations penetrated groundwater, such deposits would likely require dewatering by rigorous methods. This dewatering could lower the groundwater table adjacent to the excavation.

#### *Option A*

Construction in Option A that would affect geology and soils consists of work bridges, temporary access roads, pile-driving, cofferdams, bridge foundations and piers, excavations and embankments, temporary and permanent roadways, temporary sheet pile walls, and a bridge construction flyover ramp. Short-term effects on geology and soils from construction of Option A would be the same as those for construction common to all the Seattle options.

#### *Option K*

Construction for Option K consists of temporary detour bridges, work bridges, off ramps, access roads to work bridges, cut-and-cover tunnels, roadways several feet below lake and normal groundwater levels, an SEM tunnel, bridge foundations, excavations, and embankments. Short-term effects on geology and soils from construction of Option K might include the following:

- Noise and ground vibration would result from construction of the tunnel by excavation, secant pile and sheet pile wall installation, and drilling (see the Noise Discipline Report [WSDOT 2009b]).
- Dewatering large excavations for cut-and-cover tunnels and a freeze pit might cause settlement of adjacent loose sands.
- Dewatering large excavations would require disposal of a large volume of potentially sediment-laden water. Option K could require the largest amount of dewatering of all the options.

Freeze Pit: Excavation at the beginning of a tunnel with horizontally drilled holes around the perimeter of the tunnel. These holes are cased with pipe which have smaller circulating pipes inside. The circulating pipes circulate freezing liquid to freeze the soil.

- The deep secant pile walls planned for excavation support and groundwater control could be leaky. The following conditions would make water-tight construction of the secant pile walls at this location difficult and risky:
  - Poor soil conditions near the ground surface would make precise pile alignment difficult.

    The great depth of the planned secant pile walls would be at the upper range of precedent for seepage control. At large depths, problems with alignment, material quality control, encountering unanticipated obstructions, and operational and planning control could cause leaks that would be much more difficult to mitigate than at shallower depths and lower groundwater heads.
  - Repair could require grouting or installation of additional secant piles or slurry walls, increasing the disturbance and risk of high pH water release, as well as delaying the project.
- Because of the depth of the excavation for the cut-and-cover tunnels, it would be necessary to install bracing for the slurry walls in the form of tie backs. The lengths of these tie backs would be determined once the local soil parameters were known. However, it is expected that long tie backs would be necessary.
- The SEM requires that the ground be reasonably stable for tunneling. Dewatering of the extensive water-bearing sand layers and lenses anticipated would not be possible. Ground freezing of an annulus around each of the two tunnels appears to be the most reasonable ground stabilization alternative. Ground freezing on a curved alignment approximately 760 feet long would be difficult and of long duration. Using horizontal directional drilling methods to drill the holes for individual freeze pipes, installing the freeze pipes, waiting for ground freezing to occur, excavating the tunnel bore, and installing tunnel lining are time-consuming processes. In addition to the conventional disturbance of construction and fuel usage by heavy equipment, operation of the freezing system would be very energy-intensive and involve some risk of freeze pipe leakage or rupture and loss of brine solution into the surrounding soil.
- Much of the work from the ground surface would be over soft soils near lake level (identified as Qp and Ql in Exhibits 9 and 10), which

would require installation of work trestles or temporary work berms of coarse rock for equipment support.

#### *Option L*

Construction in Option L that would affect geology and soils consists of work bridges, temporary access roads, pile-driving, cofferdams, bridge foundations and piers, excavations and embankments, temporary and permanent roadways, temporary sheet pile walls, and a bridge construction flyover ramp. Short-term effects on geology and soils from construction of Option L would be the same as those for construction common to all the Seattle options.

### Lake Washington

Construction in the Lake Washington section that would affect geology and soils consists of construction of the floating bridge span (which includes temporary and permanent anchor installation); construction of the east approach (which includes work bridges, pile-driving, cofferdams, bridge-foundation piers, and temporary and permanent roadways); and construction of a maintenance facility that would include permanent and temporary access roads, the permanent dock substructure, excavations and embankments, retaining walls, and buildings. Short-term effects on geology and soils from construction of the Lake Washington elements might include the following:

- Sediment on the lake bottom would be disturbed from temporary and permanent anchor installation. Temporary anchors would be installed either by driving them into the ground or cranes would lower them to the mudline. Permanent anchors would be installed using a combination of their own weight and water or air-jetting to set the anchors below the mud line.
- Construction of bridge foundations and temporary or permanent anchor installation could initiate submarine slope movement. Slope movement could damage underwater structures already in place. The overall risk of these direct effects is low because slope instability is being considered during the design.
- A seiche could occur as a result of an earthquake or submarine slope movement. The risk of a seiche occurring during construction is low because the likelihood of an earthquake or submarine slope movement occurring in that time is low.
- Construction of the maintenance facility would replace soil and an existing slope. It is likely that excavation for the facility could cut

through landslide-prone soils. Evidence of slope creep and minor slope movement was observed on the steep slope between Lake Washington and the existing east bridge abutment; however, deep-seated slope instability was not observed (Shannon and Wilson 2007). Construction of the maintenance facility with cuts in these types of soils would be relatively more expensive than construction of cuts in other soils (such as the Vashon till or Vashon recessional or advance outwash deposits).

- Construction dewatering could cause ground settlement. The settlement could affect nearby structures or utilities in the zone of influence.
- Construction dewatering could affect water quality. Dewatering systems would need to be located and designed so that groundwater quality would meet discharge requirements before any water was released into stormwater systems or directed to infiltration systems. See the Water Resources Discipline Report (WSDOT 2009e) for further discussion of groundwater discharge controls.

### Eastside Transition Area

Construction of temporary and permanent roadways in the Eastside transition area would affect geology and soils. Short-term effects on geology and soils from construction of the Eastside transition area would be the same as the effects of construction common to all the Seattle options.

Construction and outfitting of the pontoons and anchors would require sand and gravel to be used in concrete, which may contribute to aggregate depletion in the region.

### Pontoon Production and Transport

The I-5 to Medina: Bridge Replacement and HOV Project would construct an additional 44 supplemental stability pontoons and anchors needed to build a 6-lane floating bridge. Pontoons and anchors may be constructed at the CTC facility in Tacoma and/or at the new Grays Harbor facility constructed for the Pontoon Construction Project. For detailed information about pontoon construction, please see the Construction Techniques Discipline Report (WSDOT 2009c). After construction in a casting basin facility, pontoons would be floated out of the basin into open water and towed to Puget Sound for outfitting or

directly to Lake Washington for incorporation into the new floating bridge.

The new pontoon construction facility at Grays Harbor may require maintenance activities in the launch channel that would be used to float pontoons out of the casting basin and into open water. Underwater currents and other natural processes would deposit soil in the dredged portion of the launch channel and would occasionally need to be removed by dredging. The dredged materials from the launch channel would be removed to an approved disposal site. Launch channel maintenance dredging would be the only activity that affects geology and soils during pontoon construction in Grays Harbor.

### Phased Implementation Scenario

Construction of the west and east approaches, the floating bridge, and the Portage Bay Bridge under the Phased Implementation scenario would affect geology and soils. The work that would affect geology and soils is described in previous sections, and the short-term effects on geology and soils from construction would be the same as the short-term effects for construction common to all Seattle options and the Lake Washington section.

# How would operation of the project permanently affect geology and soils?

Effects during operation of the project would occur after construction had been completed and the project facilities were being used. These effects would occur throughout the period of operation. Some effects result from facility construction; other effects result from the operation of the system. While the project would not cause seismic events, there is a risk of seismic events occurring during the period of operation.

## Permanent Operational Effects Common to All Project Areas and Options

The following operational effects associated with geology and soils are a consideration for the entire study area. The degree of these effects would depend on the specific site conditions, development plans, and final designs. Unique effects that would occur for a specific area and option are discussed in the next subsection , *"Area- and Option-specific Permanent Operational Effects*.

The operation of the project could result in a number of direct effects on the environment related to geology and soils, as described in the following sections.

### Erosion Hazards

After construction, vegetation would be re-established, or some nonerodible surface, would be installed to limit the effects of erosion. It might take several seasons for the vegetation to reach preconstruction protective levels. During this time, some accelerated erosion might occur, which would be a direct effect from operations. In addition, some surfaces outside the shoulders (for example, ditches) might not be allowed to revert to preconstruction vegetation levels because of maintenance requirements.

The slight acceleration of naturally occurring erosion processes would be considered unmitigatable erosion. For example, runoff might increase when grass and asphalt replaced trees. Even with detention to slow the velocities, such increased runoff might accelerate erosion that would otherwise have occurred over a longer period of time. With proper mitigation, it is not anticipated that the erosion rates would be high enough to change the character of lakebed materials or to affect lake water quality by observable amounts.

### Slope Instability and Landslides

The overall risk of slope instability and landslides would be low because the project would be designed to account for steep slopes and unstable soils. In fact, it is likely that construction through some areas would increase long-term stability because the existing slopes are at a lower factor of safety than that which would be required for design of a roadway cut or structure.

### Seismic Hazards

The project corridor is located within a seismically active area. The consequences of earthquake-induced ground shaking during a seismic event are considered medium to high. These effects could include liquefaction of loose, saturated, cohesionless soils; settlement from densification of loose soils; instability of steep slopes; downdrag loads on deep foundations; decreased lateral resistance of deep foundations; or increased earth pressures on retaining walls. These direct effects could damage the constructed facilities. The design of the facilities and earth-retaining structures

**Densification:** To make soft or loose soils stronger by increasing the density of the soil. Various methods of densification can be used, including compaction, preloading, vibration, and dewatering.

would include seismic considerations so that collapse and irrepairable damage do not occur.

### Change in Groundwater Flow

Foundations, fills, or ground improvements included in the project design could alter groundwater flow paths beneath the ground surface. By itself, the volume of earth affected by foundations would be very limited relative to groundwater flow regimes in the area. The potential direct effects on groundwater flow are considered low for the options common to all projects.

### Long-term Soil Settlement

Settlement of compressible soils beneath retaining structures, lids, or earth fills for bridge approaches or embankments would represent a direct effect. Periodically, soil settlement could require maintenance of the new infrastructure. Long-term soil settlement would be mitigated during design and construction, so its effect during operation should be low.

## Area- and Option-specific Permanent Operational Effects

Exhibit 20 provides a qualitative rating of potential permanent effects for specific areas and options within the study area. This qualitative review does not replace the detailed geotechnical work that would be required during the design phases. A qualitative rating of the frequency or seriousness of the potential effects related to geology and soils was assigned, as follows.

- A low rating (L) was given to an effect that would have a low potential of occurring or if the effect would only occur in a localized area.
- A moderate rating (M) was given to an effect that would have a moderate potential to occur or if the effect would occur at multiple locations.
- A high rating (H) was given to an effect that would have a high potential to occur or if it could cause major effects; this rating triggers the need for more detailed studies.

Based on the preliminary information that was available when performing this evaluation, none of the effects was determined to be a fatal flaw (an undue risk) that would prevent operation of the project.

Exhibit 20. Summary of Area-specific Effect Potential during Operation

| Area | Geologic Hazard | | | | | Long-Term Effects |
|---|---|---|---|---|---|---|
| | Seismic Ground Shaking | Liquefaction | Seiche Risk | Erosion | Steep Slope/ Landslide | Long–Term Settlement |
| Seattle—Overall | M-H | M | L | M | M | M |
| Seattle—Option A | M-H | L | L | L | L | L |
| Seattle—Option K | M-H | M | L | L | L | M |
| Seattle—Option L | M-H | M | L | L | L | M |
| Lake Washington | M-H | L | L | M | M | L |
| Eastside Transition | M-H | L | L | M | L | L |
| Phased Implementation Scenario | M-H | M | L | M | M | M |
| No Build | H | M | L | L | M-H | M |

Rating Legend:

H = High potential of occurring. Could cause major effects and might affect construction costs. Would require detailed studies.

M = Moderate potential of occurring or occurs in multiple locations. Could have some effects. Would require special consideration. Can be addressed using normal design and construction methods.

L = Low potential of occurring or localized occurrence. Does not appear to be a design or construction issue. Only a few locations would require consideration during design.

N/A = not applicable

The most important geologic and soil hazard for operations would result from seismic ground shaking. The following subsections describe some potential area-specific operational effects. Geologic and soil issues would be addressed during final design. Experience demonstrates that, with the implementation of appropriate design, potential effects would be avoided.

## No Build Alternative

Under the No Build Alternative, because the project would not be built, some of the permanent operational effects noted previously (such as the risk of long-term settlement) would not occur. However, some permanent effects would remain. For example, seismic hazards and the related secondary effects would occur whether or not the project was built. The existing structures were designed without consideration of liquefaction. Therefore, compared to the 6-Lane Alternative, the existing structures would be more susceptible to soil liquefaction effects.

In 1965, a large slope area between 10th Avenue East and Delmar Drive East slid downward shortly after completion of the initial construction

of SR 520. Seismic loading was not considered in that slide remediation process, so the existing structure would be more vulnerable during a seismic event than the 6-Lane Alternative.

Seismic design was not a consideration in bridges designed prior to about 1972. Over the last several years, WSDOT studies have demonstrated that these aging spans are highly vulnerable to windstorms and earthquakes. The *SR 520's bridges are vulnerable to catastrophic failure* section of the Description of Alternatives Discipline Report (WSDOT 2009a) discusses the danger of structural failure of the Evergreen Point Bridge, including its approaches, and the Portage Bay Bridge. Exhibit 1-1 in Attachment 1 of that report shows the vulnerable sections of SR 520 and describes the vulnerabilities.

## 6-Lane Alternative

### Seattle

Permanent effects on geology and soils from operation of all the Seattle options might include the following:

- Steep slopes are located along the existing project alignment, and the roadway passes through areas of historical landsliding and landslide-prone soils. The overall risk of landslide effects would be low because slope stability would be considered during the design phases of the proposed structures.
- The structures would be designed to avoid collapse during the design seismic event. Maximum design shaking could cause damage that would require temporary closures for repair.
- Overall (global) stability analyses would be performed during design, and retaining walls would be engineered to stabilize the slopes. In some cases, the factor of safety with a structure or cut slope in place would be improved over the existing factor of safety. Theoretically, steep slopes along alignments with the potential for sliding would be considered a low risk. However, to account for potential unknowns in subsurface conditions, a low to medium risk has been assigned.
- The eastern end of the bridge over Portage Bay and the western end of the Lake Washington west approach structure would cross potentially liquefiable areas. Liquefaction could cause settlement, reduction in soil support around bridge foundations, or large earth loads on bridge foundations from lateral spreading or lateral flow of liquefied soil.

- Compressible soils beneath the embankments near the abutments on the east side of the Portage Bay Bridge, the west side of the Evergreen Point Bridge, and ramps in the Arboretum area might settle over time. Design would include settlement mitigating measures, but there is always some risk that unforeseen subsurface conditions could cause settlement that occurs for longer periods or in excess of that anticipated.

#### *Option A*

Permanent effects on geology and soils from operation of Option A would be similar to those described for all the Seattle options. However, the effects would be slightly larger in magnitude because of the extensive structures associated with the bascule bridge.

Operation of the bascule bridge would put large, repeated lateral and vertical loads on the foundation shafts. Shafts with cyclic loading of this type are less commonly designed and constructed than normal shafts, so the risk of long-term reduction in soil strength would be greater. More conservative design parameters would probably be used because of the unknowns, but the risk or construction cost would be increased.

#### *Option K*

In addition to the effects common to all Seattle options, Option K would also include potential effects from constructing extensive structures below the lake level.

Piles or tie-down anchors would be required to resist the buoyancy forces that would tend to float the large structural slabs for the roadways below the lake level. Although extensive design and load testing would be performed on these elements, the risk of damage to the facilities would be greater for this option than if the facilities were located above the lake level or with enough mass to prevent floating.

Although the below-water structures, including the tunnels, would be designed to be water-tight, some leakage would occur and an active pumping system would be required to remove water. Redundant systems would be designed to limit the risk of flooding. However, the need for long-term maintenance of these systems and the risk of failure would be larger than for the other options.

#### *Option L*

Permanent effects on geology and soils from operation of Option L would be similar to those described for all the Seattle options. However, the effects would be slightly larger in magnitude because of the large,

structure-supported SPUI in the Arboretum area and the extensive structures associated with the bascule bridge.

Operation of the bascule bridge would put large, repeated lateral and vertical loads on the foundation shafts. Shafts with cyclic loading of this type are less commonly designed and constructed than normal shafts, so the risk of long-term reduction in soil strength would be greater. More conservative design parameters would probably be used because of the unknowns, but the risk or construction cost would be increased.

### Lake Washington

The City of Seattle (under Ordinance 122370) classifies the shoreline and upland areas along Lake Washington within the study area as having an "unknown risk from seiches." The floating bridge would be located on Lake Washington. Permanent effects on geology and soils from operation of the Lake Washington elements might include the following:

- Seiche or tsunami risk to the bridge if the Seattle Fault Zone, located at the southern end of Lake Washington, were to rupture. During the design life of the bridge, the likelihood of a seiche or tsunami that would be large enough to damage the Lake Washington elements is considered low.
- Waves from wind in excess of those assumed could damage the structure.
- Unanticipated and undetected settlement of temporary or permanent anchors could damage the cables.
- A submarine landslide initiated by an earthquake might cause anchors to slide (Golder Associates 2003).
- A submarine landslide could induce a seiche. During the design life of the bridge, the likelihood that a submarine landslide would be large enough to induce a seiche of a magnitude that could damage the Lake Washington elements is considered low.

### Eastside Transition Area

Permanent effects on geology and soils from operation of the Eastside transition area elements might include the following:

- The City of Seattle (under Ordinance 122370) classifies the shoreline and upland areas along Lake Washington within the study area as having an "unknown risk from seiches." The maintenance facility

dock would be located on Lake Washington. Lake Washington might also have a tsunami risk if the Seattle Fault Zone, located at the southern end of Lake Washington, were to rupture. Small seiches in Lake Union have damaged docks and pulled them from their moorings. The project's maintenance facility dock would be designed with seismic considerations in mind. In addition, during the design life of the dock, the likelihood that the Seattle Fault Zone would rupture is considered low. Waves from wind in excess of those assumed could damage the structure.

- The maintenance facility would replace soil and an existing slope with a three-story-high building. This building would be designed to withstand the loads from landslide-prone soils, which would likely increase the stability of the existing slope. However, if unanticipated subsurface conditions exist, long-term, additional loading from increased groundwater levels or an earthquake could damage the structure.

### Phased Implementation Scenario

Permanent effects on geology and soils from operation of project elements delivered under a Phased Implementation scenario would be similar to those common to all Seattle options and the Lake Washington section.

# Mitigation

## What has been done to avoid or minimize negative effects?

This report discusses various procedures that could be implemented to avoid or minimize negative effects of the project related to geology and soils. The mitigation methods and procedures listed in this report are not a comprehensive listing of all mitigation methods and procedures, but they provide potential measures for expected project effects. Mitigation measures could be identified and evaluated during detailed engineering design and construction planning and could be finalized during the Record of Decision process.

### Use of Aggregate Resources

One approach to reduce the amount of imported aggregate could be to mix onsite materials that were slightly over optimum moisture content with additives (such as fly-ash or cement) to facilitate their re-use. This approach could be costly and require additional working space and time. Therefore, the trade-offs between re-use and hauling materials offsite would have to be carefully evaluated.

Another way to reduce the amount of imported aggregate could be to recycle existing pavements or structures. It is anticipated that some or all existing pavements and structures might be recycled for this project. Onsite aggregate recycling machinery would comply with applicable noise and air quality regulations. Scheduling and space requirements might limit which recycled materials could be used on this project. However, other projects in the Puget Sound area might need recycled aggregate materials.

### Seismic Hazard

Where movement of liquefiable soils could cause collapse or irrepairable damage to structures or critical utilities, the liquefiable materials could be stabilized by one of several methods of ground improvement. The zone of improvement commonly extends vertically from the ground surface to the limits of liquefiable material. The horizontal limits of ground improvement could be determined from slope stability analyses. At the current state of design development, no ground improvement is needed or planned. Typically, if ground

improvement is needed, it can be limited horizontally to the area several feet in front of and behind the bridge abutment fill walls. WSDOT policy does not require that liquefaction be prevented, only that soil deformations caused by liquefaction be limited to prevent collapse or irreparable damage to structures, walls, or critical utilities.

Typical methods of ground improvement could include the following:

- Stone columns, which are typically 3-foot-diameter columns of compacted gravel, spaced at approximately 7 to 10 feet
- Ground densification using vibro-densification or vibro-replacement methods
- Grouted columns of cement and soil that range in diameter from 2 to 5 feet
- Excavation and replacement with nonliquefiable soil

Vibro-densification: A ground improvement process used in cohesionless soils to make the soil denser. The action of the vibrator, usually accompanied by water jetting, reduces the inter-granular forces between the soil particles, allowing the soil particles to move into a denser configuration. Compaction can be achieved above and below the water table.

Where liquefiable soils are present beneath or adjacent to bridge or elevated structure columns, the soil could be improved or the bridge could be designed to withstand the lateral loading of the liquefied soil. Lightweight embankment materials are sometimes used to reduce the driving loads that could induce movement of the liquefied soil.

Construction methods used to improve soils that are subject to liquefaction during a seismic event could generate earth spoils and water with a high sediment content and high pH where cement was used. Spoils and runoff from spoils could be contained by ditches, silt fences, berms, or possibly sheet pits, depending on the location and topography. Runoff from spoils containment and storage areas could be monitored and treated if necessary to meet specified discharge criteria.

A seismic event could also initiate one of the known submarine landslides in Lake Washington (Golder Associates 2003). The stability of slopes with a history of landsliding will be evaluated in detail during final design so that the integrity of structural anchorages is maintained during the design earthquake.

## Long-term Settlement

Much of the roadway is through soils subject to long-term settlement. Deep foundations could support the bridges, with the foundations bearing in very dense, relatively incompressible material. However, in transitional areas, retaining structures and fill materials could be

constructed over normally consolidated (that is, not overridden by glaciers) silt or clay or over existing fill, which could settle over time. Engineering could be implemented to limit long-term settlement to levels that would not damage structures or substantially reduce the life of Portland cement concrete pavement. Example solutions to minimize long-term settlement include the following:

- Preloading the soil so that most of the anticipated primary settlement occurs prior to final grading
- Lengthening the construction period to allow time for the soils to consolidate before final grading or paving
- Installing vertical drains, possibly in combination with preloading, so that the predicted settlements occur quickly, before final grading
- Strengthening the ground by installing soil cement columns or stone columns, or by jet grouting or cement deep-soil mixing so that the total settlement, over any time period, would be reduced
- Reducing the weight of the earth fill by constructing it of closed-cell polystyrene blocks (that is, expanded polystyrene or Geofoam), imported pumice, expanded shale (all three of which are petroleum-intensive), or lightweight cellular concrete so that minimal settlement would be induced
- Constructing the embankment as a pile-supported embankment where deep foundations are used to transfer earth loads to incompressible strata
- Relocating or protecting utilities in locations where ground settlement could not be mitigated
- Underpinning structures if it appeared that new fill materials would cause settlement below existing structures
- Installing recharge wells for de-watering if construction de-watering analyses indicated that de-watering would result in settlement below structures or other settlement-sensitive facilities
- Modifying construction techniques (such as the type of pile or installation equipment)

Pre-, during-, and post-construction surveys of potentially affected structures and a construction monitoring program could be established, where necessary. These could include surface survey points and

subsurface instrumentation. The monitoring program could include the use of slope inclinometers to monitor horizontal movement, borehole extensometers or settlement plates to monitor settlement within different layers, and piezometers to monitor the dissipation of excess pore-water pressures resulting from fill placement.

Groundwater flow conditions, foundation support of adjacent existing structures, and construction scheduling could be considered during design to implement the proper solution for minimizing settlement. Restrictions could be added to construction contracts that specified means to avoid the settlement of nearby facilities during construction. If settlement of facilities is unavoidable or economically infeasible, contingency measures (such as regrading and paving roadways and rerouting or pumping buried utility lines) could be required.

## Landslide Hazards

Slopes and earth-retaining structures could be designed to provide either standard factors of safety or limited permanent movement during long-term static and seismic conditions.

Measures that could be used to reduce the risk of landslides include the following:

- Using design soil properties appropriate for the material
- Improving surface and subsurface drainage to increase soil strength
- Using retaining structures or ground anchors to stabilize slope movement
- Incorporating construction specifications and quality assurance programs that would maintain soil strength

The Lawton clay and other similar glacially overconsolidated clays (glaciolacustrine deposits [Qvgl] and transitional beds [Qtb]) are known to be landslide-prone in this area. Where the Lawton clay is present, the major causes of slope instability and methods of mitigation are typically as follows:

- 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 the Lawton clay (or similar materials) could result in the material losing a substantial amount of strength. The local design practice developed over several years has been to design walls for this residual soil strength and to limit

the height of temporary unsupported cuts and slopes so that movement was limited.

