Soils and Geology Technical Report

Multnomah County | Earthquake Ready Burnside Bridge Project

Portland, OR

January 29, 2021

EARTHQUAKE READY BURNSIDE BRIDGE

Earthquake Ready Burnside Bridge Soils and Geology Technical Report

Prepared for

Multnomah County
Transportation Division – Bridges
1403 SE Water Ave
Portland, OR 97214

Prepared by

HDR
1050 SW 6th Ave, Suite 1800
Portland, OR 97204
T (503) 423-3700

Parametrix
700 NE Multnomah St, Suite 1000
Portland, OR 97232
T (503) 233-2400

Contract# DCS-SVCSGEN-857-2019-conv
HDR Project #10144814

CERTIFICATION

The technical material and data contained in this document were prepared under the supervision and direction of the undersigned, as a professional geologist.

Heather Catron

_______________ Signature Reserved for Final Version

Prepared by Rick Malin, RG (Senior Hydrogeologist)

_______________ Signature Reserved for Final Version

Checked by Richard Roché, RG (Senior Geologist)

_______________ Signature Reserved for Final Version

Approved by Heather Catron (Consultant Project Manager)

Contents

Tables

Figures

Acronyms, Initialisms, and Abbreviations

COP	City of Portland
CRBG	Columbia River Basalt Group
CSZ	Cascadia Subduction Zone
DEQ	Oregon Department of Environmental Quality
DOGAMI	Oregon Department of Geology and Mineral Industries
DSSI	dynamic soil-structure interaction
EIS	environmental impact statement
EQRB	Earthquake Ready Burnside Bridge
NRCS	Natural Resources Conservation Service
OAR	Oregon Administrative Rules
ODOT	Oregon Department of Transportation
ORS	Oregon Revised Statute
UPRR	Union Pacific Railroad
USGS	U.S. Geological Survey
UST	underground storage tank

This page is intentionally left blank.

Executive Summary

This Soils and Geology Technical Report for the Earthquake Ready Burnside Bridge Project discuss the following topics for the Project Area:

- Geologic setting and depositional units present
- Earthquake-hazard geologic mapping
- Soil types
- Groundwater conditions

This information provides context for the presentation and review of recent seismic hazard mapping completed for the Portland metropolitan region. The effects of soil type and geologic and hydrogeologic conditions on the Project depend on the physical properties of soil and rock in the region and their responses to external forces. These forces include, but are not limited to, severe ground shaking, settlement and/or liquefaction associated with a seismic event, expansion and/or contraction of soils, landslides from steep or altered slopes, scour, and erosion.

An impact assessment evaluation considers the identified conditions, then applies professional judgment to assess the level of concern that geologic conditions may pose on the Project Alternatives.

Short- and long-term environmental consequences are examined. Impacts are divided into pre-earthquake impacts, based on each Build Alternative's footprint and its day-to-day operations, as well as impacts that would occur after the next Cascadia Subduction Zone earthquake event, including how each Alternative would affect resiliency, emergency response, and longer-term recovery.

Regional and Project-specific investigation findings indicate that earth-materials near the surface in the Project Area have poor soil strength and are highly susceptible to liquefaction and earthquake-induced ground deformation. Therefore, construction of a seismically resilient Burnside Bridge would require that existing bridge foundations be enhanced or replaced such that they are situated on seismically competent earth-material. Drilling, excavating, and improving poor-strength earth-material would be required. These actions would result in various degrees of impact on existing soils and geology in the Project Area.

1 Introduction

As a part of the preparation of the Environmental Impact Statement (EIS) for the Earthquake Ready Burnside Bridge (EQRB) Project, this technical report has been prepared to identify and evaluate existing soils and geologic conditions within the Project's Area of Potential Impact (API).

1.1 Project Location

The Project Area is located within the central city of Portland. The Burnside Bridge crosses the Willamette River connecting the west and east sides of the city. The Project Area encompasses a one-block radius around the existing Burnside Bridge and W/E Burnside Street, from NW/SW 3rd Avenue on the west side of the river and NE/SE Grand Avenue on the east side. Several neighborhoods surround the area including Old Town/Chinatown, Downtown, Kerns, and Buckman. Figure 1 shows the Project Area.