- Removing upper soil layers can sometimes allow surface water infiltration to saturate preexisting vertical cracks in the top of the Lawton clay; the water reduces the strength of the Lawton clay. Most of the widening could be by constructing walls rather than cutting, so there would be small risk of changing how water infiltrates. The addition of subsurface drainage in the form of seepage collection trenches and horizontal drains could be considered to lower the possibility of additional infiltration into the Lawton clay. Surface water runoff could be diverted around known clay slopes to minimize the risk of infiltration.
- 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 be used to control this type of sloughing.
- Cyclic weathering deterioration can reduce the strength of the Lawton clay. As noted previously, little is planned to change the topography outside of the roadway prism made by retaining walls. In some locations, however, surcharge weights might be considered over exposed Lawton clay to limit this strength loss.

The global stability of a hillside is considered during design. The boundaries of this stability analysis are natural features that tend to halt the natural progression of movement downslope, as illustrated on Exhibit 21. Therefore, the design would consider both the right-of-way and the surrounding property.

Where stability conditions appear to be uncertain, a monitoring program could be developed to monitor changes in pore-water pressures in the soil and horizontal movement during construction.

## Erosion and Sedimentation Control

A comprehensive temporary pollution control plan would be required before construction began. The temporary pollution control plan would be implemented using best management practices (BMPs) for erosion

control and a monitoring plan to ensure continued mitigation throughout construction.

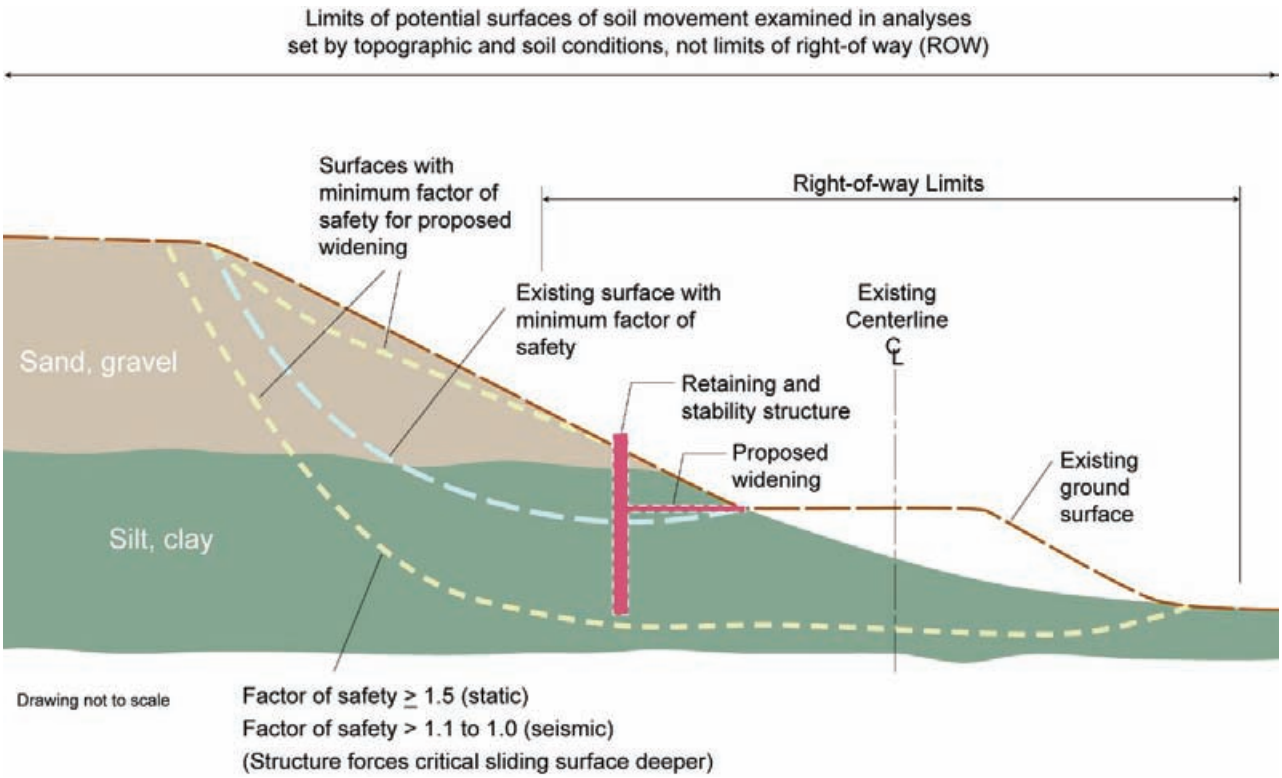


Exhibit 21. Limits of Slope Stability Analysis

Erosion and sedimentation could be reduced by limiting the work season to drier months of the year where soil was disturbed or where soil was exposed in erosion and landslide hazard areas. The contractor would be required to implement erosion and sedimentation control practices to limit the amount of suspended solids in the runoff that left the site and to apply BMPs to achieve water quality.

BMPs might include the following:

- Maintaining vegetative growth and providing adequate surface water runoff systems
- Using quarry spalls and, possibly, truck washes at construction vehicle exits from the construction site
- Regularly sweeping and washing adjacent roadways
- Constructing silt fences downslope of all exposed soil

- Using quarry spall-lined temporary ditches, with periodic straw bales or other sediment catchment dams
- Providing temporary covers over soil stockpiles and exposed soil
- Using temporary erosion-control blankets and mulching to minimize erosion prior to vegetation establishment
- Constructing temporary sedimentation ponds for removal of settleable solids prior to discharge
- Limiting the area exposed to runoff at any given time
- Frequently watering exposed surface soils to minimize visible dust

WSDOT, the contractor, and regulatory agency personnel would monitor BMP performance and compliance with all federal, state, and local regulations.

Permanent erosion control could be achieved by as the following:

- Constructing stormwater detention facilities to limit flow velocities
- Reestablishing erosion-resistant vegetation on disturbed slopes
- Collecting concentrated drainage in rock-lined ditches or pipes
- Providing energy dissipation upstream of discharge points where appropriate

These facilities and measures could be monitored to verify function and could be maintained, as necessary, over the life of the project.

## Vibration Mitigation

Construction specifications (including demolition specifications) could limit the amount of ground vibrations. The limitations would depend on the types of structures nearby and the consequences of any potential damage to these structures. To minimize the effect of ground vibrations during construction, equipment that minimizes the potential for vibration could be selected or operated.

Methods to minimize vibration may include the following:

- Using drilled piles or shafts instead of pile-driving
- Switching to a different hammer or preboring pilot holes before pile-driving

- Driving piles that are within water bodies inside cofferdams to attenuate vibrations (which could allow pile-driving work to continue during in-water fish windows) or scheduling as much pile-driving as possible to occur outside the fish window to reduce effects to fish

**Fish Window**

Time of year when juvenile salmonids and bull trout are least likely to be in the area. This is when in-water work is allowed.

- Using bubble curtains to minimize the effect of in-water vibrations on fish. Bubble curtains are further discussed in the Noise Discipline Report (WSDOT 2009b).

**Bubble Curtain**

Constant stream of bubbles provided by a submerged diffuser (usually a tube type), which surrounds a specified area.

A pile-vibration test program is planned for fall 2009. This test program involves collecting underwater and in-air sound data during test pile-driving using three sound attenuation methods to evaluate the geotechnical sound propagation characteristics in the study area and to provide information necessary for a contractor to design the temporary work trestles.

## Contaminated Soils

Contaminated soils, if encountered, could require special handling and disposal considerations. A project-specific health and safety plan could be developed to address potential worker hazards posed by the soil contamination. Workers performing the excavations could be required to wear special protective clothing. Requirements related to contaminated soils might include transporting soils in watertight bed liners, having trucks pass through wheel washes before leaving the work area, and disposing of such soils at regulated landfills. Additional discussions of hazardous waste issues are provided in the *Construction Effects Common to All Project Areas and Options* section and the Hazardous Materials Discipline Report (2009d).

## Groundwater

Where construction dewatering could result in settlement that might damage adjacent facilities, mitigation could include the following:

- Reinjecting the pumped groundwater between the dewatering wells and the affected facility
- Using construction methods that do not require dewatering, such as:
  - Slurry cutoff walls, secant pile walls, or sheet pile walls with a bottom tremie plug

  - Using existing low permeability soil layers to reduce flow under the walls

- Ground freezing used as a groundwater cutoff

# What would be done to mitigate negative effects that could not be avoided or minimized?

Negative effects on geology and soils could be minimized through mitigation. The only effects that could not be avoided are those related to seismic ground shaking.

# What negative effects would remain after mitigation?

An unavoidable adverse effect would be one that has a high likelihood of occurrence and would present a risk to public property or public safety, one that might require new locations for the project, or one that might require a different method of supporting a roadway or structure. An example of an unavoidable adverse effect for geology and soils would be a landslide risk on a new roadway in an area of steep slopes. In this example, it might be necessary to change the roadway alignment to reduce risk to an acceptable level.

The most substantial unavoidable adverse effect related to geology and soils is the potential effect of earthquake ground-shaking on the stability of soils supporting the project structural components. Appropriate mitigation methods are available to deal with the consequences of seismic loading, including mitigation for liquefaction potential and densification of the soil through use of ground improvement methods. In addition, designers must follow WSDOT and American Association of State Highway and Transportation Officials design requirements for seismic loading in their designs of all bridges, retaining walls, and related components of the project.

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# Attachment 1

## Collected Existing Geotechnical Information

Exhibit 1-1 lists existing geotechnical reports that were collected and evaluated in support of this Geology and Soils Discipline Report. Those reports that had duplicate information, did not have enough spatial references to be useful, or were of boring logs of less than 15 feet deep have not been included.

Exhibit 1-2 indicates areas for which existing information was collected.

Exhibit 1-1. **Existing Geotechnical Information**

| General Area | Date | Author or Consultant | Name of Document | Description of Reference | Geologic Descriptions | Geologic Plan View | Profiles/ Sections | Boring Logs | Slope Stability / Landslides | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| SR 520; Montlake | August 2001 | Shannon and Wilson | "Sound Transit, Montlake," Seattle, Washington, Prepared for Sound Transit, Boring No. NB-387, NB-388, NB-389, NB-394, NB-395. | Shannon and Wilson test borings and layout. | | | | X | | No section. |
| SR 520; Montlake I/C | November 18, 1960 | WSDOT | "Montlake Blvd Interchange, Test Hole Location," Department of Engineering, City of Seattle | Layout and stick borings; single, full-sized sheet. | | | | X | | |
| SR 520; Montlake I/C | September 26, 1961 | McKibben, W.E. (WSDOT) | "RO 467 - Montlake Interchange, Soil Investigation," Washington State Highway Commission, Department of Highways District No. 7 | Soil Investigation letter. | X | | | | | No figures; soil descriptions. |
| SR 520; Montlake I/C | June 1, 1961 | Bugge, W.A. (WSDOT) | "Montlake Interchange - City of Seattle Construction," Washington State Highway Commission, Department of Highways District No. 7 | Foundation/Embankment Letter. | X | | | X | | Soils investigation attached with written descriptions of logs. |
| SR 520; Montlake Bridge | May 1995 | Shannon and Wilson | "Geotechnical Recommendations, Seismic Evaluation of the Montlake Bridge, Seattle, Washington," prepared for Parsons Brinkerhoff | Shannon and Wilson seismic evaluation of bridge. | X | | X | | X | |
| SR 520; Montlake Blvd. | January 22, 1988 | Terracon | Response to Review Comments, U.S. West Tower Site, SEA 014, 2605 22nd Ave E. | Boring logs and site plan | | | | X | | |
| SR 520; Montlake Blvd. | June 28, 1945? | Dames and Moore | 2000 East Roanoke | Boring logs and site plan | | | | X | | |
| Montlake Blvd. | May 1994 | Shannon and Wilson | Geotechnical Report, Aquaculture Laboratory Addition, Northwest Fisheries Science Center | Portions of geotechnical report | | | | X | | |
| Montlake Bridge area | 1968 | Metropolitan Engineers | Final Report, Soils Investigation Montlake Regulator | Portions of geotechnical report | | | | X | | |
| Montlake Bridge area | February 1924 | City of Seattle | City of Seattle, Double Leaf Trunnion Bascule Bridge Over Lake Washington Ship Canal on Montlake Boulevard | Footing diagram and cross section | | | X | X | | |
| SR 520; Arboretum I/C | September 28, 1961 | Johnson, K.A. (WSDOT) | "R.O. 522 Second Lake Washington Bridge, West End, Arboretum Interchange, STA 46+50 to STA 55+00," District Soil Engineer | Arboretum I/C- written letter with boring layout. | X | | | X | | Boring logs in text, location on plan sheet. |
| SR 520; Arboretum I/C | October 1961 | WSDOT | "West-South Line, West Approach 2nd Lake Washington Bridge, Arboretum Interchange," Foundation Investigation, Materials Laboratory, Federal Road Division No. 8, Washington, Sheets 1-3 of 3 | West-South Line; Arboretum I/C; sections with stick logs. | | | X | X | | No plan view included. |
| SR 520; Arboretum I/C | October 1961 | WSDOT | "North-Montlake Line, West Approach 2nd Lake Washington Bridge, Arboretum Interchange," Foundation Investigation, Materials Laboratory, Federal Road Division No. 8, Washington, Sheets 1-3 of 3 | North-Montlake Line; Arboretum I/C; Sections with stick logs. | | | X | X | | No plan view included. |
| SR 520; Arboretum I/C | October 1961 | WSDOT | " West Montlake Line, West Approach 2nd Lake Washington Bridge, Arboretum Interchange," Foundation Investigation, Materials Laboratory, Federal Road Division No. 8, Washington, Sheets 1-2 of 2 | West Montlake Line; Arboretum I/C; Sections with stick logs. | | | X | X | | No plan view included. |
| SR 520; Arboretum I/C | October 1961 | WSDOT | " North-South Baseline, West Approach 2nd Lake Washington Bridge, Arboretum Interchange," Foundation Investigation, Materials Laboratory, Federal Road Division No. 8, Washington, Sheet 1 of 1 | North-South Baseline; Arboretum I/C; Sections with stick logs. | | | X | X | | No plan view included. California Pen. Logs mostly. |
| SR 520; Arboretum I/C | October 1961 | WSDOT | " North-East Line, West Approach 2nd Lake Washington Bridge, Arboretum Interchange," Foundation Investigation, Materials Laboratory, Federal Road Division No. 8, Washington, Sheets 1-3 of 3 | North-East Line; Arboretum I/C; Sections with stick logs. | | | X | X | | No plan view included. One sheet with California Pen and one with stick logs. |
| SR 520; Arboretum I/C | October 1961 | WSDOT | "East-West Line, West Approach 2nd Lake Washington Bridge, Arboretum Interchange," Foundation Investigation, Materials Laboratory, Federal Road Division No. 8, Washington, Sheets 1-4 of 4 | East-West Line; Arboretum I/C; Sections with stick logs. | | | X | X | | No plan view included. |
| SR 520; Arboretum I/C | October 1961 | WSDOT | "North-West Line, West Approach 2nd Lake Washington Bridge, Arboretum Interchange," Foundation Investigation, Materials Laboratory, Federal Road Division No. 8, Washington, Sheets 1 of 1 | North-West Line; Arboretum I/C; Sections with stick logs. | | | X | X | | No plan view included. One boring with a couple California Pen logs. |
| SR 520; Arboretum I/C | February 1961 | WSDOT | "2nd Lake Washington Bridge, Unit No. 2 West Approach Structure," Foundation Investigation, Materials Laboratory, Federal Road Division No. 8, Washington, Sheets 1-4 of 4 | Arboretum I/C; Approach Sections; no plan view. | | | X | X | | Sections with boring logs. Duplicates. |
| SR 520; Arboretum I/C | October 1961 | WSDOT | "Roanoke Expressway, Arboretum Interchange, Test Hole Location," Foundation Investigation, Materials Laboratory | Arboretum I/C; Boring Locations. | | | | | | Boring locations with proposed alignment for previous eight references. Duplicate. |
| SR 520; Arboretum I/C | March 1961 | WSDOT | "Test Boring Location, Roanoke Interchange to Evergreen Pt. Bridge, Arboretum Interchange" | Arboretum I/C; Boring Locations. | | | | | | Hand drawn - but neat. |
| SR 520; Arboretum I/C | June 1, 1962 | Johnson, K.A. (WSDOT) | "Cont. 6872. Arboretum Interchange Vic. N.S. Sta 77," Inter-department communication, Washington State Highway Commission, Department of Highways | Arboretum I/C inter-department communication. | | | | X | | Memo discussing borings and pile foundations. Maybe a duplicate of earlier material. |
| SR 520; Arboretum I/C | October 31, 1961 | Bugge, W.A. (WSDOT) | "Second Lake Washington Bridge, Arboretum Interchange, Foundation Investigation," Washington State Highway Commission, Department of Highways | Arboretum I/C letter on foundations. | X | | | | | One-page letter discussing foundations. |

Exhibit 1-1. **Existing Geotechnical Information**

| General Area | Date | Author or Consultant | Name of Document | Description of Reference | Geologic Descriptions | Geologic Plan View | Profiles/ Sections | Boring Logs | Slope Stability / Landslides | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| SR 520; Arboretum I/C | November 3, 1960 | Bugge, W.A. (WSDOT) | "Second Lake Washington Bridge, Arboretum Interchange, Test Hole Locations," Washington State Highway Commission, Department of Highways | Arboretum I/C letter with boring log descriptions. | | | | X | | Very brief boring log descriptions. |
| SR 520; Arboretum I/C | May 18, 1955 | Bugge, W.A. (WSDOT) | "2nd Lake Washington Bridge and Approaches," Washington State Highway Commission, Department of Highways | Arboretum I/C letter on borings and lab data. | X | | | X | | General soil profile descriptions included. |
| SR 520; Arboretum I/C | March 9, 1961 | Bugge, W.A. (WSDOT) | "Second Lake Washington Bridge, Unit No. 2 - West Approach Structure, Foundation Investigation," Washington State Highway Commission, Department of Highways | Arboretum I/C letter on Foundation Investigation. | X | | | | | General soil profile descriptions included. |
| SR 520; Arboretum I/C | October 5, 1958 | Bugge, W.A. (WSDOT) | Untitled Letter, Washington State Highway Commission, Department of Highways | Arboretum I/C letter on Toll Bridge Authority proposal for 520 bridge. | | | | | | Discusses thick peat layer, embankments, and disposal of peat. |
| SR 520; West Approach | October 1960 | WSDOT | "2nd Lake Washington Bridge, West Approach, Foundation Investigation," Materials Laboratory, Federal Road Division No. 8, Washington | Boring Locations; West Approach. | | | | | | Duplicate. |
| SR 520; West Approach | January 1961 | WSDOT | "Evergreen Point Bridge - West Approach, Test Boring Location & Profile," Federal Road Division No. 8, Washington | Plan/Profile of West Approach. | | | X | X | | Very helpful section. |
| SR 520; Union Bay | November 21, 1960 | Dunn, W.L. (UW) | "Some Characteristics of Union Bay Peat," Office of the University of Architect, University of Washington, Seattle | Report on Union Bay Peat. | X | | X | X | X | Discussion on properties of peat, geology of area, logs, sections, etc. |
| SR 520; Union Bay | 1962 | McManus, D.A. (UW) | "Postglacial Sediments in Union Bay, Lake Washington, Seattle, Washington," Contribution No. 281, Department of Oceanography, University of Washington, Vol. 37 | Post Glacial Sediments in Union Bay. | X | | X | | | Journal paper. |
| SR 520; Foster Island Area | 1987 | WSDOT | Windermere CSO | Boring logs and site plan | | | | X | | |
| SR 520; Foster Island Area | 1987 | WSDOT | Windermere CSO II | Boring logs and site plan | | | | X | | |
| SR 520; Arboretum I/C | 1985 | WSDOT | 1985 Arterial Resurfacing | Boring logs and site plan | | | | X | | |
| SR 520; Foster Island to Arboretum I/C Area | 1985 | WSDOT | Windermere CSO II | Boring logs and site plan | | | | X | | |
| SR 520; Foster Island Area | August 1961 | Horton Dennis and Associates | Report of Engineering Surveys, Empire Expressways Crossing of Union Bay | Portions of report | | | X | X | | |
| SR 520; Foster Island Area | May 8, 1962 | City of Seattle | East Park Drive E, et al, Sewer Replacement | Test hole logs and site plan | | | | X | | |
| SR 520; Foster Island Area | 1987 | WSDOT | Windermere CSO II-A | Boring logs and site plan | | | | X | | |
| SR 520; Montlake to I-5 | ? | ? | No Source - WSDOT Files?? | Boring locations. | | | | X | X | Plan and section on oversized sheet. |
| SR 520 Portage Bay | April 1961 | WSDOT | "West Approach 2nd Lake Washington Bridge, Portage Bay, Foundation Investigation, Federal Road Division No. 8, Washington, Materials Laboratory, Sheet 1, 2, and 3 of 3 | Foundation Investigation section. | | | X | X | | boring logs in section; full set of full sized, sheet 2 in half size too. |
| SR 520/I-5; Delmar Dr | July 2, 1967 | Shannon and Wilson | "Faculty Residence, Seattle Preparatory School." Sound Transit Files | Seattle Preparatory School; Plan and Profiles. | | | X | X | | May need better copy from Sound Transit. |
| SR 520; 10th Ave and Delmar | May 1961 | WSDOT | "2nd Lake Washington Bridge, 10th Ave N. Undercrossing" and "2nd Lake Washington Bridge, Delmar Drive Undercrossing Foundation Investigation," Materials Laboratory | 2nd Lake Washington Bridge (SR 520) 10th Ave and Delmar undercrossings. | | | X | X | | Profiles with stick logs; could be separate references. |
| SR 520; Roanoke I/C | March 1961 | WSDOT | "Roanoke Interchange to Evergreen Point Bridge, 10th Avenue N. Undercrossing," Materials Lab | Roanoke Interchange to Evergreen Point Bridge; 10th Ave N. undercrossing. | | | | | | Plan view of undercrossing; some boring locations; maybe related to SR 520; 10th Ave and Delmar |
| SR 520; Delmar | December 21, 1960 | WSDOT | "Test Boring Information, Evergreen Point Bridge West Approach, Vic. Delmar Drive," Federal Road Division No. 8, Washington, Sheet 1 of 1 | Test Boring Info for 520 near Delmar Drive. | | | | X | | Stick logs and layout. Could be associated with SR 520; 10th Ave and Delmar and SR 520; Roanoke I/C |
| SR 520; | August 13, 1958 | WSDOT | "Test Boring Location, 2nd Lake Washington Bridge - West Appr., Delmar Drive to Portage Bay," Toll Bridge Authority, Sheet 2 of 2 | SR 520 boring locations. | | | | | | Boring locations; plan view only. Could be associated with SR 520; 10th Ave and Delmar and SR 520; Roanoke I/C and SR 520; Delmar |
| SR 520; 10th Ave and Delmar | 1966 | Anon. (WSDOT?) | "Cause, Effect, and Corrective Action, Slide Vicinity N-E Ramp, Station 2341+00 on Right," Contract C-3544, PSH No. 1 (SR 520) | Discussion on landslide cause, effect and corrective action. | X | | X | | X | Lab data, verbal description, reports, sections; photos missing. |
| SR 520; 10th Ave and Delmar | January 4, 1965 | WSDOT | "10th Ave. Slide," As-Builts, Region No. 8, Washington | 10th Ave. Slide. | | | | X | X | Boring locations; plan view, stick logs, structural sections, corrective measures. |
| SR 520; Delmar Drive | December 20, 1960 | Johnson, K.A. (WSDOT) | "Evergreen Point Bridge, West Approach, RO 463, Structure Foundation, Vicinity of Delmar Drive," District Soils Engineer | Foundation Letter; missing attached figures. | X | | | | | Written descriptions only; foundation, soils, walls, etc. |
| SR 520; Delmar Drive | October 1960 | WSDOT? | "Evergreen Point Bridge, West Approach, Existing Drainage Installations, Delmar Drive to Boyer Avenue," Federal Road Division No. 8, Washington, Sheet 1 of 1 | Existing Drainage Installations; Delmar Drive to Boyer Ave. | | | X | | X | Single sheet with plan & profile of slide. |

Exhibit 1-1. **Existing Geotechnical Information**

| General Area | Date | Author or Consultant | Name of Document | Description of Reference | Geologic Descriptions | Geologic Plan View | Profiles/ Sections | Boring Logs | Slope Stability / Landslides | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| SR 520; 10th Ave to Delmar Dr | October 24, 1961 | WSDOT and Sound Transit files | "Primary State Highway No. 1, Roanoke Expressway, 10th Avenue North to Delmar Drive," Washington State Highway Commission, Department of Highways, Sheets 5, 6, 7, 8, 29, 30, 30-A, 31, 40, 51 | SR 520 As-Builts; 10th Ave to Delmar Dr. | | | | X | | Half-size sheets; some doubles, stick logs a last few sheets, wall and slope plans. |
| SR 520; Delmar | March 1966 | WSDOT | "Location of Test Holes, Delmar Drive East and 11th Avenue North Slide Area," WPA | Borings and slide location. | | | | X | X | Hand-drawn; with some as-builts. |
| Boyer Ave E, just N of SR 520 | November 26, 1990 | Earth Consultants, Inc. | Geotechnical Engineering Study, Addition to Queen City Yacht Club Building, 2608 Boyer Avenue E. | Portions of geotechnical report | | | | X | | |
| SR 520; Delmar Drive | March 1942 | WSDOT | Improvement of Delmar Drive Slide, Drainage System, Etc. | Boring logs and site plan | | | | X | X | |
| I-5: Mercer & Roanoke I/C | ? | Sound Transit files | Sound Transit Files. Boring logs on file at Sound Transit (not copied). | Sound Transit plot of boring locations. | | | | | | Boring logs not copied, but available at Sound Transit. |
| I-5; Roanoke St | ? | WSDOT files | WSDOT Files. | Roanoke St. undercrossing; foundations and stick log. | | | | X | | Plan with some boring location and section showing foundations; one stick log. No reference information. (Maybe part of I-5; E. Galer St to Shelby, 1958, WSDOT.) |
| I-5/SR520 I/C | October 1999 | Shannon and Wilson | Central Link Lightrail, LB235-GDR, prepared for Sound Transit (some documents not published) | Misc. Shannon and Wilson Boring logs/plans. | | | X | X | | Hand-drawn profiles and boring locations. |
| I-5: Galer St. to Newton | October 1, 1959 | WSDOT | "Primary State Highway No. 1, Seattle Freeway, East Galer St. to Lakeview Blvd. - Viaduct Plans," Washington State Highway Commission, Department of Highways, Federal and Interstate Project No. I-5-3(71)167 | Soil Test Data and Bridge/Viaduct Layout Plans. | | | X | X | | Stick Logs, Boring locations, pier locations. |
| I-5 & E. Galer St. | March 11, 1965 | WSDOT | "Seattle Freeway East Galer Street Slide Control Plans," King County, Sheets 2 through 6 | East Galer Street Slide Control Plans. | | | X | | X | Small x-section only. |
| N. Broadway & Lakeview Blvd | 1939 | Sound Transit files | Sound Transit Files. | North Broadway Storm Drainage Proposal. | | | X | | X | Maybe be better copy available from Sound Transit. |
| I-5; E. Republican to Galer St. | July 1961 | WSDOT | Primary State Highway No. 1, Seattle Freeway Plans, Republican Street to East Galer, King County, Washington State Highway Commission, Department of Highways | I-5 Cylinder Piles WSDOT Plans. | | | | | X | Retaining wall plans. |
| I-5; Olive Way to Galer Street | July 12, 1963 | Shannon and Wilson | "Foundation Studies, Seattle Freeway, E. Olive Way to Galer Street, Seattle, Washington," Prepared for Department of Highways, District 7 | Foundation Studies; Seattle Freeway. | X | | | X | X | Shannon and Wilson study of slope stability (Cylinder Piles): 3 copies and Appendix I. |
| I-5; Shelby to Ship Canal | May 1993 | Shannon and Wilson | "Geotechnical Seismic Evaluation, I-5 Ship Canal Bridge, Seattle, Washington," prepared for Anderson Bjornstad Kane Jacobs | Geotechnical Seismic Evaluation, I-5 Ship Canal Bridge, Seattle, Washington. | X | | X | X | X | Shannon and Wilson seismic study of bridge; good sections & boring logs. |
| I-5; Shelby to Ship Canal | February 16, 1959 | WSDOT | "Primary State Highway No. 1, Seattle Freeway Plans, Lake Washington Ship Canal BR, South Approach," Washington State Highway Commission, Department of Highways | Lake Washington Ship Canal Bridge Piers No. 18 to 24, Plans. | | | X | X | | Soil stick logs, sections, pier foundations; maybe several plans mixed together (dates are not same). Doubles of several sheets. |
| I-5; Ship Canal | July 3, 1958 | WSDOT | Primary State Highway No. 1, Seattle Freeway Plans, Lake Washington Ship Canal Bridge, piers No. 18 to 24, King County," Washington State Highway Commission, Department of Highways | Plans; boring layout and sections. | | | X | X | | Stick logs on sections, foundations, layout; Hand-drawn section included with plans. |
| I-5; Olive Way to Shelby | 1959 | WSDOT | Test Hole Location, Seattle Freeway Plans | Test hole location, Seattle Freeway. | | | X | X | | Boring locations and sections; need better copy (from Sound Transit). |
| I-5: Lakeview to Shelby | April 8, 1972 | WSDOT | "Seattle Freeway, Lakeview to Shelby, Foundation Investigation," Johnson, K.A., District Soils Engineer, Washington State Highway Commission, Department of Highways | Seattle Freeway, Lakeview to Shelby, Foundation Investigation. | X | | | | | Foundations, walls, soils - written descriptions only. |
| I-5; E. Galer St to Shelby | 1958 | WSDOT | Tunnel Section, Foundation Investigation, E. Galer to Shelby II. Job No. L-1940 | Tunnel Section, Foundation Investigation. | X | | X | X | | Doesn't look like published documents (no stamp). |
| I-5; E. Galer St to Shelby | August 5, 1958 | Johnson, K.A. (WSDOT) | "Soil Profile, Seattle Freeway, Olive Way to Shelby Street" | Hand-drawn sections with stick logs. | | | X | X | | Difficult to read. |
| I-5; Boylston Ave. and Louisa St. | July 29, 1996 | Earth Consultants, Inc. | Geotechnical Engineering Study, Proposed Seward School Renovation, 2515 Boylston Avenue E. | Portions of geotechnical report | | | | X | | |
| SR 520; Floating Bridge | March 1993 | Shannon and Wilson | "Seismic Evaluation, SR-520 Floating Bridge, Seattle, Washington," prepared for KPFF Consulting Engineers | Shannon and Wilson seismic evaluation of bridge. | X | | X | X | | |
| SR 520; Floating Bridge | February 2, 1997 | WSDOT | "SR 520, Evergreen Pt. Bridge, Anchor Cable Replacement," WSDOT, Layouts 1 and 2 | Evergreen Point Bridge Anchor Cable Replacement Plans. | | | X | | | Plan/profile of anchors; no soils info. |
| SR 520; East Approach | March 1955 | WSDOT | "Soil Profile, Lake Wash. Floating Bridge #2, Approach Eastside of Lake," Sheets 1-2 of 2 | Soil Profiles. | | | X | X | | No plan view. Stick logs included. |
| SR 520; East Approach | February 3, 1961 | Bugge, W.A. (WSDOT) | "Second Lake Washington Bridge, Unit No. 2 - East Approach Structure, Foundation Investigation," Washington State Highway Commission, Department of Highways | Foundation Investigation Letter on SR 520 East Approach. | X | | | | | Descriptions of geology, foundation recommendations. |
| SR 520; East Approach | July 1960 | WSDOT | "Second Lake Washington Bridge, Unit No. 2 - East Approach Structure," Federal Road Division No. 8, Washington, Sheet 5 | Plan & Profile of bridge foundations. | | | | | | Single sheet. No soils information. Foundation types included. |

Exhibit 1-1. **Existing Geotechnical Information**

| General Area | Date | Author or Consultant | Name of Document | Description of Reference | Geologic Descriptions | Geologic Plan View | Profiles/ Sections | Boring Logs | Slope Stability / Landslides | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| SR 520; East Approach | December 1960 | WSDOT | "Second Lake Washington Bridge, Unit No. 2 - East Approach Structure, Foundation Investigation," Materials Laboratory, Federal Road Division No. 8, Washington | Soil Profiles of each approach. | | | X | X | | No Plan view. Stick logs included. Duplicate. |
| SR 520; 76th, 84th, 92nd | March 1961 | WSDOT | "76th, 84th, and 92nd Ave Undercrossings, Easterly Approach, 2nd Lake Wash Brdg.," Federal Road Division No. 8, Washington | SR 520 Easterly Approach Borings and Foundation layout at 76th, 84th, and 92nd. | | | | X | | Stick logs and foundation types included. |
| SR 520; East Approach | March 15, 1961 | Bugge, W.A. (WSDOT) | "East Approach to Evergreen Point Bridge - Slide Area, Station 279+00 to Station 299+00, Foundation Investigation," Washington State Highway Commission, Department of Highways | Foundation Investigation Letter on SR 520 East Approach - Alignment change due to landslide. | X | | | X | X | Location given as, "along Points Drive, south of Yarrow Bay." Plan & Profiles Included. |
| UW | March 11, 1975 | Shannon and Wilson | Subsurface Investigation, Utility Tunnel Extension - 1975, Hall Health Center and Johnson Hall | Portions of geotechnical report | | | | X | | |
| UW | April 23, 1987 | Terra Associates, Inc. | Geotechnical Engineering Report, Indoor Tennis Facility | Portions of geotechnical report | | | | X | | |
| UW | October 16, 1990 | Dames and Moore | Report of Geotechnical Investigation, Proposed Physics/Astronomy Building | Portions of geotechnical report | | | | X | | |
| UW | February 1993 | RZA AGRA, Inc. | Subsurface Exploration and Geotechnical Engineering Report, University of Washington Boiler No. 4 Replacement | Portions of geotechnical report | | | | X | | |
| UW | May 3, 1989 | Rittenhouse-Zeman and Associates, Inc. | Geotechnical Review Comments, Proposed Stack Addition | Portions of geotechnical report | | | | X | | |
| UW | July 23, 1981 | Hart-Crowser and Associates, Inc. | Subsurface Exploration and Geotechnical Engineering Study, Proposed Addition to the Intramural Athletics Building | Portions of geotechnical report | | | | X | | |
| UW | June 24, 1988 | Shannon and Wilson | Geotechnical Report-West Stands Reconstruction, Husky Stadium | Portions of geotechnical report | | | | X | | |
| UW | May 1996 | AGRA | Subsurface Exploration and Preliminary Geotechnical Engineering Report, ICA Soccer and Baseball Field Development | Portions of geotechnical report | | | | X | | |
| UW | January 24, 1978 | Hart-Crowser and Associates, Inc. | Soils and Foundation Engineering Study, Proposed Biological Sciences Facility | Portions of geotechnical report | | | | X | | |
| UW | March 6, 1981 | Roger Lowe Associates, Inc. | Soil and Foundation Investigation, Proposed Neutron Therapy Building | Portions of geotechnical report | | | | X | | |
| UW | October 10, 1990 | Converse Consultants NW | Geotechnical Design Report, Proposed Health Sciences K-Wing Addition | Portions of geotechnical report | | | | X | | |
| UW | September 1995 | Shannon and Wilson | Geotechnical Report, University of Washington Medical Center, Linear Accelerator NN145D Replacement | Portions of geotechnical report | | | | X | | |
| UW | September 30, 1977 | Dames and Moore | Report of Soils Investigation, Proposed Freezer Box Addition | Portions of geotechnical report | | | | X | | |
| UW | January 1996 | Shannon and Wilson | Geotechnical Report for Seismic Upgrade, South Campus Parking Garage | Portions of geotechnical report | | | | X | | |
| UW | April 3, 1989 | Seattle Engineering Department | NE Pacific Street HOV | Portions of geotechnical report | | | | X | | |
| UW | March 1992 | Shannon and Wilson | Phase 2 NE 45th Street Viaduct | Portions of geotechnical report | | | | X | | |
| UW | July 1993 | Shannon and Wilson | Geotechnical Report, ICA Women's Softball Facility | Portions of geotechnical report | | | | X | | |
| UW | December 19, 1980 | Rittenhouse-Zeman and Associates, Inc. | Subsurface Exploration, Physical Plant Offices Addition | Portions of geotechnical report | | | | X | | |
| UW | November 1971 | Shannon and Wilson | Fuel Oil Storage Tank | Portions of geotechnical report | | | | X | | |
| UW | October 1975 | Rittenhouse-Zeman and Associates, Inc. | Proposed Chiller Building and Cooling Tower | Portions of geotechnical report | | | | X | | |
| UW | May 1996 | Milbor-Pita, Inc. | Subsurface Exploration and Geotechnical Engineering Study for UW Chiller No. 7 Addition Project | Portions of geotechnical report | | | | X | | |
| UW | May 1974 | Metropolitan Engineers | Final Report, Soils Investigation University Regulator | Portions of geotechnical report | | | | X | | |
| UW | September 1963 | Geo-Recon, Inc. | Intramural Athletic Building, Seismic Profiles | Portions of geotechnical report | | | | X | | |
| UW | March 2001 | Shannon and Wilson | Geotechnical Report, IMA Sports Field No. 3 | Portions of geotechnical report | | | | X | | |
| UW | October 19, 1990 | Converse Consultants NW | Geotechnical Design Report, Proposed Radiation Waste Facility/B-Wing | Portions of geotechnical report | | | | X | | |
| UW | April 9, 1990 | Converse Consultants NW | Geotechnical Design Report, Health Services GHI Wind Additions | Portions of geotechnical report | | | | X | | |
| UW | April 3, 2000 | AGRA | Limited Geotechnical Report, Outdoor Practice Facility | Portions of geotechnical report | | | | X | | |
| UW | February 11, 1972 | Shannon and Wilson | Soils Boring Mountain Climbing Practice Facility | Portions of geotechnical report | | | | X | | |
| UW | April 26, 1968 | Shannon and Wilson | Proposed Tennis Courts Intramural Project Area | Portions of geotechnical report | | | | X | | |
| UW | December 4, 1973 | Shannon and Wilson | Foundation Study, Hall Health Center Addition | Portions of geotechnical report | | | | X | | |
| UW | July 26, 1976 | Earth Consultants, Inc. | Soil and Foundation Investigation, Proposed Addition to Hec Edmundson Pavilion | Portions of geotechnical report | | | | X | | |
| UW | January 7, 1977 | Roger Lowe Associates Earth Sciences | Final Report Site Investigation Proposed Continuing Education Center | Portions of geotechnical report | | | | X | | |
| UW | March 6, 1981 | Roger Lowe Associates | Soil and Foundation Investigation, Proposed Neutron Therapy Building | Portions of geotechnical report | | | | X | | |
| UW | August 13, 1984 | Earth Engineers, Inc. | Geotechnical Engineering Study Roberts Hall Underground Building | Portions of geotechnical report | | | | X | | |
| UW | June 4, 1982 | Shannon and Wilson | Geotechnical Report, University of Washington Stadium Expansion | Portions of geotechnical report | | | | X | | |
| UW | June 18, 1970 | Dames and Moore | Report Test Borings to Check Sewer Location, Proposed Pedestrian Overpass | Portions of geotechnical report | | | | X | | |
| UW | April 1970 and June 1975 | Metropolitan Engineers | Rehabilitation North Interceptor, Phase III | Portions of geotechnical report | | | | X | | |

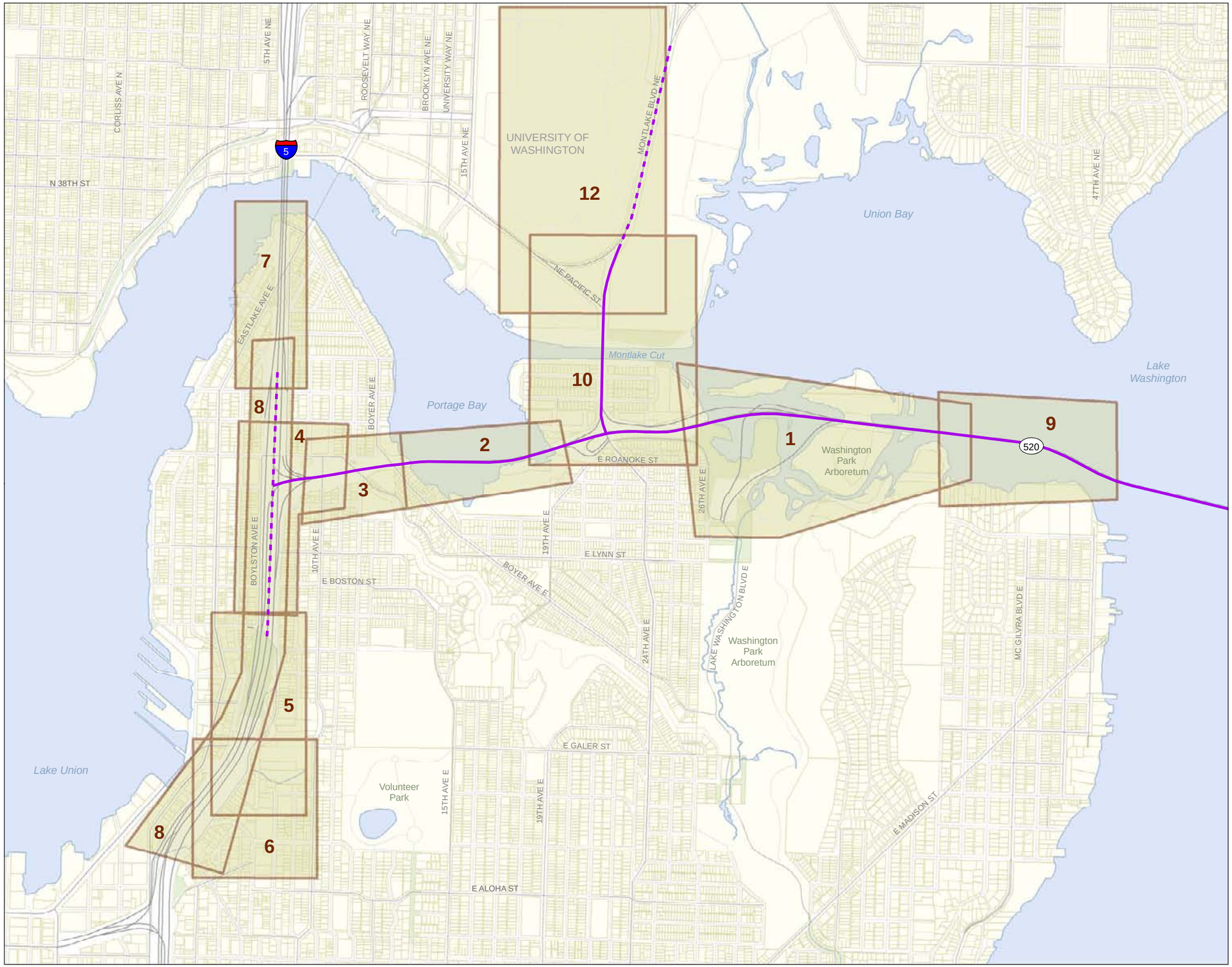
Exhibit 1-1. **Existing Geotechnical Information**

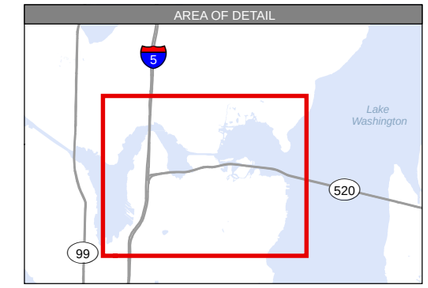
| General Area | Date | Author or Consultant | Name of Document | Description of Reference | Geologic Descriptions | Geologic Plan View | Profiles/ Sections | Boring Logs | Slope Stability / Landslides | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| UW | May 13, 1970 | Shannon and Wilson | Foundation Investigation Auxiliary Air System, Kirsten Wind Tunnel | Portions of geotechnical report | | | | X | | |
| UW | October 16, 1969 | Dames and Moore | Report of Soils Investigation, Proposed Pedestrian Overpass | Portions of geotechnical report | | | | X | | |
| UW | March 1968 | Dames and Moore | Report of Soils Investigation, Proposed Zoology Building | Portions of geotechnical report | | | | X | | |
| UW | April 25, 1967 | Dames and Moore | Report of Preliminary Soils Investigation, Proposed Printing Plant Building | Portions of geotechnical report | | | | X | | |
| UW | January 10, 1966 | Shannon and Wilson | Report on Foundation Investigation for Proposed Utility Tunnel Extensions, Central Campus and MRCD Complex | Portions of geotechnical report | | | | X | | |
| UW | May 10, 1966 | Dames and Moore | Report of Soils Investigation, Proposed Oceanography Building, Unit II | Portions of geotechnical report | | | | X | | |
| UW | July 23, 1969 | Dames and Moore | Report of Soils Investigation, Proposed Health Sciences Teaching Increment, Phase I | Portions of geotechnical report | | | | X | | |
| UW | November 1964 | Shannon and Wilson | Foundation Investigation, Project X | Portions of geotechnical report | | | | X | | |
| UW | February 25, 1969 | Dames and Moore | Report of Preliminary Soils Investigation, Proposed Electrical Receiving Station | Portions of geotechnical report | | | | X | | |
| UW | August 21, 1968 | Dames and Moore | Report of Additional Soils Investigation, Proposed Zoology Building | Portions of geotechnical report | | | | X | | |
| UW | July 21, 1966 | Dames and Moore | Report of Soils Investigation, Support of Floor Slab, Edmundson Pavilion | Portions of geotechnical report | | | | X | | |
| UW | March 1994 | Shannon and Wilson | Ravenna Creek Storm Drainage Project, NE 45th Street Diversion | Portions of geotechnical report | | | | X | | |
| UW | February 5, 2001 | Shannon and Wilson | Geotechnical Report, Intramural Activities Building Expansion | Portions of geotechnical report | | | | X | | |
| UW | June 27, 1996 | Dames and Moore | Report of Geotechnical Investigation, Oceanography Building 2122 | Portions of geotechnical report | | | | X | | |
| UW | November 1963 | Shannon and Wilson | Report on Foundation Studies, New Arts and Science Building and Garage | Portions of geotechnical report | | | | X | | |
| UW | August 1963 | Shannon and Wilson | Foundation Investigation, Residence Hall Unit IV | Portions of geotechnical report | | | | X | | |
| UW | April 21, 1967 | Shannon and Wilson | Phase II, Foundation Investigation, Power Plant Expansion - 1967 | Portions of geotechnical report | | | | X | | |
| UW | July 14, 1969 | Shannon and Wilson | University of Washington Physical Plan Services Building, Phase II | Portions of geotechnical report | | | | X | | |
| UW | October 1963 | Shannon and Wilson | Report on Foundation Investigation, Cooling Towers | Portions of geotechnical report | | | | X | | |
| UW | September 29, 1966 | Shannon and Wilson | Report on Union Bay Reclaimed Land | Portions of geotechnical report | | | | X | | |
| UW | January 25, 1965 | Dames and Moore | Foundation Evaluation and Review of Existing Data, Proposed Intramural Athletics Building | Portions of geotechnical report | | | | X | | |
| UW | October 9, 1964 | Shannon and Wilson | Intramural Athletic Building | Portions of geotechnical report | | | | X | | |
| UW | June 7, 1965 | Dames and Moore | Report of Soils Investigation, Revised Location, Proposed Intramural Athletics Building | Portions of geotechnical report | | | | X | | |
| UW | July 1962 | Shannon and Wilson | Foundation Investigation, Proposed Athletic Department Office Building | Portions of geotechnical report | | | | X | | |
| UW | September 2001 | Shannon and Wilson | Geotechnical Report, University of Washington Golf Driving Range | Portions of geotechnical report | | | | X | | |
| UW | July 1963 | Shannon and Wilson | Foundation Investigation for Proposed Utilities Tunnels | Portions of geotechnical report | | | | X | | |
| UW | November 21, 1989 | Seattle Engineering Department | NE 44th Street Pavement Settlement | Portions of geotechnical report | | | | X | | |
| UW | May 12, 1972 | Seattle Engineering Department | NE 45th Street Viaduct East Approach Replacement | Portions of geotechnical report | | | | X | | |
| UW | May 1965 and July 1965 | Dames and Moore | Proposed Intramural Athletics Building and Final Location of Intramural Athletics Building | Portions of geotechnical report | | | | X | | |
| UW | October 14, 1965 | Pacific Testing Laboratories | University of Washington Athletic Area Extension | Portions of geotechnical report | | | | X | | |
| UW | September 1, 1966 | Shannon and Wilson | University of Washington Engineering Classroom - Library | Portions of geotechnical report | | | | X | | |
| UW | August 1939 | Seattle Engineering Department | East 45th Street Viaduct Foundation Data | Portions of geotechnical report | | | | X | | |
| UW | June 25, 1970 | Dames and Moore | Report of Foundation Investigation, Proposed New Scientific Stores Addition | Portions of geotechnical report | | | | X | | |
| UW | September 1971 | Geolabs, Inc. | South Campus Center | Portions of geotechnical report | | | | X | | |
| UW | March 26, 1952 | Pacific Testing Laboratories | Subgrade Investigation, Teaching Hospital and Ultimate Hospital Development, Division of Health Sciences | Portions of geotechnical report | | | | X | | |
| UW | January 1986 | AESI | Site and Exploration Plan, Husky Stadium Expansion | Portions of geotechnical report | | | | X | | |
| UW | April 27, 1970 | Shannon and Wilson | Radiation Therapy and Hospital Clinic | Portions of geotechnical report | | | | X | | |
| UW | July 12, 1974 | Shannon and Wilson | Foundation Investigation for East Approach Replacement, NE 45th Street Viaduct | Portions of geotechnical report | | | | X | | |
| UW | August 28, 2003 | Shannon and Wilson | Plans Review, Conibear Shellhouse Renovation and Addition | Portions of geotechnical report | | | | X | | |
| UW | April 17, 1974 | Dames and Moore | Report of Soils Investigation, Proposed Aquatic Recreation Facility | Portions of geotechnical report | | | | X | | |
| UW | October 29, 1984 | Shannon and Wilson | Geotechnical Report, Montlake Triangle Garage, University of Washington | Portions of geotechnical report | | | | X | | |
| UW | December 14, 2001 | Shannon and Wilson | Memorandum, Sound Transit, Central Link Light Rail, Montlake Alignment | Portions of geotechnical report | | | | X | | |

Exhibit 1-1. **Existing Geotechnical Information**

| General Area | Date | Author or Consultant | Name of Document | Description of Reference | Geologic Descriptions | Geologic Plan View | Profiles/ Sections | Boring Logs | Slope Stability / Landslides | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| SR 520; Lake Wash. | 2000 | ? | "Figure 2, Navigational Corridor, University Bridge to Union Bay," Trans-Lake Washington Project | Navigational corridor of Union to Portage Bay. | | X | | | | Shows marsh locations. |
| Ship Canal | ? | Galster, R. W. | "Geologic Aspects of Navigation Canals of Western Washington," Engineering Geology in Washington Volume 2, Washington Division of Geology and Earth Resources Bulletin 78. | Engineering Geology discussion on ship canal construction. | X | | | | | General geology and construction information. |
| Ship Canal | ? | Chrzastowiski, M. | "Historical Changes to Lake Washington and Route of the Lake Washington Ship Canal, King County, Washington," Department of Interior, United States Geological Survey, Open File Report 81-1182. | Geological Survey discussion of ship canal. | X | | | | | |
| Ship Canal | 1992 | Willingham, W.F. | "Northwest Passages: A History of the Seattle District, U.S. Army Corps of Engineers, 1896-1920." | U.S. Army Corps of Engineers, Ship Canal construction. | X | | | | | Photos. |

Anon. = anonymous
HOV = high-occupancy vehicle
I/C = interchange
UW = University of Washington
WSDOT = Washington State Department of Transportation




Project Extent

Limited Improvement

Parcel

Park

12 General Area of Existing Geotechnical Information Listed in Exhibit 1-1

N

0 500 1,000 2,000 Feet

Source: King County (2005) GIS Data (Streams and Streets), King County (2007) GIS Data (Waterbodies), King County (2004) GIS Data (City Limits). Horizontal datum for all layers is NAD83(91); vertical datum for layers is NAVD88.