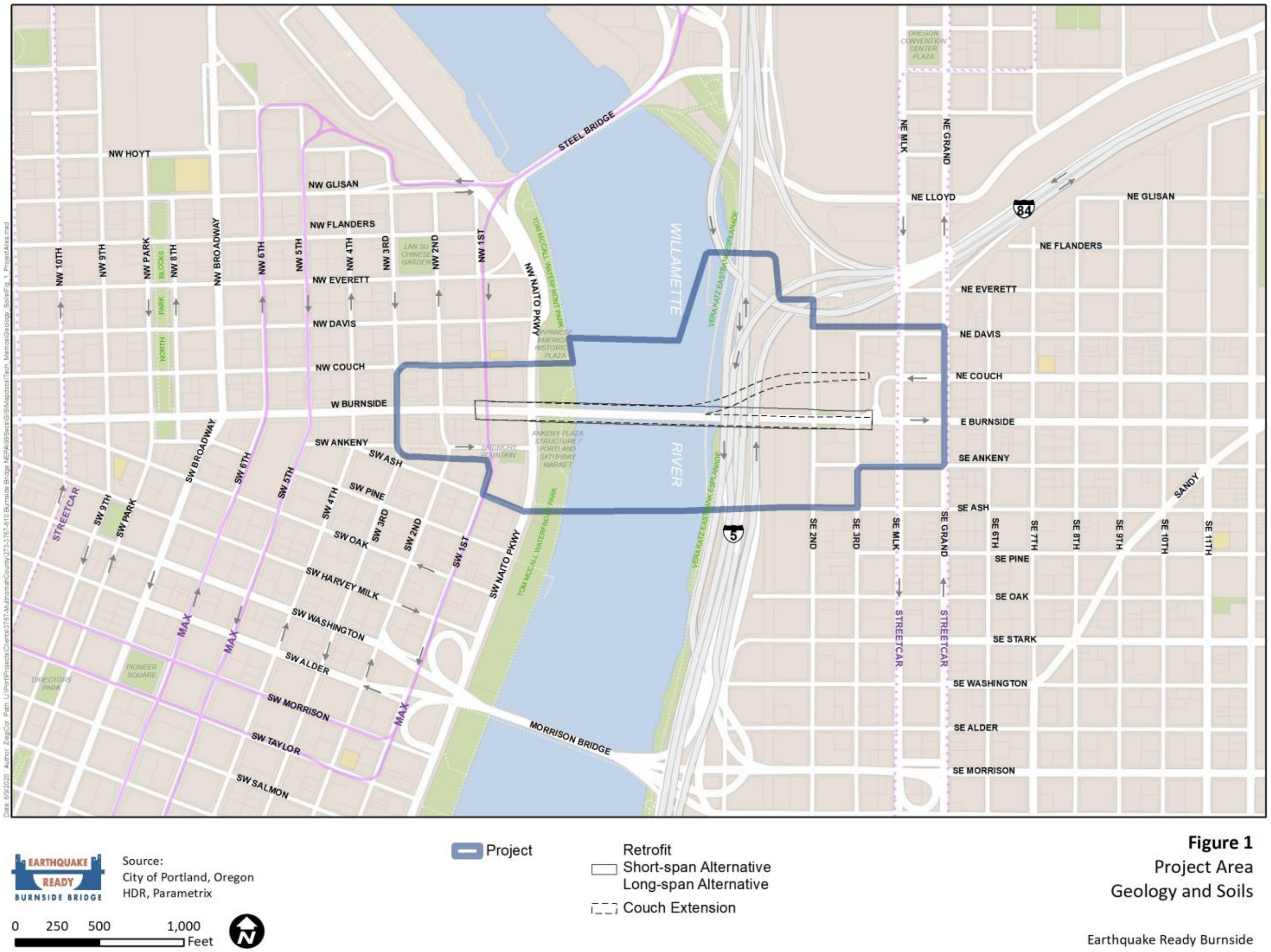
1.2 Project Purpose

The primary purpose of the Project is to build a seismically resilient Burnside Street lifeline crossing over the Willamette River that will remain fully operational and accessible for vehicles and other modes of transportation following a major Cascadia Subduction Zone (CSZ) earthquake. The Burnside Bridge will provide a reliable crossing for emergency response, evacuation, and economic recovery after an earthquake. Additionally, the bridge will provide a long-term safe crossing with low-maintenance needs.