Exhibit 1-2. **Area of Collected Existing Geotechnical Information**

I-5 to Medina: Bridge Replacement and HOV Project

# Attachment 2

## Subsurface Profiles from Preliminary 10-Percent Design Geotechnical Report

# GEOLOGIC UNIT EXPLANATION

## NON OVERRIDDEN

### HOLOCENE DEPOSITS

| | |
|---|---|
| Hf | FILL: Fill placed by humans, both engineered and nonengineered. Various materials, including debris; cobbles and boulders may be common; commonly dense or stiff if engineered, but very loose to dense or very soft to stiff if nonengineered. |
| Hc | COLLUVIUM: Hillside slope accumulations. Commonly disturbed heterogenous mixture of more than one soil type, including organic debris. Loose or soft. |
| Hls | LANDSLIDE DEPOSITS: Deposits of landslides, normally at and adjacent to the toe of slopes. Disturbed, heterogeneous mixture of one or more soil types; may contain wood and other organics; loose or soft, with random dense or hard pockets. |
| Ha | ALLUVIUM: River or creek deposits, normally associated with historical streams, including deltaic and overbank deposits. Sand, silty Sand, gravelly Sand; very loose to very dense. |
| Hp | PEAT DEPOSITS: Depression fillings of organic materials. Peat, peaty Silt, organic Silt; very soft to medium stiff. |
| Hl | LAKE DEPOSITS: Depression fillings of fine-grained soils. Sandy Silt, Silt, clayey Silt, silty Clay; commonly with scattered organics; very soft to stiff or very loose to medium dense. |

### QUATERNARY VASHON DEPOSITS

| | |
|---|---|
| Qvro | RECESSIONAL OUTWASH DEPOSITS: Glaciofluvial sediment deposited as glacial ice retreated. Clean to silty Sand, gravelly Sand, sandy Gravel; cobbles and boulders common; loose to very dense. |
| Qvrl | RECESSIONAL LACUSTRINE DEPOSITS: Glaciolacustrine sediment deposited as glacial ice retreated. Fine Sand, Silt, and Clay; dense to very dense, soft to hard. |

## GLACIALLY OVERRIDDEN

### QUATERNARY VASHON DEPOSITS

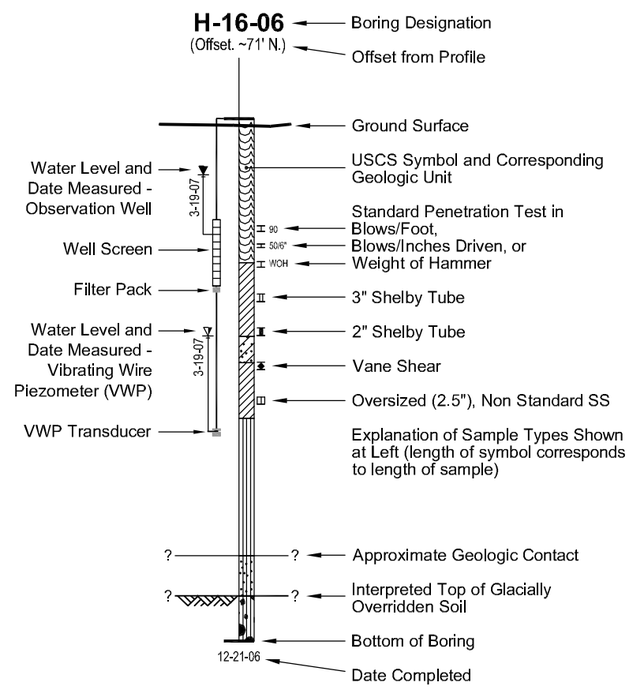
| | |
|---|---|
| Qvt | TILL: Lodgment till laid down along the base of glacial ice. Gravelly silty Sand, silty gravelly Sand ("hardpan"); cobbles and boulders common; very dense. |
| Qva | ADVANCE OUTWASH: Glaciofluvial sediment deposited as the glacial ice advanced through the Puget Lowland. Clean to silty Sand, gravelly Sand, sandy Gravel; dense to very dense. |
| Qvgl | GLACIOLACUSTRINE DEPOSITS: Fine-grained glacial flour deposited in proglacial lake in Puget Lowland. Silty clay, Clayey Silt, with interbeds of Silt and fine Sand; locally laminated; scattered organic fragments locally; hard or dense to very dense. |

### QUATERNARY PRE-VASHON DEPOSITS

| | | |
|---|---|---|
| Nonglacial | Qpnf | FLUVIAL DEPOSITS: Alluvial deposits of rivers and creeks. Clean to silty Sand, gravelly Sand, sandy Gravel; very dense. |
| | Qpnl | LACUSTRINE DEPOSITS: Fine-grained lake deposits in depressions, large and small. Fine sandy Silt, silty fine Sand, clayey Silt; scattered to abundant fine organics; dense to very dense or very stiff to hard. |
| Glacial | Qpgo | OUTWASH: Glaciofluvial sediment deposited as the glacial ice advanced or retreated through the Puget Lowland. Clean to silty Sand, gravelly Sand, sandy Gravel; very dense. |
| | Qpgl | GLACIOLACUSTRINE DEPOSITS: Fine-grained glacial flour deposited in proglacial lake in Puget Lowland. Silty Clay, clayey Silt, with interbeds of Silt and fine Sand; very stiff to hard or very dense. |
| | Qpgt | TILL: Lodgment till laid down along the base of glacial ice. Gravelly silty Sand, silty gravelly Sand ("hardpan"); cobbles and boulders common; very dense. |
| | Qpgm | GLACIOMARINE DEPOSITS: Till-like deposit with clayey matrix deposited in proglacial lake by icebergs, floating ice, or gravity currents. Variable mixture of Clay, Silt, Sand, and Gravel; scattered shells locally; cobbles and boulders common; very dense or hard. |

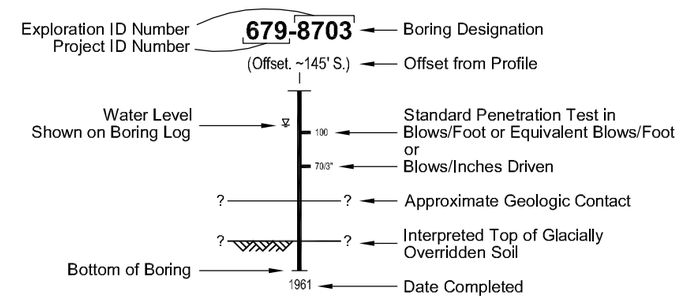
# PROFILE LEGEND

## PROJECT BORING




## PREVIOUS BORING

(By Shannon & Wilson or others)




## NOTES

1. This subsurface profile is generalized from materials presented on existing boring logs from several sources and in recent 10 Percent Design borings. Variations likely exist between the profile and actual conditions.
2. The locations of the existing explorations were determined from existing site plans and profiles, sometimes of marginal quality; they should not be considered exact.
3. Surface topography was developed from Microstation files received 8-9-06 and 10-4-06 from Parametrix.
4. Proposed road surface is from files received 2-20-07 from the project team.
5. Profiles and cross sections relate to the proposed alignments, received 8-9-06, as follows: West Approach, eastbound stationing line; 10th Avenue East, road centerline stationing; Delmar Drive East, road centerline stationing; Pacific Interchange / Union Bay Crossing, road centerline stationing; East Approach, eastbound stationing; Evergreen Point Road, road centerline stationing; 84th Avenue NE, road centerline stationing; 92nd Avenue NE, road centerline stationing; 96th to 108th, westbound road stationing; NE Points Drive, crosses westbound SR 520 approximately at stationing 332+11.4.
6. Refer to Appendix A for logs of previous borings; refer to Appendix B for logs of 10 Percent Design borings.

## LEGEND

MLW = Mean Low Water

MHW = Mean High Water

SR 520 Bridge Replacement
10 Percent Design

**PROFILE LEGEND AND GEOLOGIC UNIT EXPLANATION**

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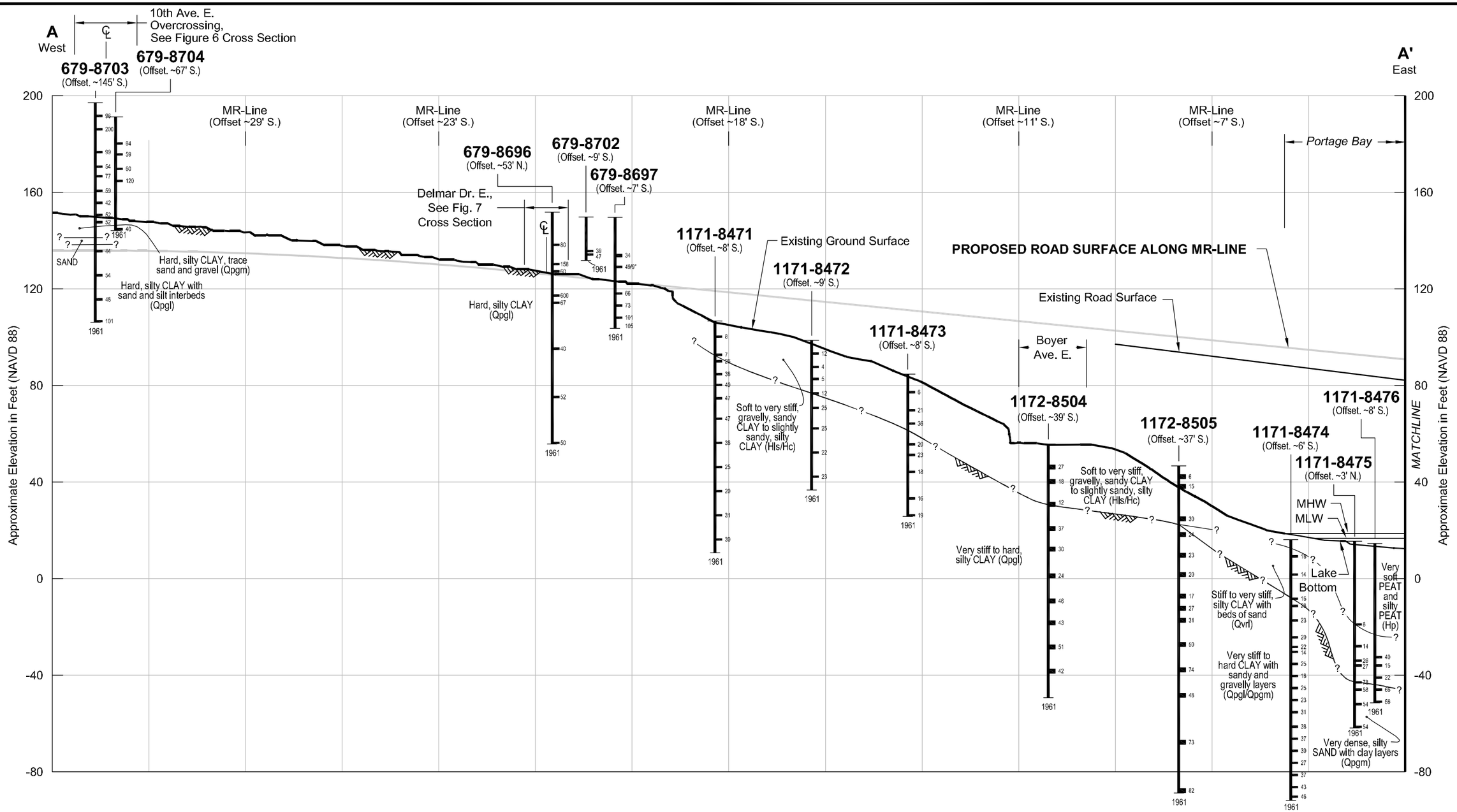
**FIG. 4**

**PRELIMINARY**

Filename: J:\211\20624-014\21-1-20624-014 Profiles Legend (Current).dwg Date: 05-25-2007 Login: BAC




NOTE

See Figure 4, Profile Legend and Geologic Unit Explanation, for legends and notes.

SR 520 Bridge Replacement
10 Percent Design

**GENERALIZED SUBSURFACE PROFILE A-A' WEST SIDE**

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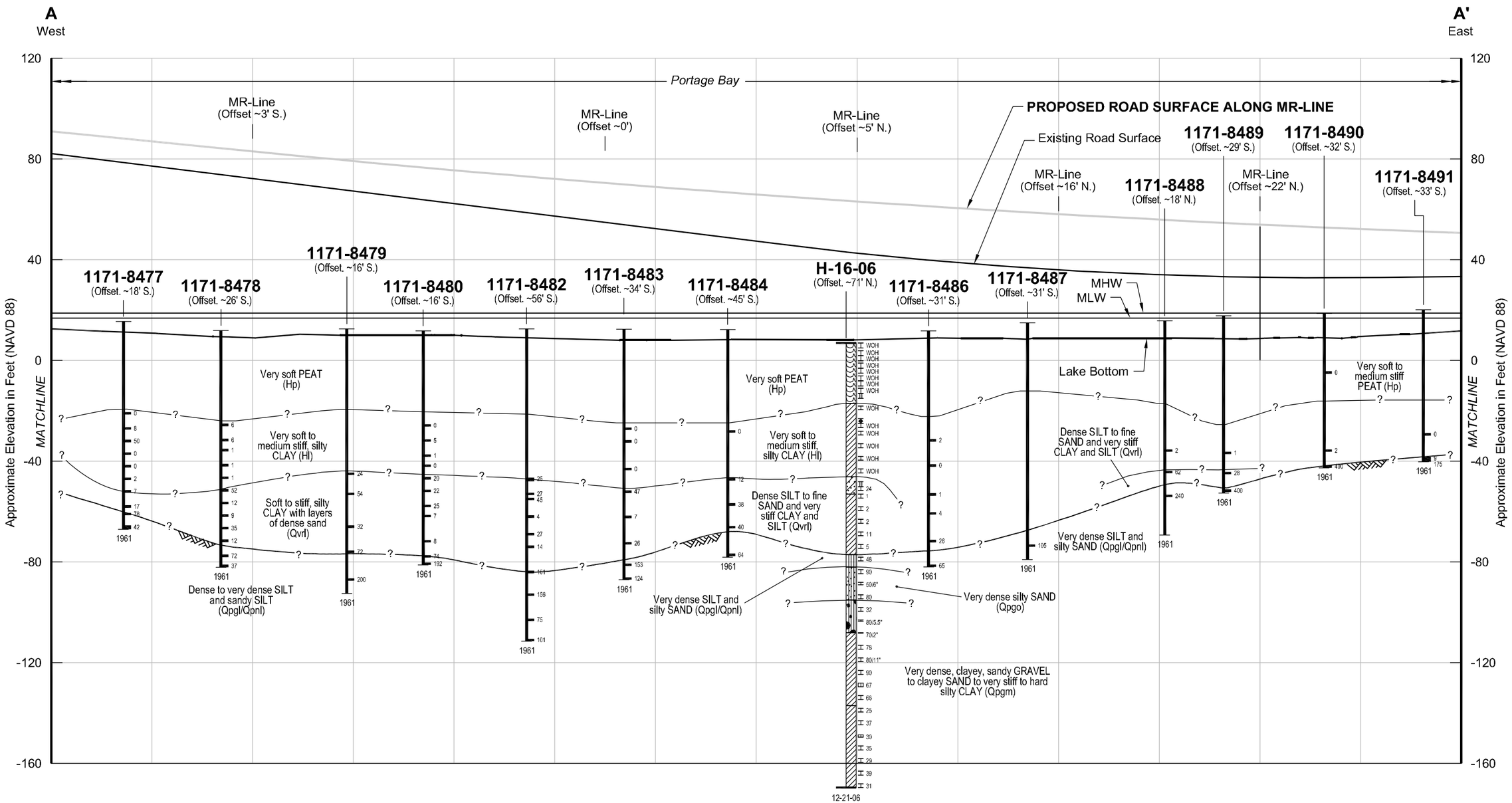
**FIG. 5**
Sheet 1 of 9

**PRELIMINARY**

Filename: J:\211\20624-014\21-1-20624-014 Profiles West (Current).dwg Layout: West Approach 1 Date: 05-25-2007 Login: BAC




0 40 80 — Vertical Scale in Feet

0 100 200 — Horizontal Scale in Feet

Vertical Exaggeration = 2.5X

NOTE

See Figure 4, Profile Legend and Geologic Unit Explanation, for legends and notes.

SR 520 Bridge Replacement
10 Percent Design

**GENERALIZED SUBSURFACE PROFILE A-A' WEST SIDE**

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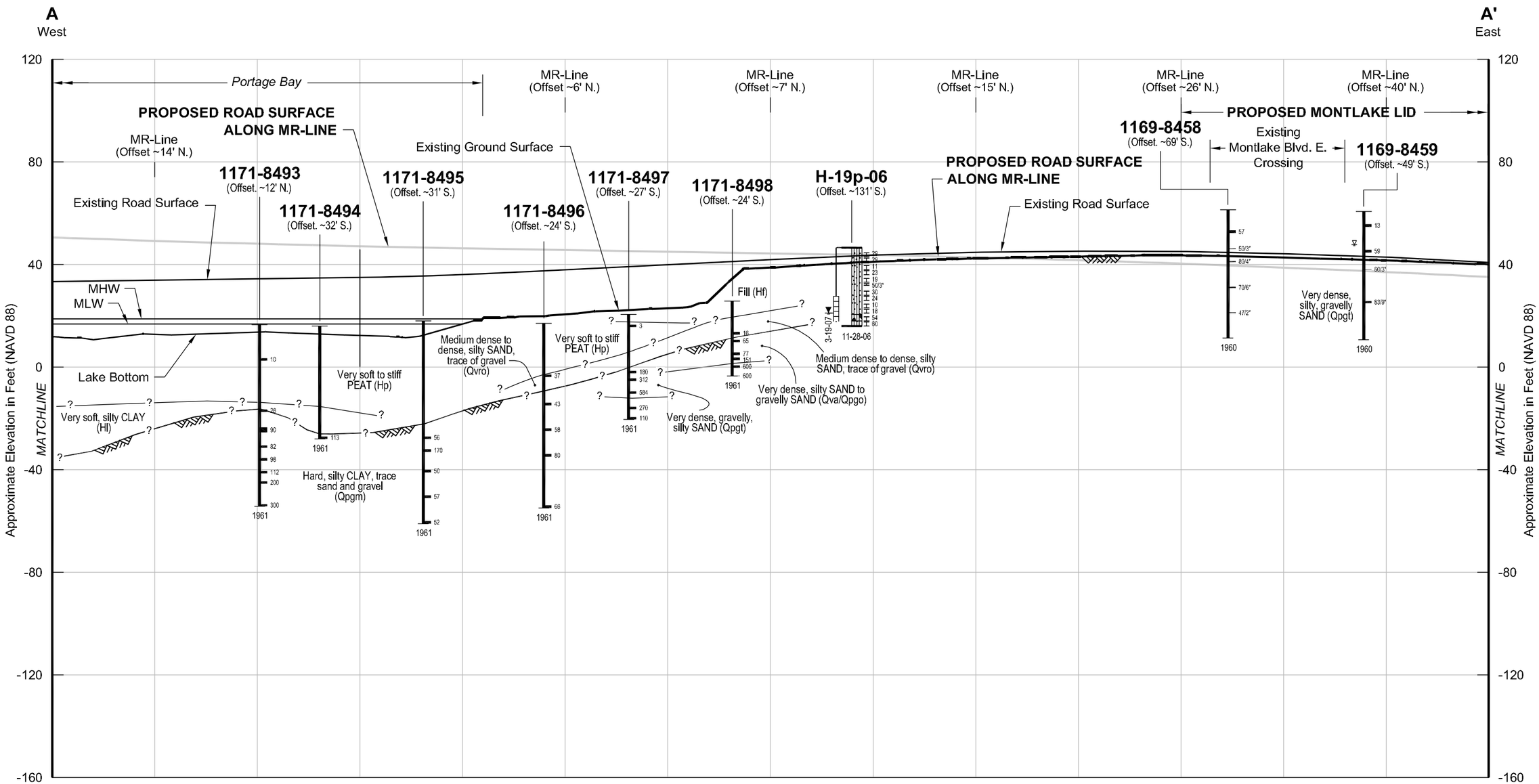
**FIG. 5**
Sheet 2 of 9

**PRELIMINARY**

Filename: J:\211\20624-014\21-1-20624-014 Profiles West (Current).dwg Layout: West Approach 2 Date: 05-25-2007 Login: BAC




0 40 80 — Vertical Scale in Feet

0 100 200 — Horizontal Scale in Feet

Vertical Exaggeration = 2.5X

NOTE

See Figure 4, Profile Legend and Geologic Unit Explanation, for legends and notes.

SR 520 Bridge Replacement
10 Percent Design

**GENERALIZED SUBSURFACE PROFILE A-A' WEST SIDE**

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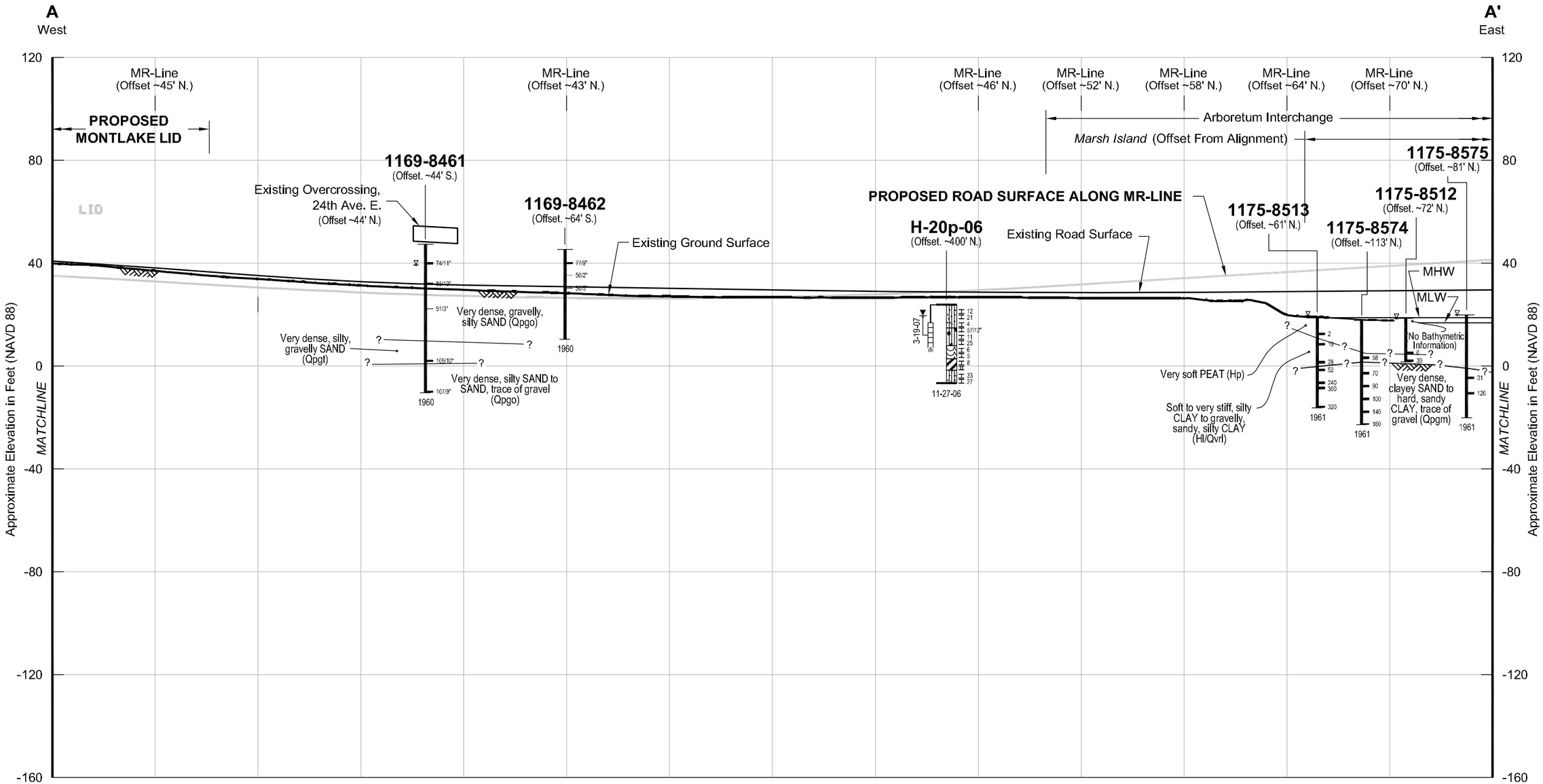
**FIG. 5**
Sheet 3 of 9

**PRELIMINARY**

Filename: J:\211\20624-014\21-1-20624-014 Profiles West (Current).dwg Layout: West Approach 3 Date: 05-25-2007 Login: BAC




0 40 80 — Vertical Scale in Feet

0 100 200 — Horizontal Scale in Feet

Vertical Exaggeration = 2.5X

NOTE

See Figure 4, Profile Legend and Geologic Unit Explanation, for legends and notes.

SR 520 Bridge Replacement
10 Percent Design

**GENERALIZED SUBSURFACE PROFILE A-A' WEST SIDE**

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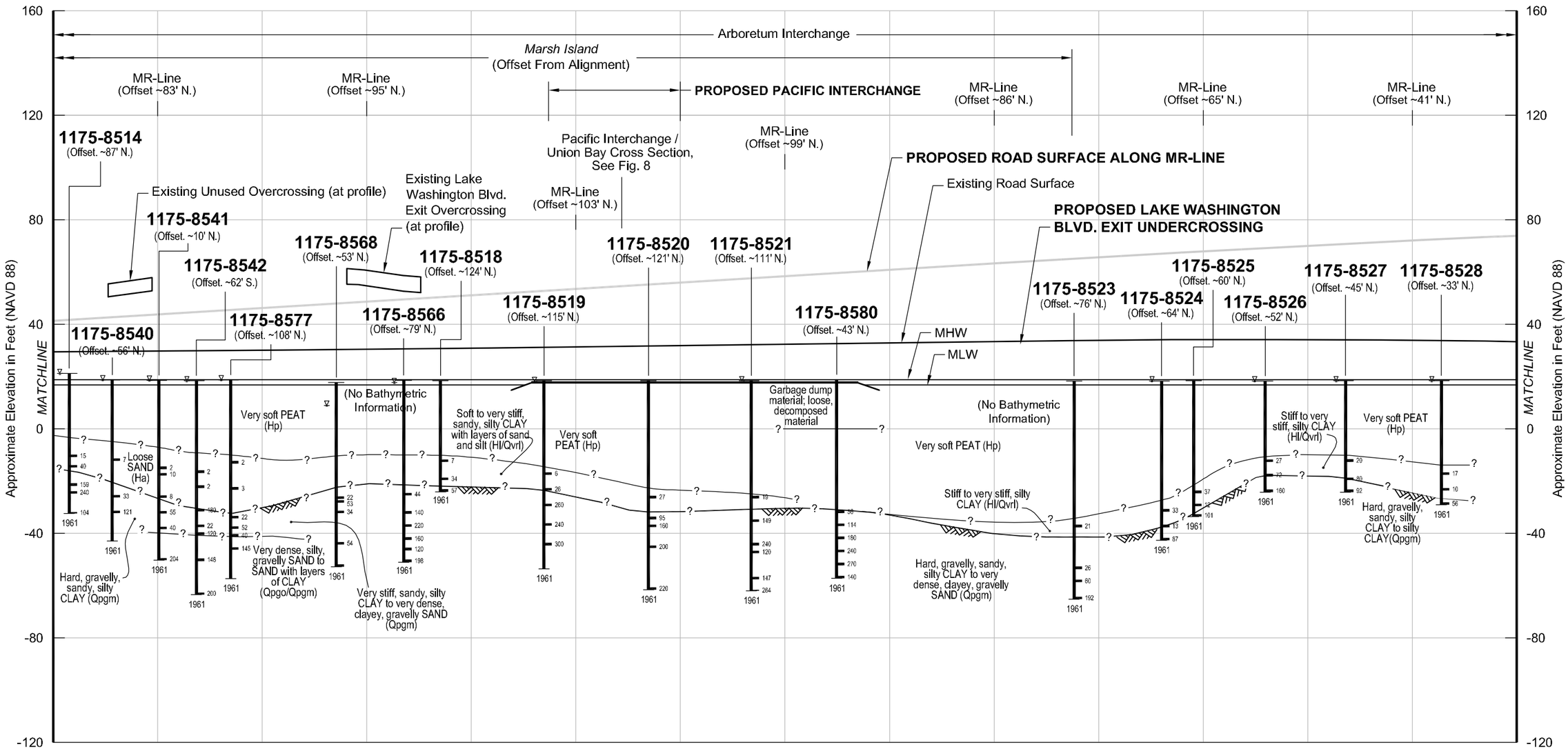
**FIG. 5**
Sheet 4 of 9

**PRELIMINARY**

Filename: J:\21\20624-014\21-1-20624-014 Profiles West (Current).dwg Layout: West Approach 4 Date: 05-25-2007 Login: BAC




0 40 80
Vertical Scale in Feet

0 100 200
Horizontal Scale in Feet

Vertical Exaggeration = 2.5X

NOTE

See Figure 4, Profile Legend and Geologic Unit Explanation, for legends and notes.

SR 520 Bridge Replacement
10 Percent Design

**GENERALIZED SUBSURFACE PROFILE A-A' WEST SIDE**

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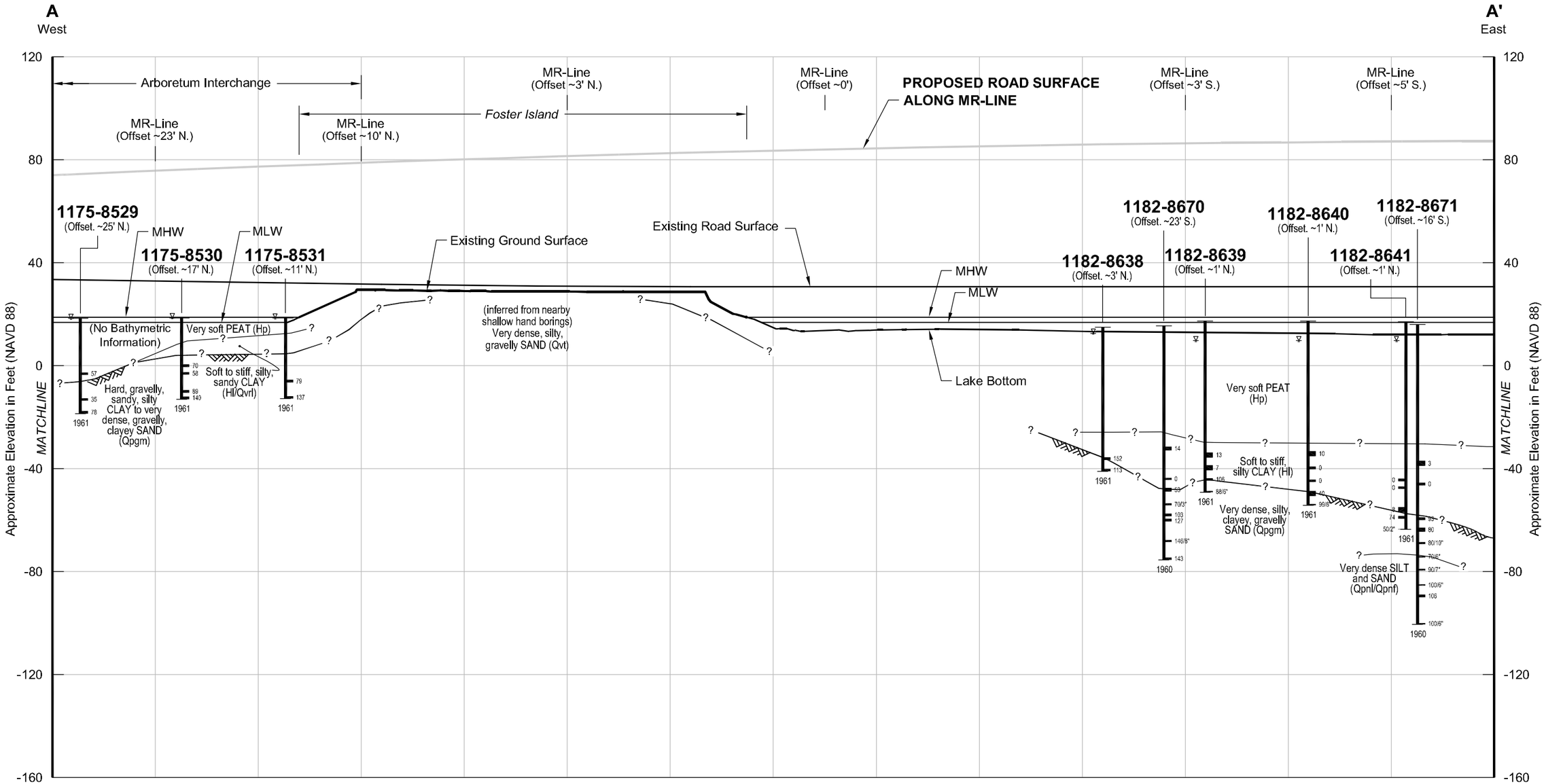
**FIG. 5**
Sheet 5 of 9

**PRELIMINARY**

Filename: J:\211\20624-014\21-1-20624-014 Profiles West (Current).dwg Layout: West Approach 5 Date: 05-25-2007 Login: BAC




0 40 80
Vertical Scale in Feet

0 100 200
Horizontal Scale in Feet

Vertical Exaggeration = 2.5X

NOTE

See Figure 4, Profile Legend and Geologic Unit Explanation, for legends and notes.

SR 520 Bridge Replacement
10 Percent Design

**GENERALIZED SUBSURFACE PROFILE A-A' WEST SIDE**

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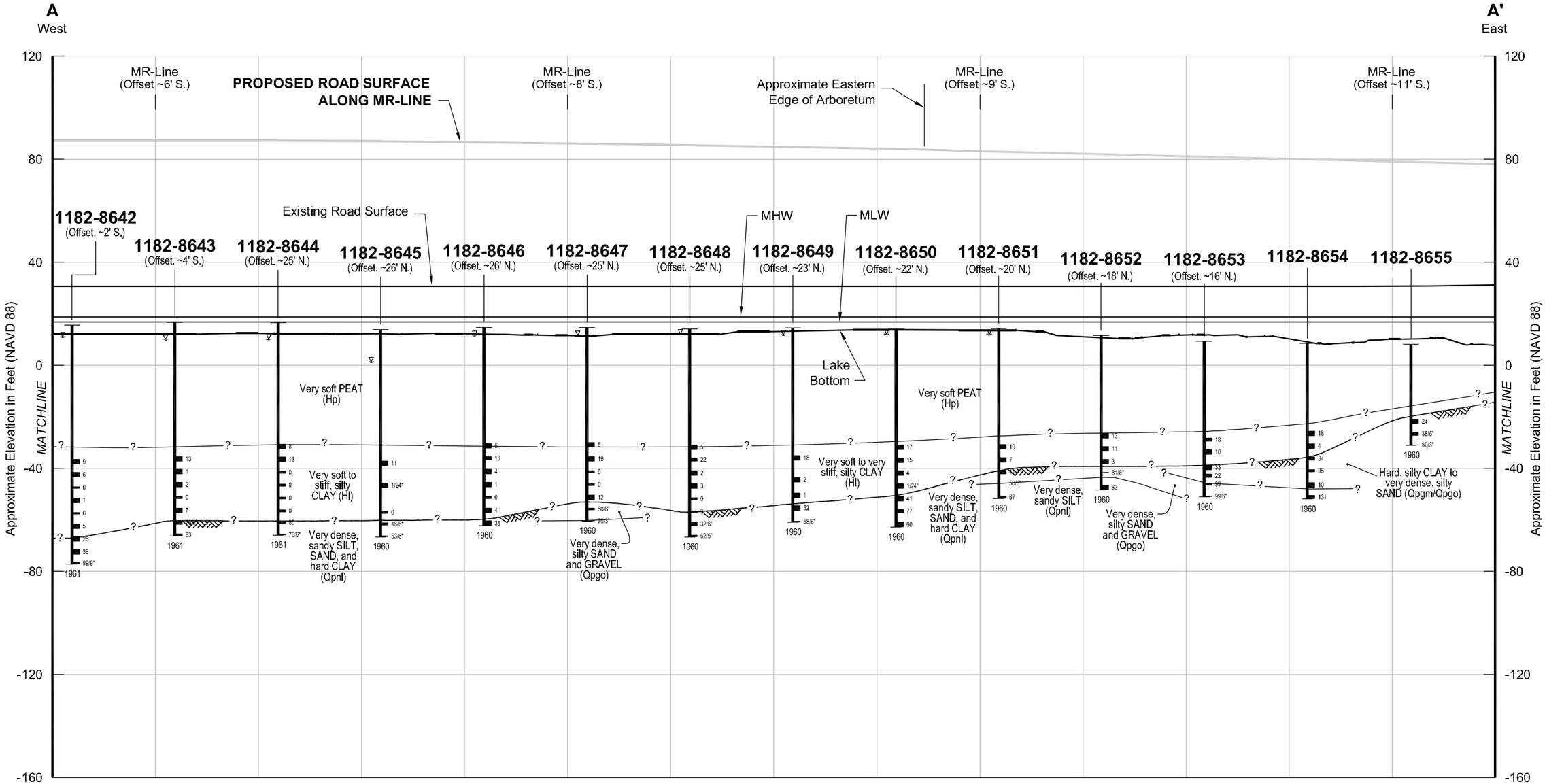
**FIG. 5**
Sheet 6 of 9

**PRELIMINARY**

Filename: J:\211\20624-014\21-1-20624-014 Profiles West (Current).dwg Layout: West Approach 6 Date: 05-25-2007 Login: BAC




0 40 80 — Vertical Scale in Feet

0 100 200 — Horizontal Scale in Feet

Vertical Exaggeration = 2.5X

NOTE

See Figure 4, Profile Legend and Geologic Unit Explanation, for legends and notes.

SR 520 Bridge Replacement
10 Percent Design

**GENERALIZED SUBSURFACE PROFILE A-A' WEST SIDE**

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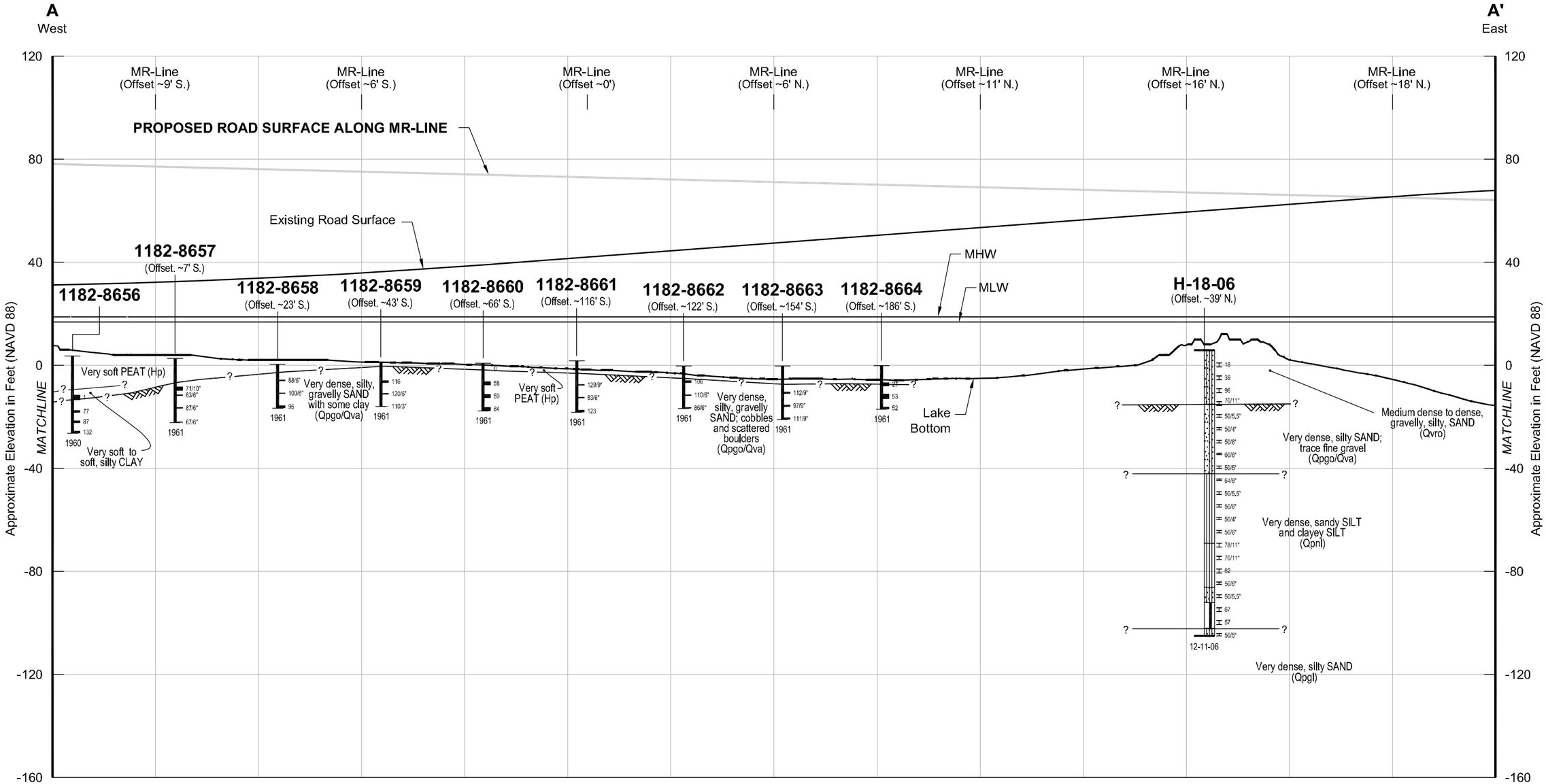
**FIG. 5**
Sheet 7 of 9

**PRELIMINARY**

Filename: J:\211\20624-014\21-1-20624-014 Profiles West (Current).dwg Layout: West Approach 7 Date: 05-25-2007 Login: BAC




0 40 80
Vertical Scale in Feet

0 100 200
Horizontal Scale in Feet

Vertical Exaggeration = 2.5X

NOTE

See Figure 4, Profile Legend and Geologic Unit Explanation, for legends and notes.

SR 520 Bridge Replacement
10 Percent Design

**GENERALIZED SUBSURFACE PROFILE A-A' WEST SIDE**

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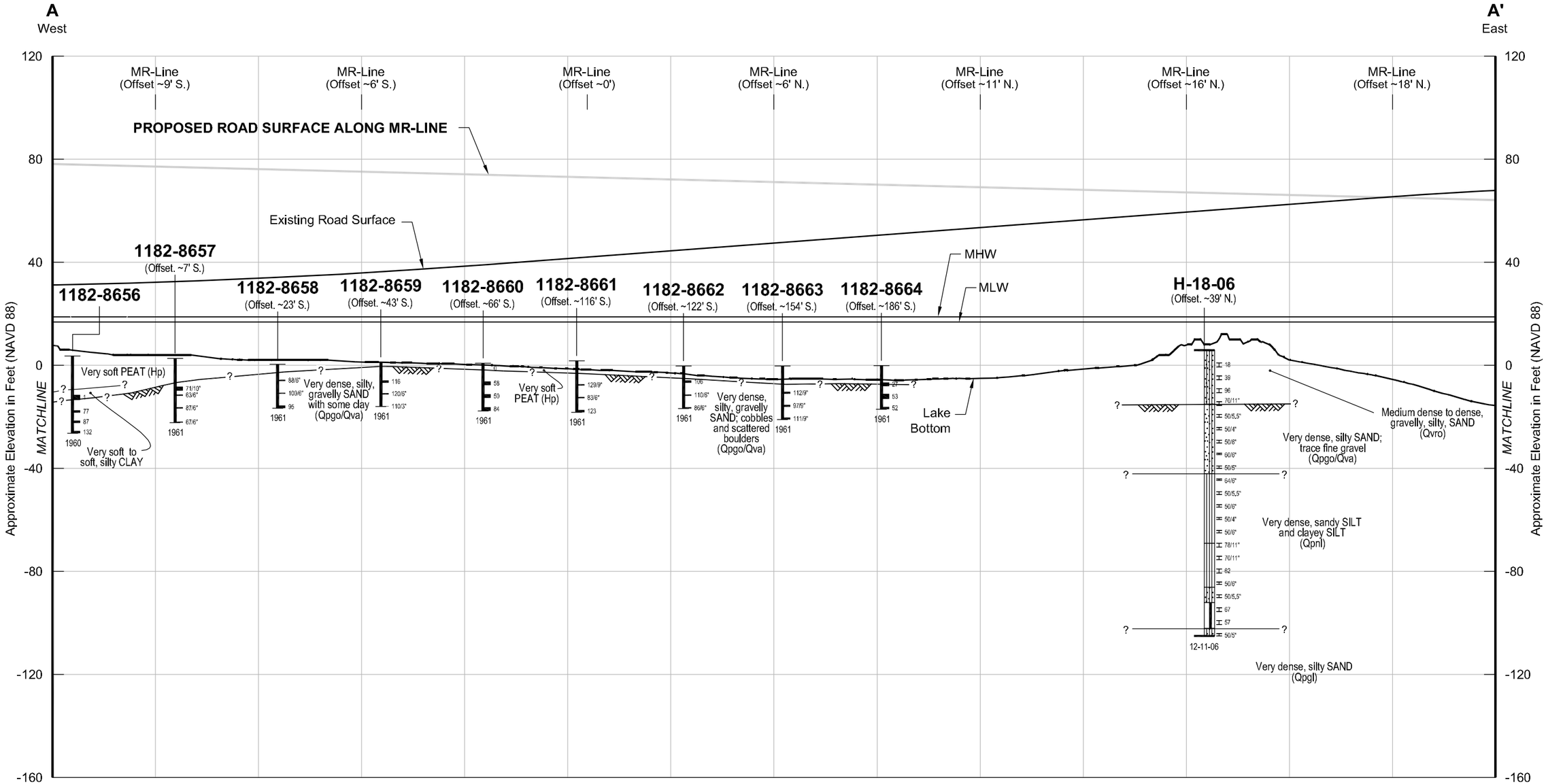
**FIG. 5**
Sheet 8 of 9

**PRELIMINARY**

Filename: J:\211\20624-014\21-1-20624-014 Profiles West (Current).dwg Layout: West Approach 8 Date: 05-25-2007 Login: BAC




0 40 80
Vertical Scale in Feet

0 100 200
Horizontal Scale in Feet

Vertical Exaggeration = 2.5X

NOTE

See Figure 4, Profile Legend and Geologic Unit Explanation, for legends and notes.