2 Project Alternatives

The Project Alternatives are described in detail with text and graphics in the EQRB Description of Alternatives Report (Multnomah County 2021c). That report describes the Alternatives' current design as well as operations and construction assumptions.

Figure 1. Project Area



Source: City of Portland, HDR, Parametrix

Briefly, the Draft EIS evaluates the No-Build Alternative and four Build Alternatives. Among the Build Alternatives there is an Enhanced Seismic Retrofit Alternative that would replace certain elements of the existing bridge and retrofit other elements. There are three Replacement Alternatives that would completely remove and replace the existing bridge. In addition, the Draft EIS considers options for managing traffic during construction. Nomenclature for the Alternatives/options are listed below:

- No-Build Alternative
- Build Alternatives
  - Enhanced Seismic Retrofit (Retrofit Alternative)
  - Replacement Alternative with Short-span Approach (Short-span Alternative)
  - Replacement Alternative with Long-span Approach (Long-span Alternative)
  - Replacement Alternative with Couch Extension (Couch Extension Alternative)
- Construction Traffic Management Options
  - Temporary Detour Bridge Option (Temporary Bridge) includes three modal options:
    - Temporary Bridge: All Modes
    - Temporary Bridge: Transit, Bicycles and Pedestrians only
    - Temporary Bridge: Bicycles and Pedestrians only
  - Without Temporary Detour Bridge Option (No Temporary Bridge)

Please see the EQRB Description of Alternatives Report (Multnomah County 2021c) for text and graphical descriptions of the Alternatives.

3 Definitions

The following terminology will be used when discussing geographic areas:

- **Project Area –** The area within which improvements associated with the Project Alternatives would occur and the area needed to construct these improvements. The Project Area includes the area needed to construct all permanent infrastructure, including adjacent parcels where modifications are required for associated work such as utility realignments or upgrades. For the EQRB Project, the Project Area includes approximately a one-block radius around the existing Burnside Bridge and W/E Burnside Street, from NW/SW 3rd Avenue on the west side of the river and NE/SE Grand Avenue on the east side.
- **Area of Potential Impact (API) –** This is the geographic boundary within which physical impacts to the environment could occur with the Project Alternatives. The API is resource-specific and differs depending on the environmental topic being addressed. For all topics, the API will encompass the Project Area, and for some topics, the geographic extent of the API will be the same as that for the Project Area; for other topics (such as for transportation effects) the API will be

substantially larger to account for impacts that could occur outside of the Project Area. The API for existing soils and geologic conditions is defined in Section 5.1.

- **Project vicinity –** The environs surrounding the Project Area. The Project vicinity does not have a distinct geographic boundary but is used in general discussion to denote the larger area, inclusive of the Old Town/Chinatown, Downtown, Kerns, and Buckman neighborhoods.
- **Earth-material** – Refers to soil and geologic depositional units present at a given location in the API.

4 Legal Regulations and Standards

4.1 Laws, Plans, Policies, and Regulations

There are no specific regulations and laws pertaining to soils or geology that are specifically applicable to the Project. However, the *Environmental Procedures Manual* published by Oregon Department of Transportation (ODOT 2002) establishes generally accepted industry practice for transportation projects.