SR 520 Bridge Replacement
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**GENERALIZED SUBSURFACE PROFILE A-A' WEST SIDE**

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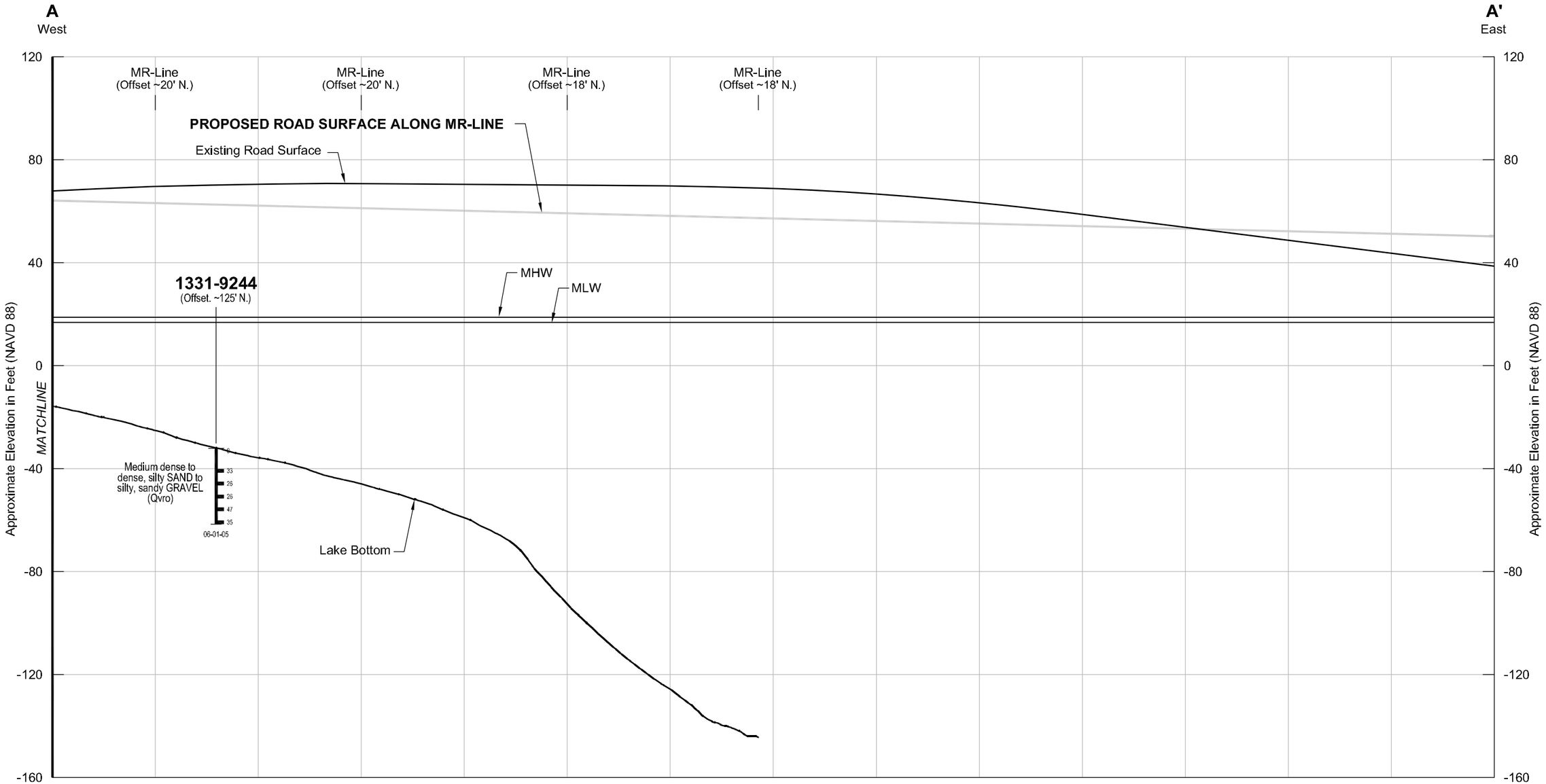
**FIG. 5**
Sheet 8 of 9

**PRELIMINARY**

Filename: J:\211\20624-014\21-1-20624-014 Profiles West (Current).dwg Layout: West Approach 8 Date: 05-25-2007 Login: BAC




0 40 80
Vertical Scale in Feet

0 100 200
Horizontal Scale in Feet

Vertical Exaggeration = 2.5X

NOTE

See Figure 4, Profile Legend and Geologic Unit Explanation, for legends and notes.

SR 520 Bridge Replacement
10 Percent Design

**GENERALIZED SUBSURFACE PROFILE A-A' WEST SIDE**

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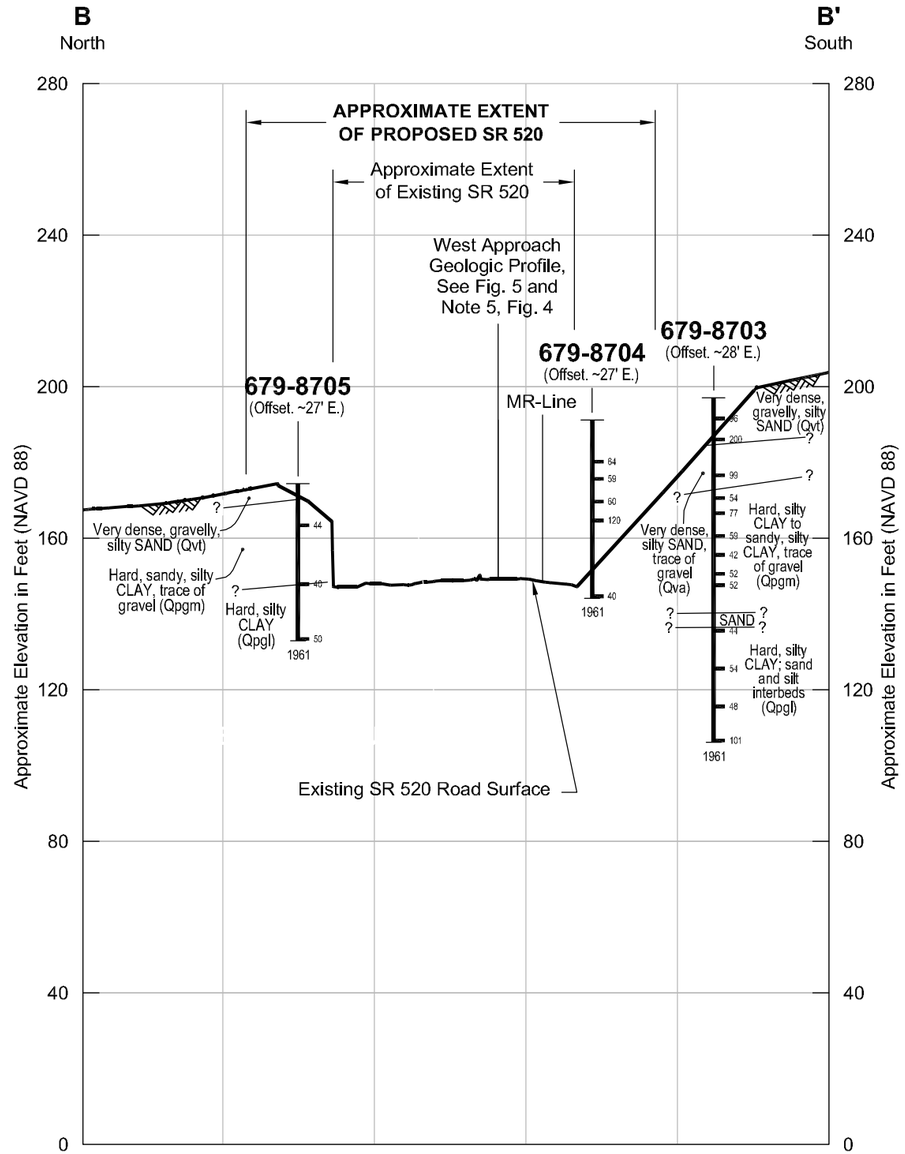
**FIG. 5**
Sheet 9 of 9

**PRELIMINARY**

Filename: J:\211\20624-014\21-1-20624-014 Profiles West (Current).dwg Layout: West Approach 9 Date: 05-25-2007 Login: BAC




0 40 80
Vertical Scale in Feet

0 100 200
Horizontal Scale in Feet

Vertical Exaggeration = 2.5X

NOTE

See Figure 4, Profile Legend and Geologic Unit Explanation, for legends and notes.

SR 520 Bridge Replacement
10 Percent Design

**GENERALIZED SUBSURFACE CROSS SECTION B-B'**
**10TH AVENUE EAST**

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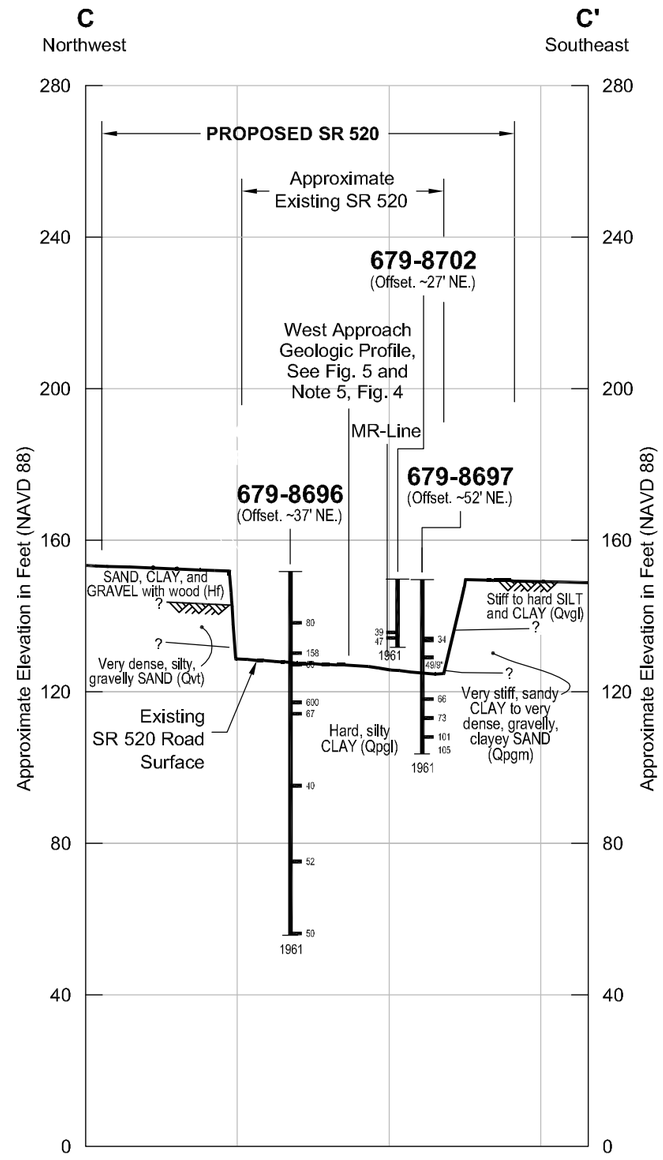
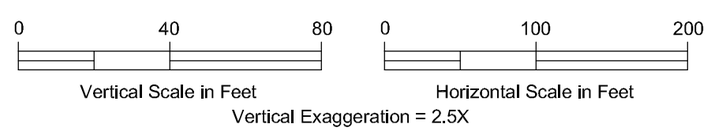
**FIG. 6**

**PRELIMINARY**

Filename: J:\211\20624-014\21-1-20624-014 Profiles West (Current).dwg Layout: 10th Date: 05-25-2007 Login: BAC




NOTE

See Figure 4, Profile Legend and Geologic Unit Explanation, for legends and notes.

SR 520 Bridge Replacement
10 Percent Design

**GENERALIZED SUBSURFACE CROSS SECTION C-C' DELMAR DRIVE EAST**

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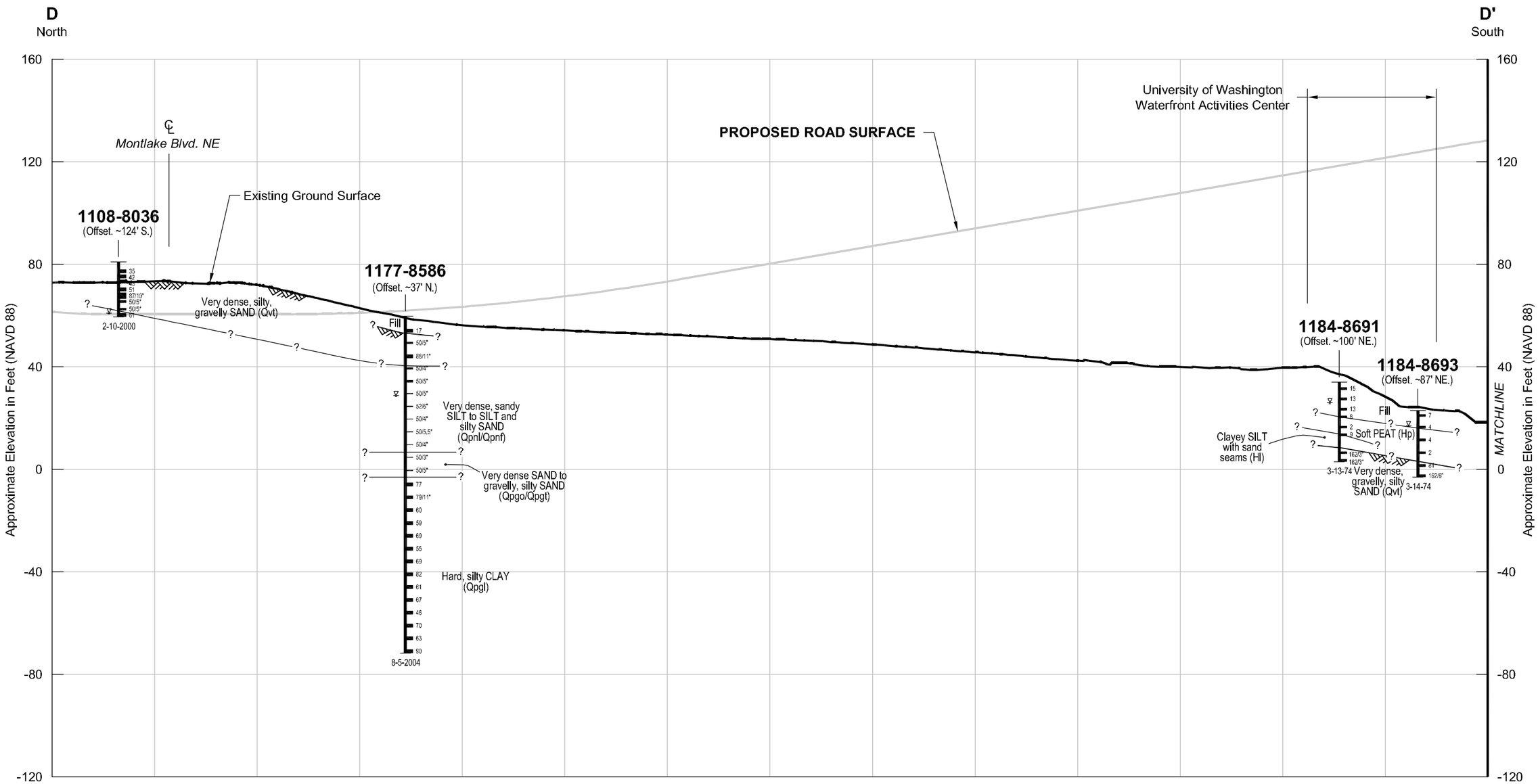
**FIG. 7**

**PRELIMINARY**

Filename: J:\211\20624-014\21-1-20624-014 Profiles West (Current).dwg Layout: Delmar Date: 05-25-2007 Login: BAC




0 40 80
Vertical Scale in Feet

0 100 200
Horizontal Scale in Feet

Vertical Exaggeration = 2.5X

NOTE

See Figure 4, Profile Legend and Geologic Unit Explanation, for legends and notes.

SR 520 Bridge Replacement
10 Percent Design

**GENERALIZED SUBSURFACE CROSS SECTION D-D' PACIFIC INTERCHANGE / UNION BAY CROSSING**

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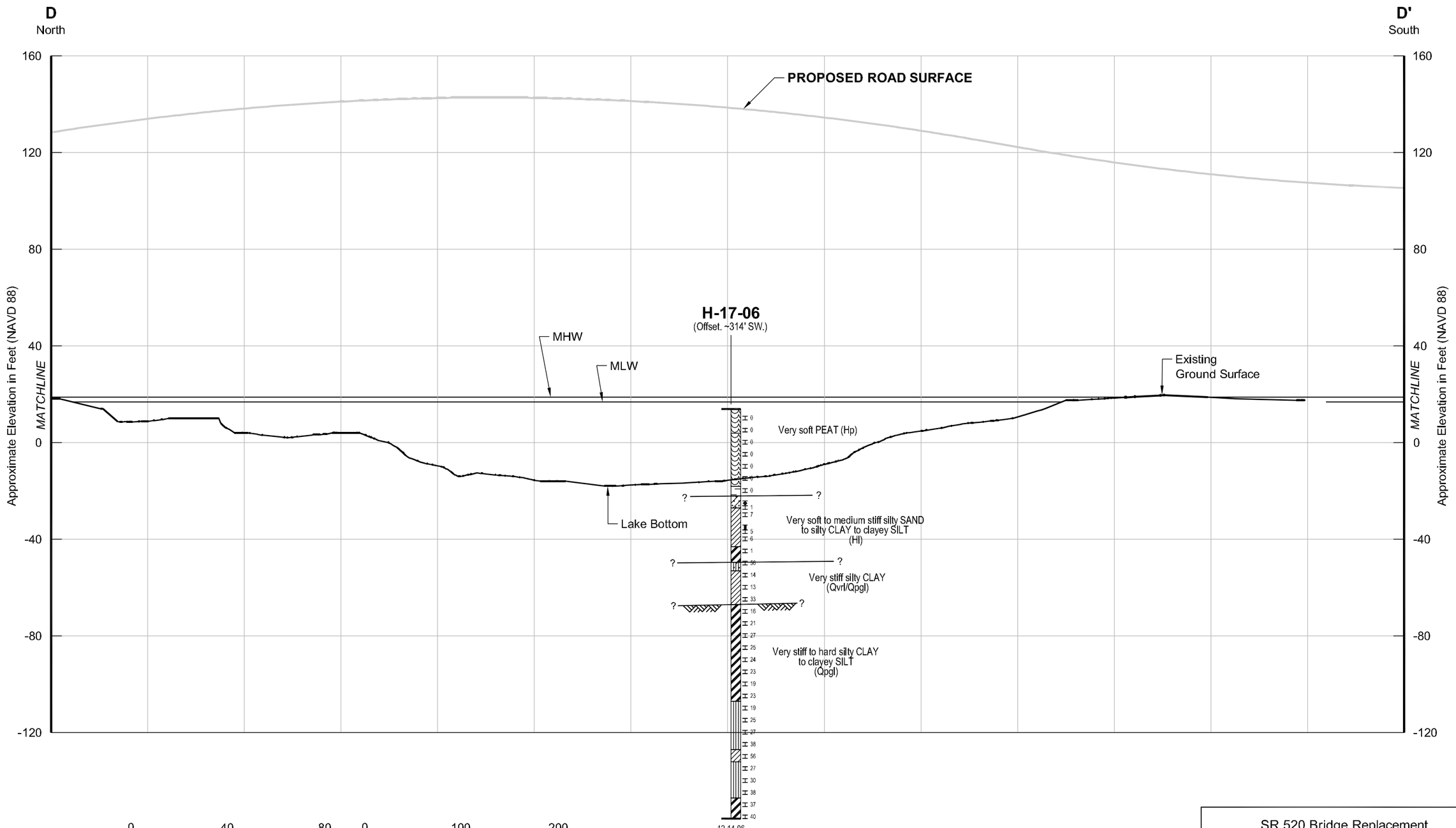
**FIG. 8**
Sheet 1 of 4

**PRELIMINARY**

Filename: J:\211\20624-014\21-1-20624-014 Profiles West (Current).dwg Layout: Pacific-IC 1 Date: 05-25-2007 Login: BAC




NOTE

See Figure 4, Profile Legend and Geologic Unit Explanation, for legends and notes.

SR 520 Bridge Replacement
10 Percent Design

**GENERALIZED SUBSURFACE CROSS SECTION D-D' PACIFIC INTERCHANGE / UNION BAY CROSSING**

May 2007 | 21-1-20624-014

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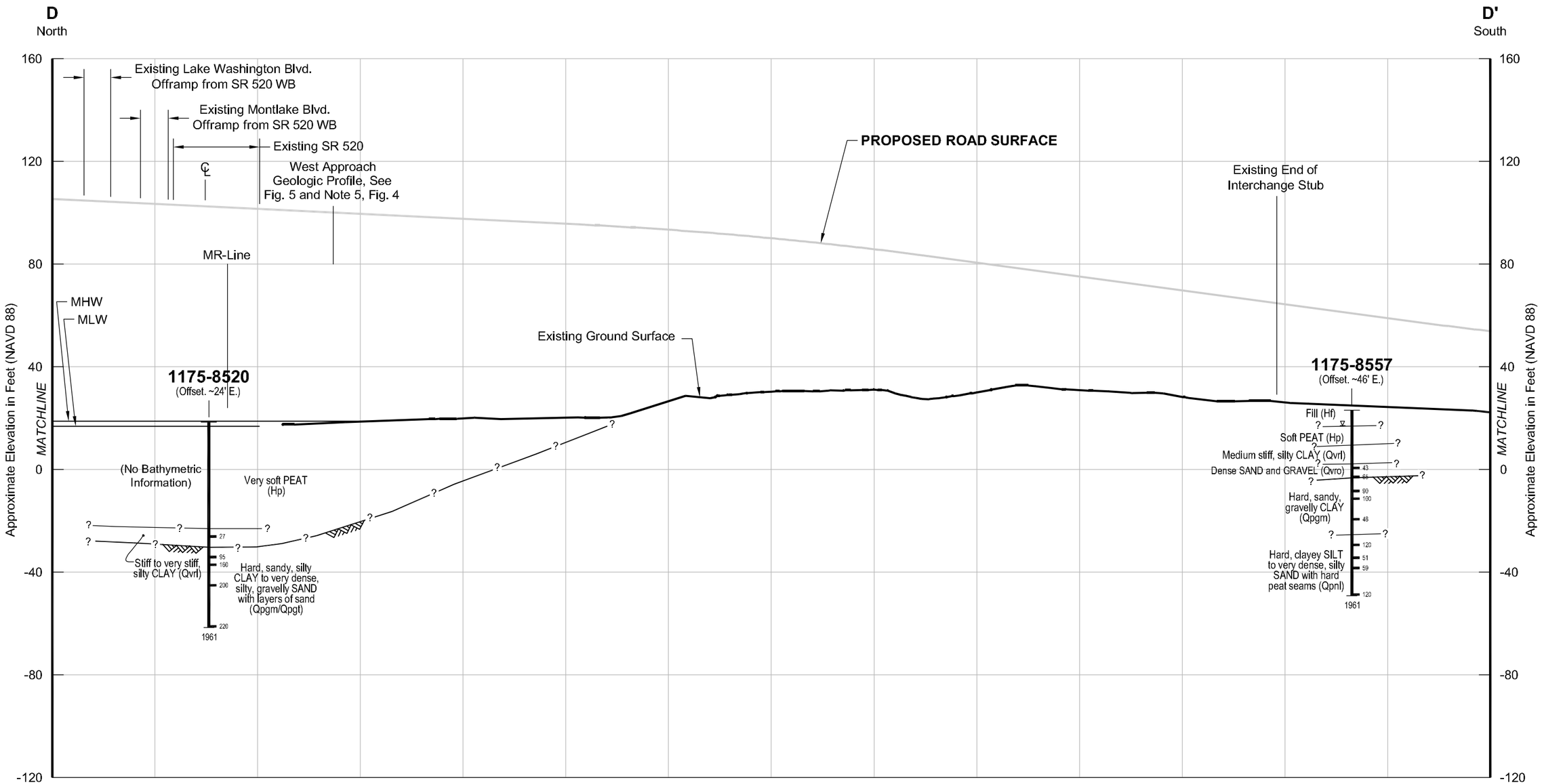
Geotechnical and Environmental Consultants

**FIG. 8**
Sheet 2 of 4

**PRELIMINARY**

Filename: J:\211\20624-014\21-1-20624-014 Profiles West (Current).dwg Layout: Pacific-IC 2 Date: 05-25-2007 Login: BAC




0 40 80
Vertical Scale in Feet

0 100 200
Horizontal Scale in Feet

Vertical Exaggeration = 2.5X

NOTE

See Figure 4, Profile Legend and Geologic Unit Explanation, for legends and notes.