4.2 Design Standards

Seismic design standards that were previously used during the preparation of the Burnside Bridge Seismic Feasibility Study (Shannon & Wilson 2017) included the following:

ODOT Geotechnical Design Manual (2016)

ODOT Bridge Design and Drafting Manual (2016)

AASHTO LRFD Bridge Design Specifications (2014)

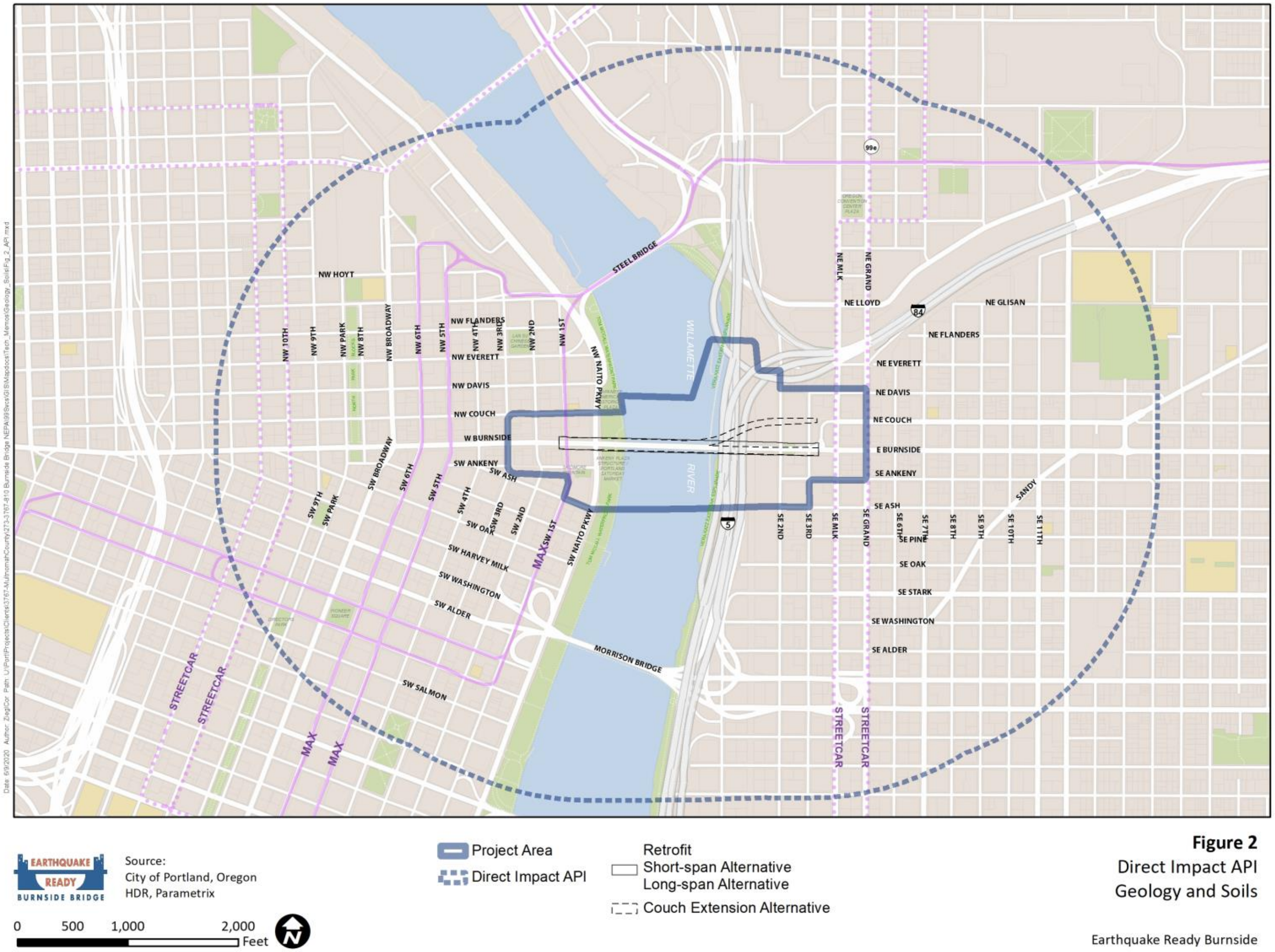
Site-specific design standards for seismic safety for this phase of the Project are presently being developed in coordination with the design team, geotechnical specialists, Multnomah County, and ODOT. Once developed, these will be reviewed and summarized in the Draft EIS.