SR 520 Bridge Replacement
10 Percent Design

**GENERALIZED SUBSURFACE CROSS SECTION D-D' PACIFIC INTERCHANGE / UNION BAY CROSSING**

May 2007 21-1-20624-014

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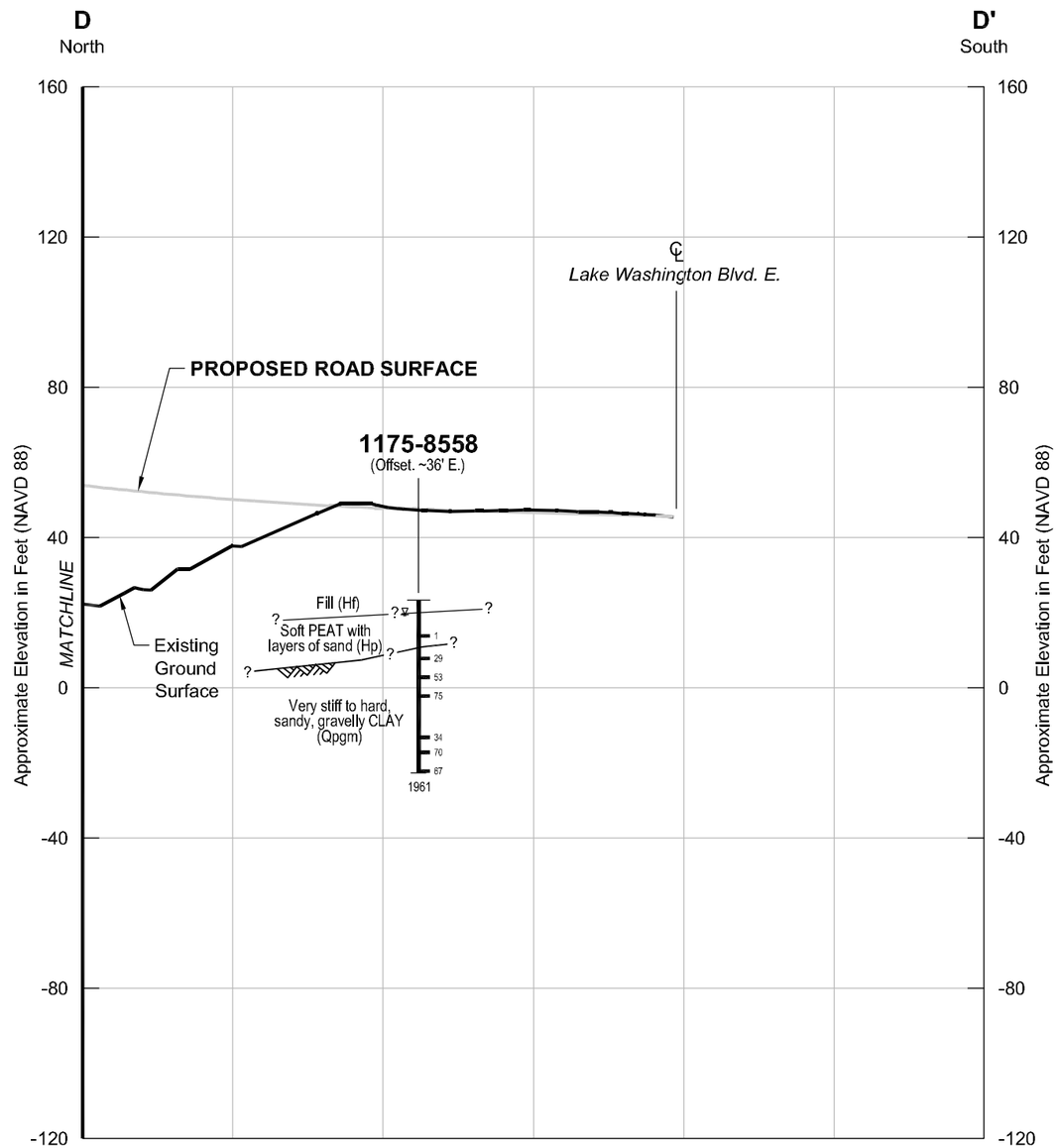
**FIG. 8**
Sheet 3 of 4

**PRELIMINARY**

Filename: J:\21\20624-014\21-1-20624-014 Profiles West (Current).dwg Layout: Pacific-IC 3 Date: 05-25-2007 Login: BAC




0 40 80
Vertical Scale in Feet

0 100 200
Horizontal Scale in Feet

Vertical Exaggeration = 2.5X

NOTE

See Figure 4, Profile Legend and Geologic Unit Explanation, for legends and notes.

SR 520 Bridge Replacement
10 Percent Design

**GENERALIZED SUBSURFACE CROSS SECTION D-D' PACIFIC INTERCHANGE / UNION BAY CROSSING**

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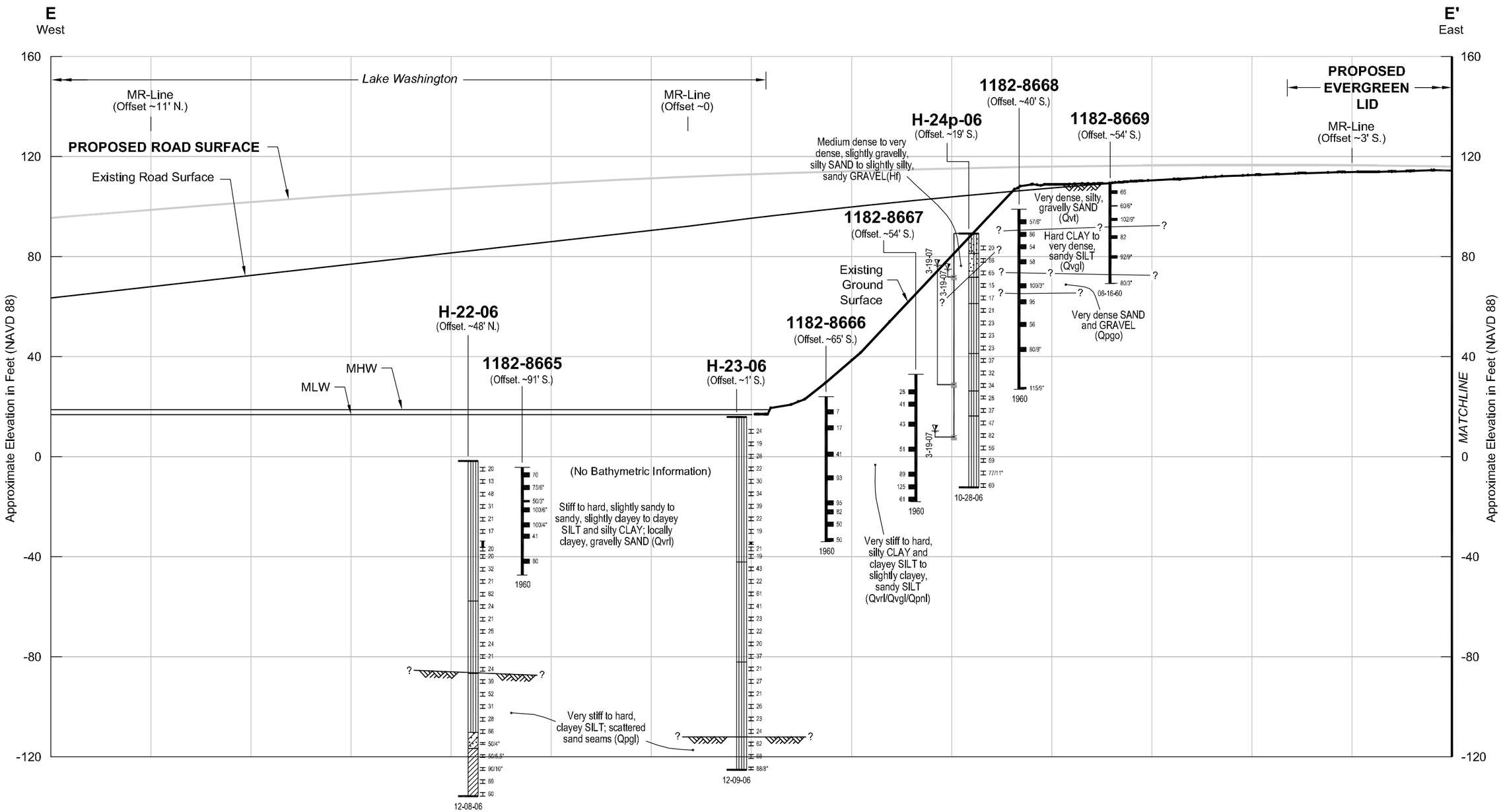
**FIG. 8**
Sheet 4 of 4

**PRELIMINARY**

Filename: J:\211\20624-014\21-1-20624-014 Profiles West (Current).dwg Layout: Pacific-IC 4 Date: 05-25-2007 Login: BAC




0 40 80 — Vertical Scale in Feet

0 100 200 — Horizontal Scale in Feet

Vertical Exaggeration = 2.5X

NOTE

See Figure 4, Profile Legend and Geologic Unit Explanation, for legends and notes.

SR 520 Bridge Replacement
10 Percent Design

**GENERALIZED SUBSURFACE PROFILE E-E' EAST SIDE**

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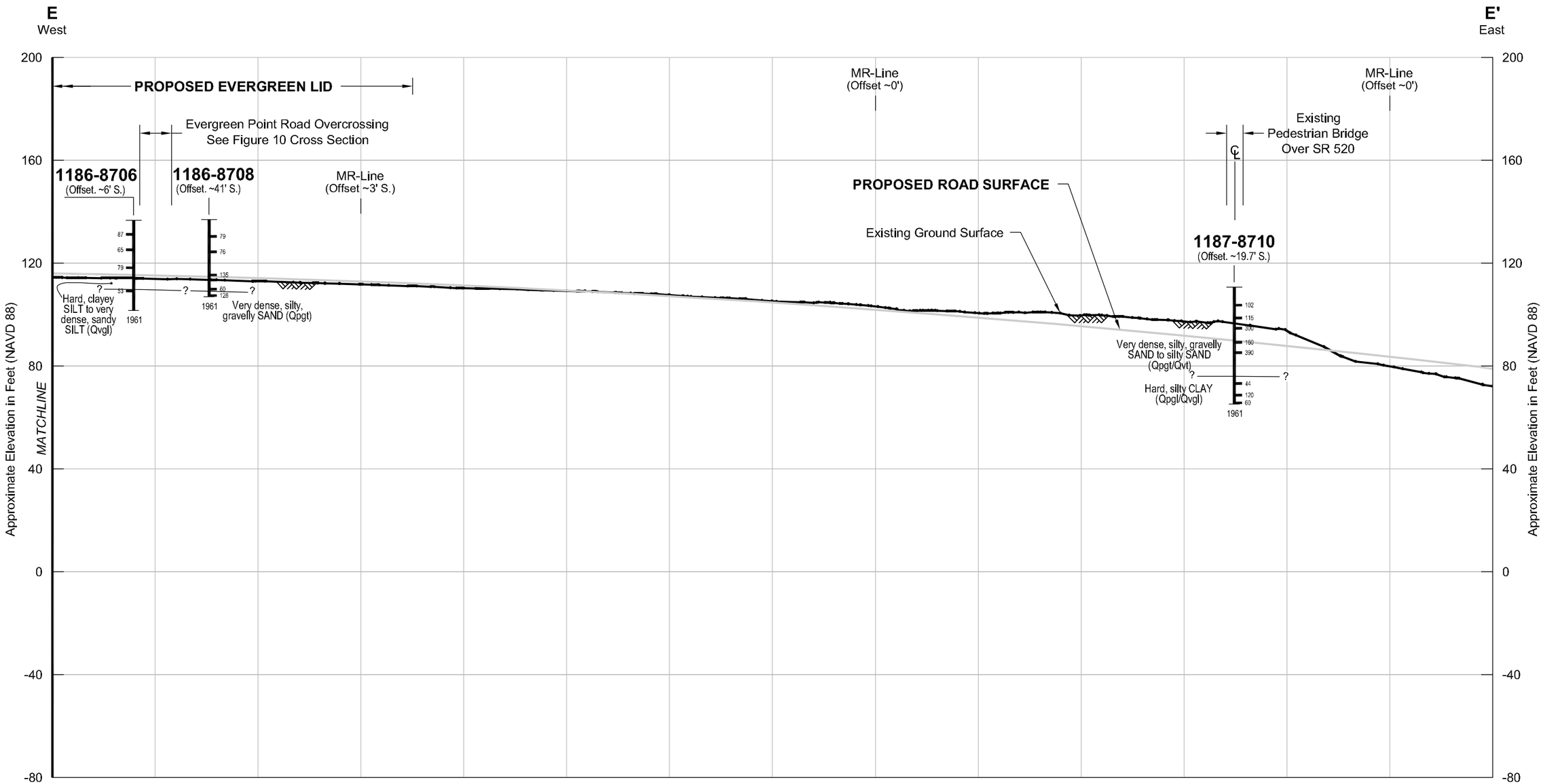
**FIG. 9**
Sheet 1 of 2

**PRELIMINARY**

Filename: J:\211\20624-014\21-1-20624-014 Profiles East (Current).dwg Layout: East Approach 1 Date: 05-25-2007 Login: BAC




0 40 80
Vertical Scale in Feet

0 100 200
Horizontal Scale in Feet

Vertical Exaggeration = 2.5X

NOTE

See Figure 4, Profile Legend and Geologic Unit Explanation, for legends and notes.

SR 520 Bridge Replacement
10 Percent Design

**GENERALIZED SUBSURFACE PROFILE E-E' EAST SIDE**

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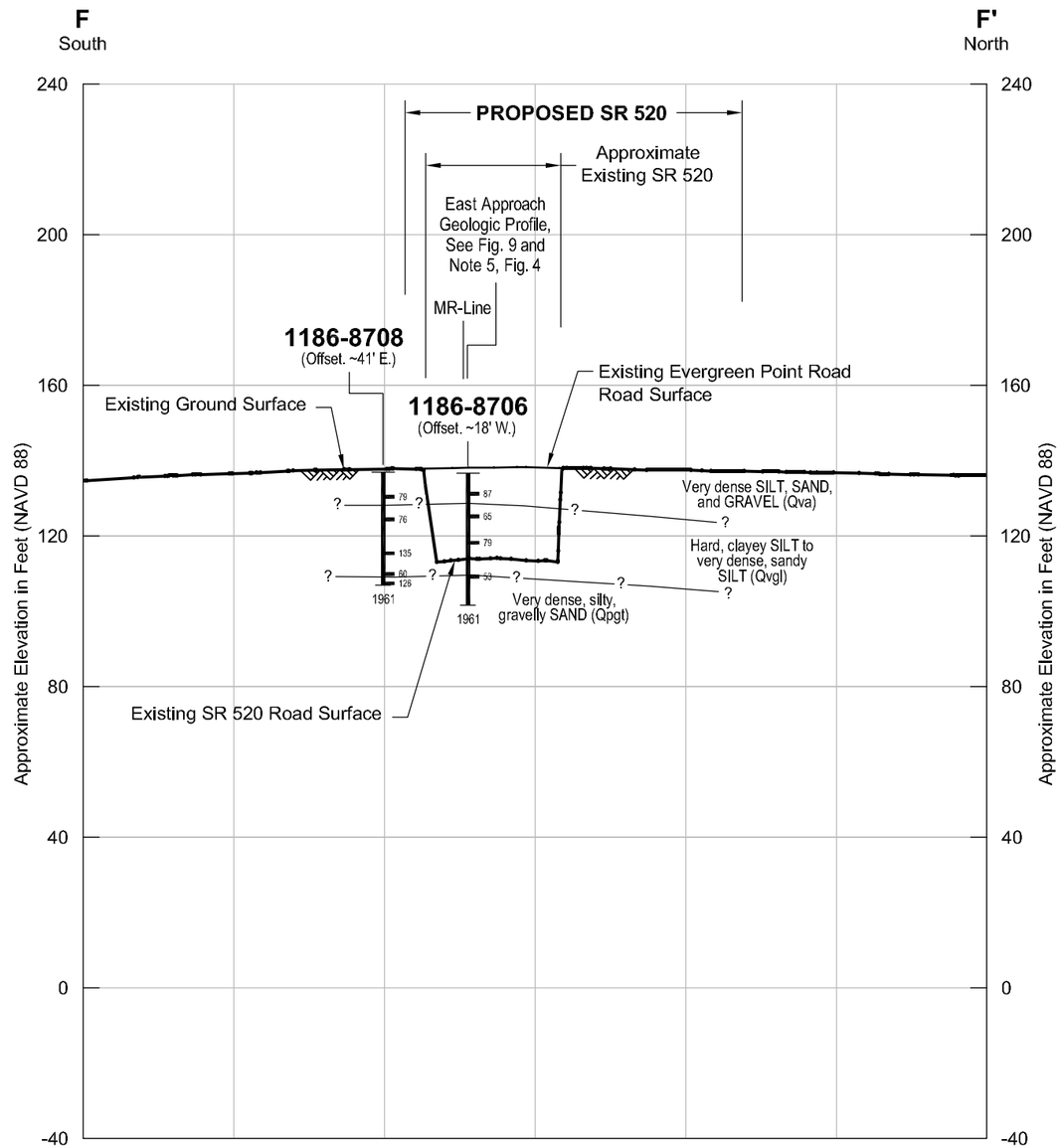
**FIG. 9**
Sheet 2 of 2

**PRELIMINARY**

Filename: J:\21\20624-014\21-1-20624-014 Profiles East (Current).dwg Layout: East Approach 2 Date: 05-25-2007 Login: BAC




0 40 80
Vertical Scale in Feet

0 100 200
Horizontal Scale in Feet

Vertical Exaggeration = 2.5X

NOTE

See Figure 4, Profile Legend and Geologic Unit Explanation, for legends and notes.

SR 520 Bridge Replacement
10 Percent Design

**GENERALIZED SUBSURFACE CROSS SECTION F-F' EVERGREEN POINT ROAD**

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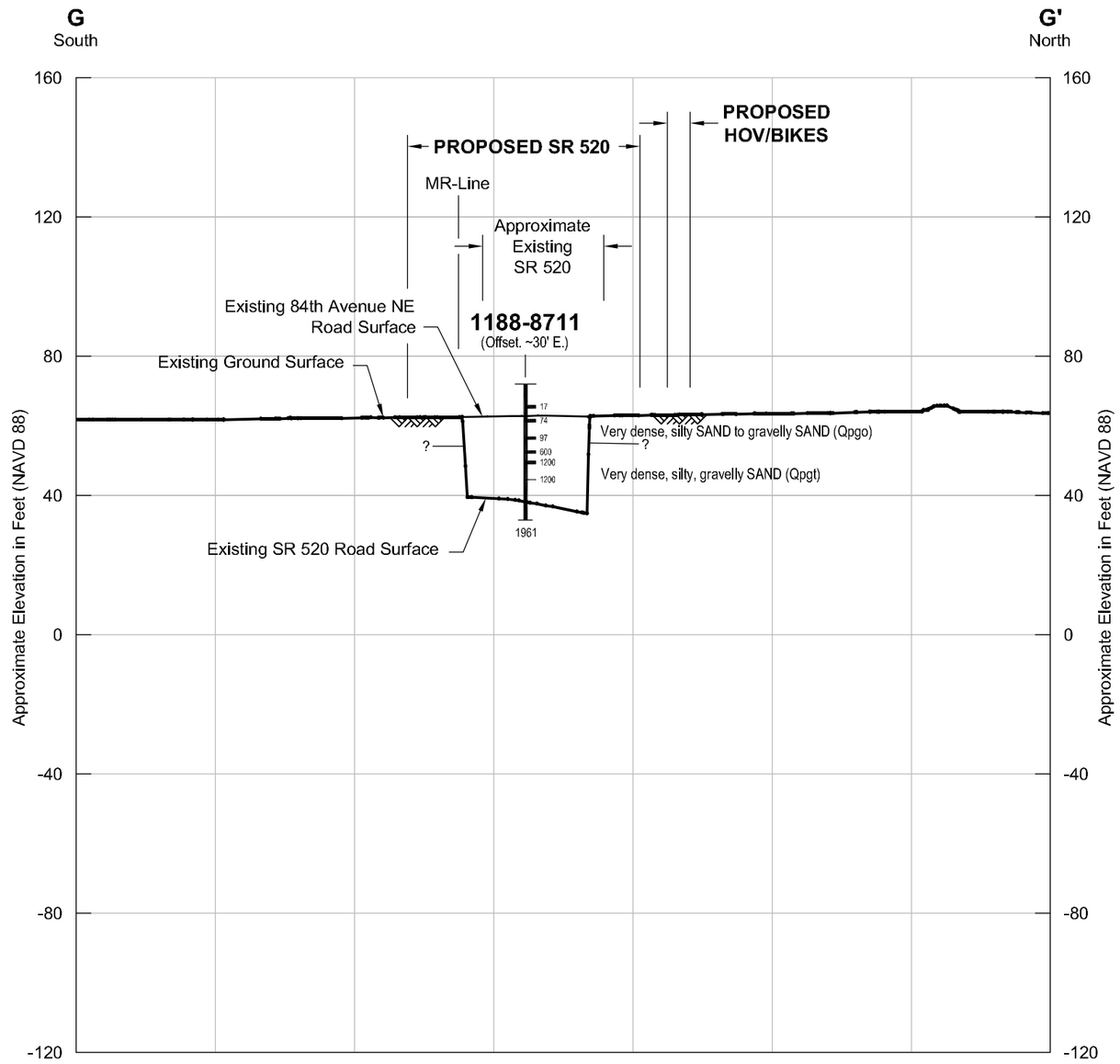
**FIG. 10**

**PRELIMINARY**

Filename: J:\21\20624-014\21-1-20624-014 Profiles East (Current).dwg Layout: Evergreen Date: 05-25-2007 Login: BAC




0 40 80 — Vertical Scale in Feet

0 100 200 — Horizontal Scale in Feet

Vertical Exaggeration = 2.5X

NOTE

See Figure 4, Profile Legend and Geologic Unit Explanation, for legends and notes.

SR 520 Bridge Replacement
10 Percent Design

**GENERALIZED SUBSURFACE CROSS SECTION G-G'**
**84TH AVENUE NE**

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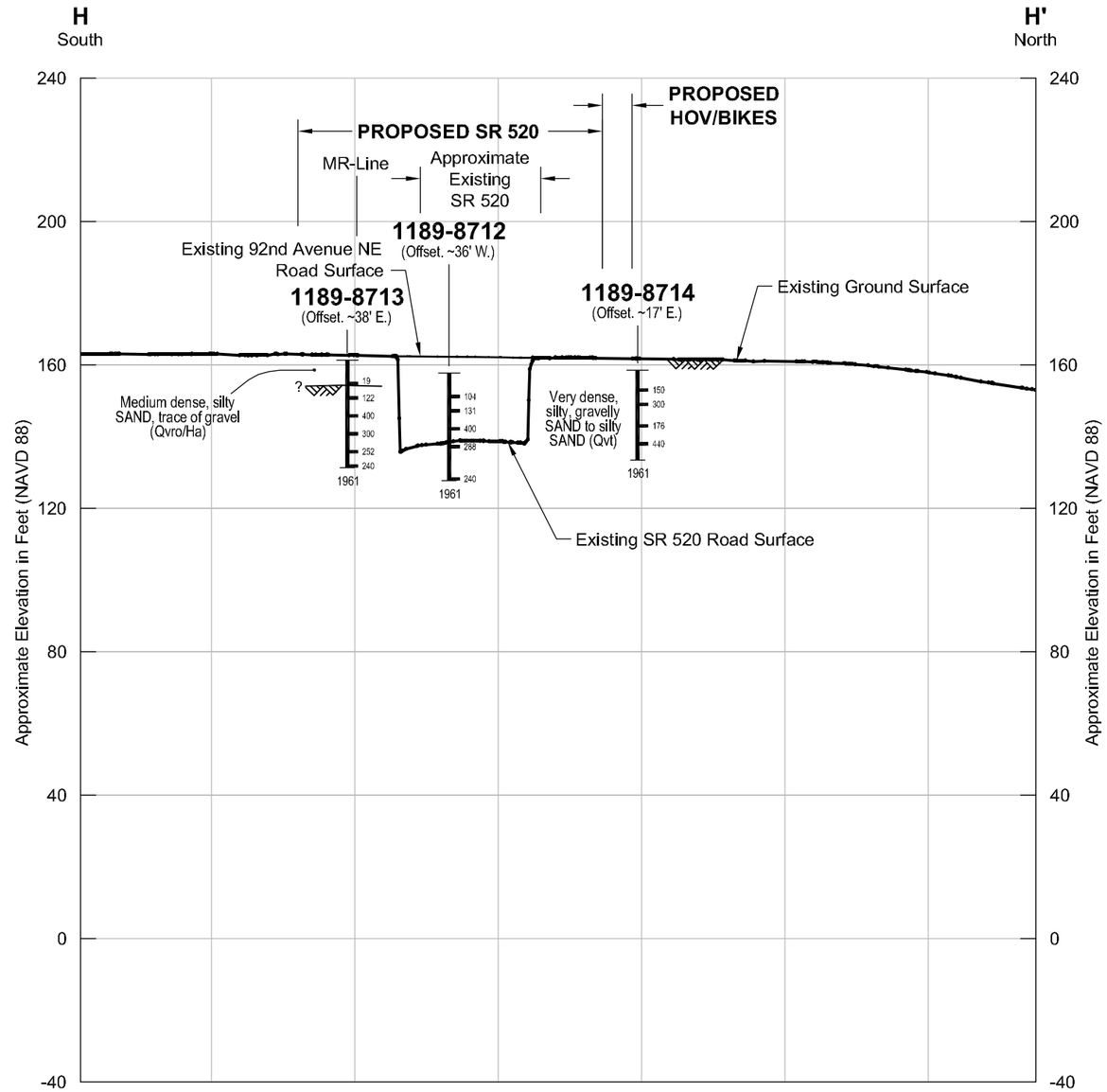
**FIG. 11**

**PRELIMINARY**

Filename: J:\211\20624-014\21-1-20624-014 Profiles East (Current).dwg Layout: 84TH Date: 05-25-2007 Login: BAC




0 40 80
Vertical Scale in Feet

0 100 200
Horizontal Scale in Feet

Vertical Exaggeration = 2.5X

NOTE

See Figure 4, Profile Legend and Geologic Unit Explanation, for legends and notes.

SR 520 Bridge Replacement
10 Percent Design

**GENERALIZED SUBSURFACE CROSS SECTION H-H'**
**92ND AVENUE NE**

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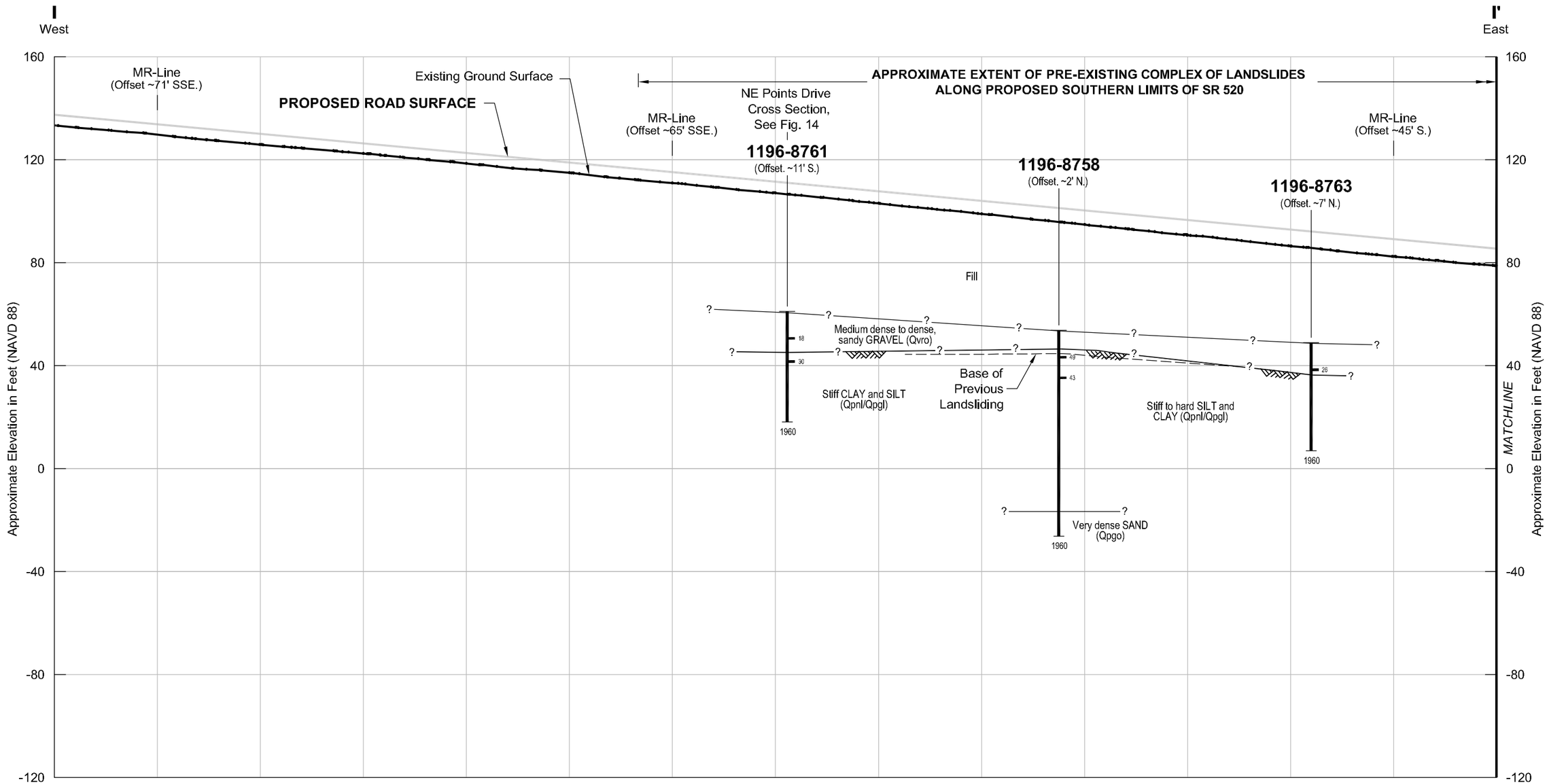
**FIG. 12**

**PRELIMINARY**

Filename: J:\21\20624-014\21-1-20624-014 Profiles East (Current).dwg Layout: 92ND Date: 05-25-2007 Login: BAC




0 40 80
Vertical Scale in Feet

0 100 200
Horizontal Scale in Feet

Vertical Exaggeration = 2.5X

NOTE

See Figure 4, Profile Legend and Geologic Unit Explanation, for legends and notes.

SR 520 Bridge Replacement
10 Percent Design

**GENERALIZED SUBSURFACE PROFILE I-I'**
**96TH to 108TH**

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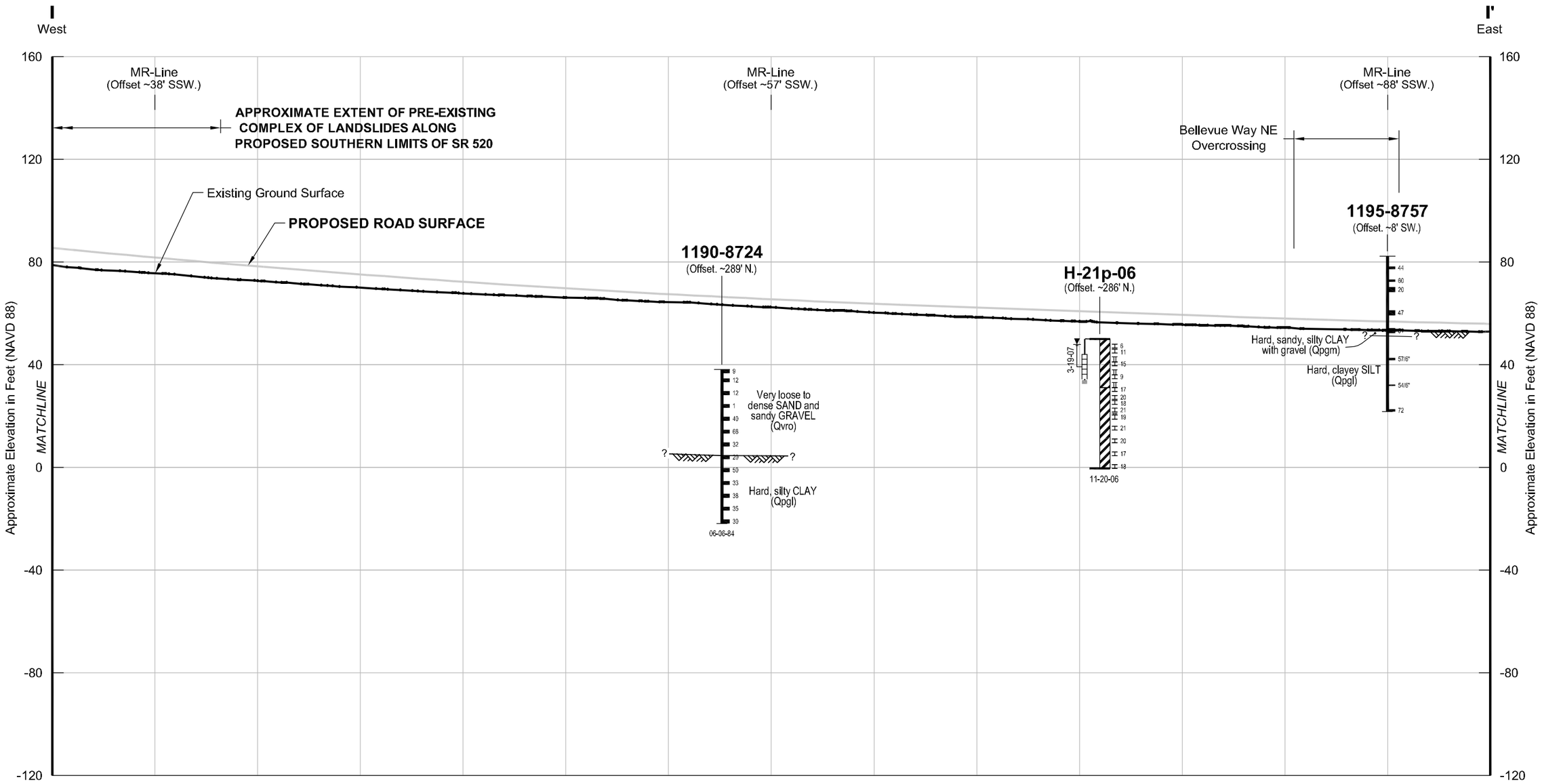
**FIG. 13**
Sheet 1 of 4

**PRELIMINARY**

Filename: J:\211\20624-014\21-1-20624-014 Profiles East (Current).dwg Layout: 96TH to 108TH 1 Date: 05-25-2007 Login: BAC




0 40 80
Vertical Scale in Feet

0 100 200
Horizontal Scale in Feet

Vertical Exaggeration = 2.5X

NOTE

See Figure 4, Profile Legend and Geologic Unit Explanation, for legends and notes.

SR 520 Bridge Replacement
10 Percent Design

**GENERALIZED SUBSURFACE PROFILE I-I'**
**96TH to 108TH**

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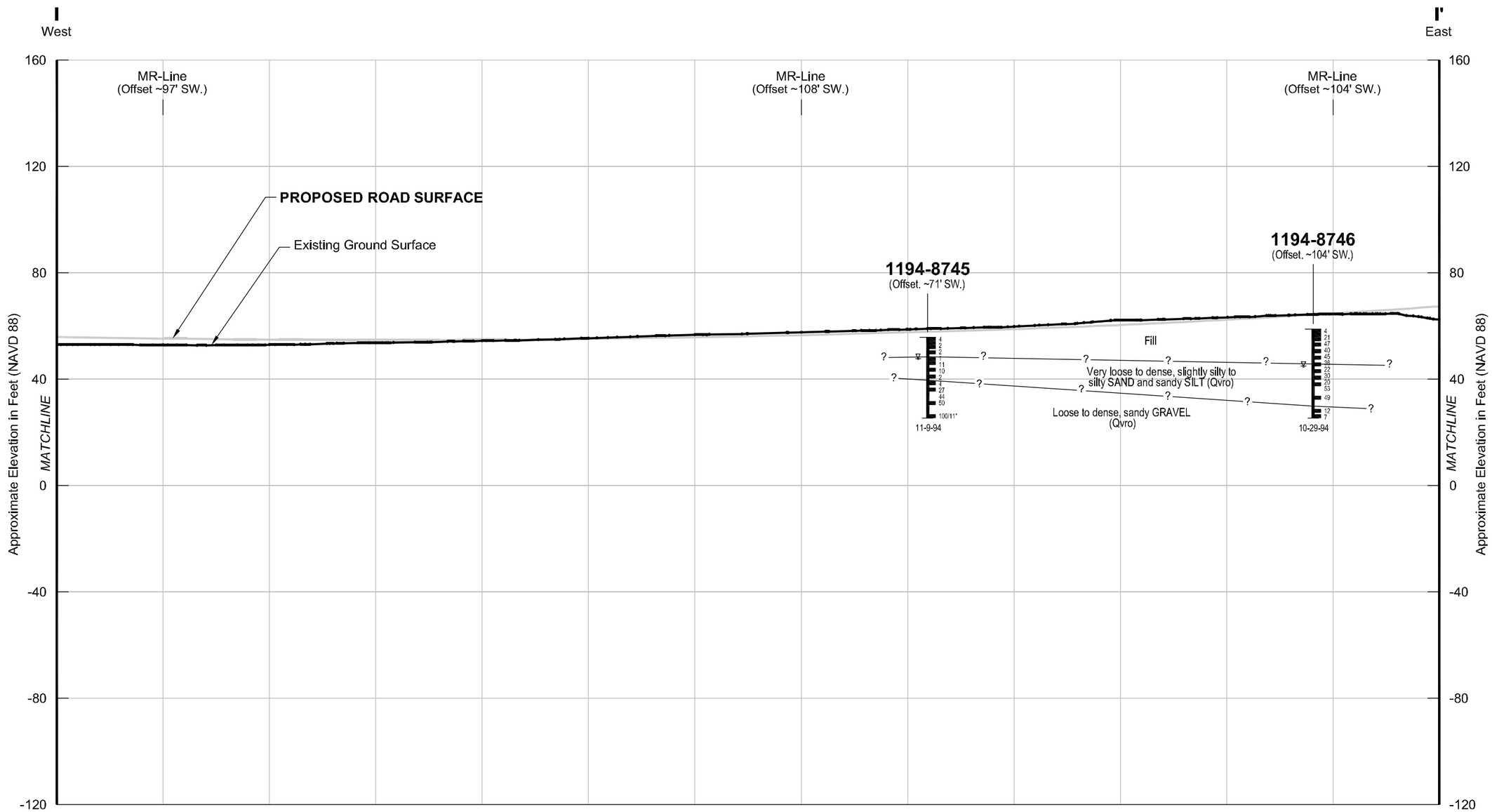
**FIG. 13**
Sheet 2 of 4

**PRELIMINARY**

Filename: J:\211\20624-014\21-1-20624-014 Profiles East (Current).dwg Layout: 96TH to 108TH 2 Date: 05-25-2007 Login: BAC




0 40 80
Vertical Scale in Feet

0 100 200
Horizontal Scale in Feet

Vertical Exaggeration = 2.5X

NOTE

See Figure 4, Profile Legend and Geologic Unit Explanation, for legends and notes.

SR 520 Bridge Replacement
10 Percent Design

**GENERALIZED SUBSURFACE PROFILE I-I'**
**96TH to 108TH**

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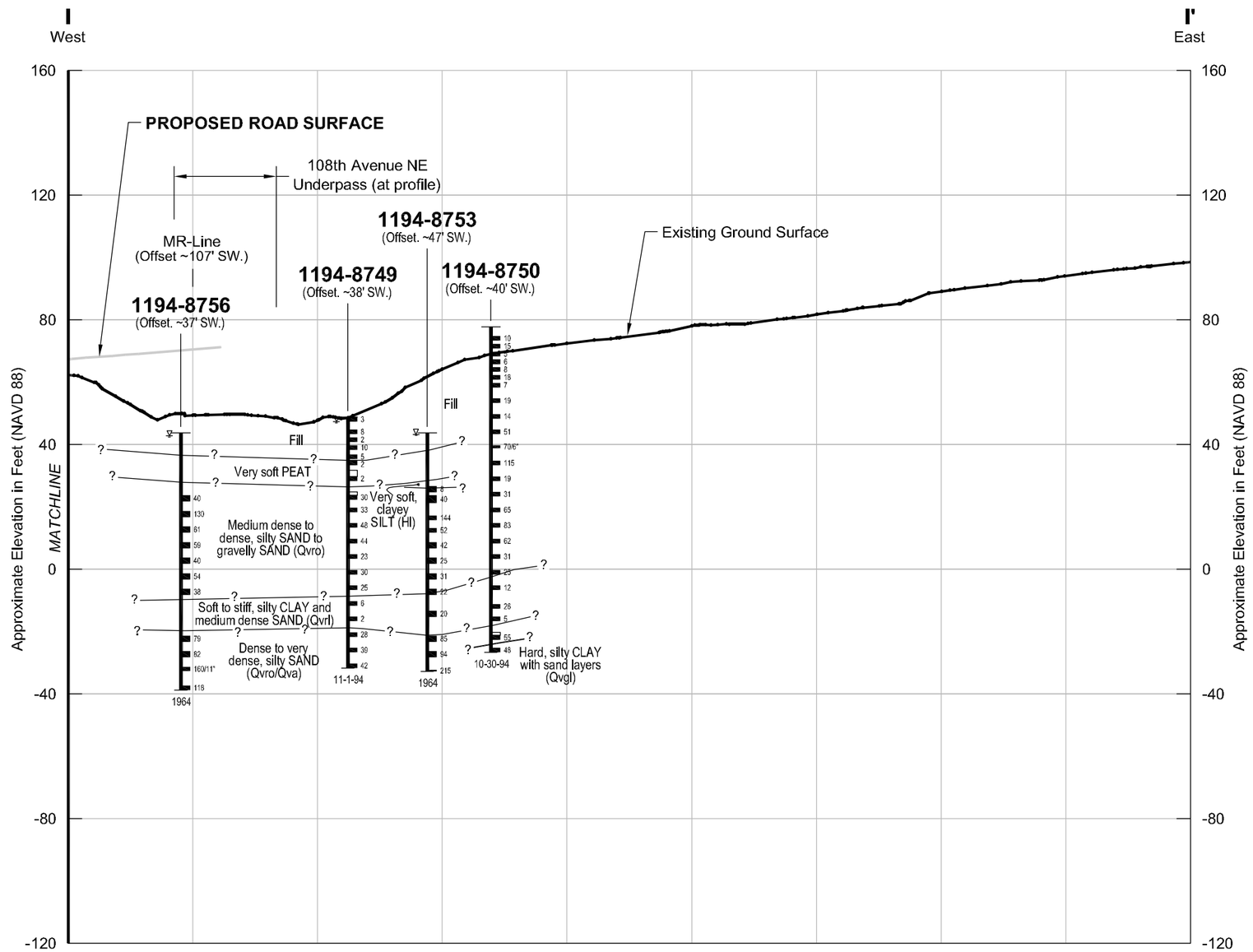
**FIG. 13**
Sheet 3 of 4

**PRELIMINARY**

Filename: J:\211\20624-014\21-1-20624-014 Profiles East (Current).dwg Layout: 96TH to 108TH 3 Date: 05-25-2007 Login: BAC




0 40 80
Vertical Scale in Feet

0 100 200
Horizontal Scale in Feet

Vertical Exaggeration = 2.5X

NOTE

See Figure 4, Profile Legend and Geologic Unit Explanation, for legends and notes.

SR 520 Bridge Replacement
10 Percent Design

**GENERALIZED SUBSURFACE PROFILE I-I'**
**96TH to 108TH**

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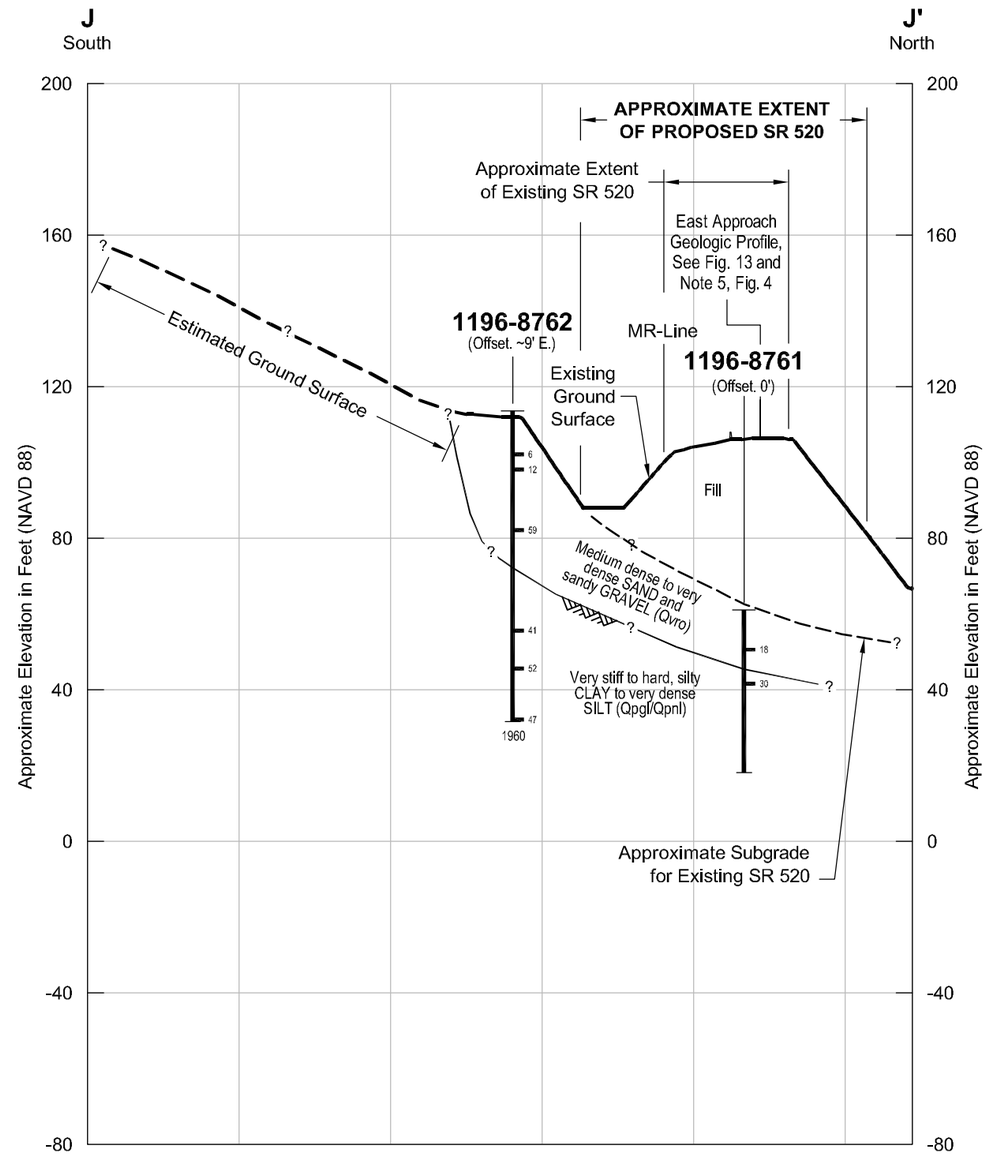
**FIG. 13**
Sheet 4 of 4

**PRELIMINARY**

Filename: J:\21\20624-014\21-1-20624-014 Profiles East (Current).dwg Layout: 96TH to 108TH 4 Date: 05-25-2007 Login: BAC




0 40 80 — Vertical Scale in Feet

0 100 200 — Horizontal Scale in Feet

Vertical Exaggeration = 2.5X

NOTE

See Figure 4, Profile Legend and Geologic Unit Explanation, for legends and notes.

SR 520 Bridge Replacement
10 Percent Design

**GENERALIZED SUBSURFACE CROSS SECTION J-J'**
**NE POINTS DRIVE**

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**FIG. 14**

**PRELIMINARY**

Filename: J:\211\20624-014\21-1-20624-014 Profiles East (Current).dwg Layout: NE Points Date: 05-25-2007 Login: BAC