5 Affected Environment

5.1 Area of Potential Impact

The API established for the soils and geology analysis includes an approximately 0.5-mile buffer from the centerline of the EQRB Project. The use of this API allows for a comprehensive review of potential earth-material conditions near the Project Area that have some potential for impacts, including direct long-term and short-term impacts. A larger regional assessment of seismic hazards will also be required to support the analysis. Figure 2 shows the API for the soils and geology analysis.

Figure 2. Direct Impact API



Source: City of Portland, HDR, Parametrix

5.2 Resource Identification and Evaluation Methods

5.2.1 Published Sources and Databases

The data required for evaluating how construction may be impacted by geologic properties (e.g., what are the seismic hazards to the EQRB Project?) and how the construction may impact geology (e.g., will construction of the Project impact local geologic conditions?) were obtained from analysis conducted specifically for the EQRB Project, as well as existing technical reports, maps, and other publicly available information. Existing maps and technical reports published by the U.S. Geological Survey (USGS), Oregon Department of Geology and Mineral Industries (DOGAMI), local and state agencies with past or current projects in the Project vicinity, and the Natural Resources Conservation Service (NRCS) were reviewed for pertinent geologic, hydrogeologic, seismic, and soil property information.

Information from the EQRB geotechnical report (Shannon & Wilson 2020) provides information on existing conditions, including regional soil types and seismic history, and design recommendations.

Existing soil and geology conditions within the direct API were assessed based on review of the following:

- State and federal geologic maps with coverage in the direct API. This review focused on recent mapping efforts completed primarily to assess geohazards.
- Geotechnical reports and data specific to the Project Area. This review focused on the EQRB geotechnical report (Shannon & Wilson 2020).

The following reports were used to identify soil and geology conditions in the Project Area:

- Coseismic Landslide Susceptibility, Liquefaction Susceptibility, and Soil Amplification Class Maps, Clackamas, Columbia, Multnomah, and Washington Counties, Oregon. Prepared by DOGAMI, Open-File Report O-19-09. 2019.
- Earthquake Regional Impact Analysis for Clackamas, Multnomah, and Washington Counties, Oregon. Prepared by DOGAMI, Open-File Report O-18-02. 2018.
- 3D Geology and Shear-Wave Velocity Models of the Portland, Oregon, Metropolitan Area. Prepared by DOGAMI, Open-File Report O-13-12. 2013.
- Lidar-Based Surficial Geologic Map and Database of the Greater Portland Area, Clackamas, Columbia, Marion, Multnomah, Washington, and Yamhill Counties, Oregon, and Clark County, Washington. Prepared by DOGAMI, Open-File Report O-12-02. 2012.
- Geologic Map of the Portland Quadrangle, Multnomah and Washington Counties, Oregon, and Clark County, Washington. Prepared by DOGAMI, Geologic Map Series GMS-75. 1991.
- Soil Survey of Multnomah County, Oregon. Prepared by U.S. Department of Agriculture, Soil Conservation Service and Forest Service. Issued August 1983.

Agencies and organizations will be notified of the intent to prepare an EIS through the Federal Register and through other Project outreach activities. Participating agencies will have the opportunity to review and comment on the geologic and hydrogeologic conditions analyses during the course of the Project.

The following agencies may be contacted or be cited as data sources for the collection of data and review of Project Alternatives:

- The U.S. Army Corps of Engineers
- The U.S. Geological Survey (USGS)
- The U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS)
- Oregon Department of Transportation (ODOT)
- Oregon Department of Geology and Mineral Industries (DOGAMI)
- Oregon Department of State Lands
- Oregon Department of Environmental Quality (DEQ)
- Oregon Water Resources Department
- Local county, city, and regional agencies

It is also important to note that the Project includes an extensive public involvement and agency coordination effort, which will include local jurisdictions and neighborhoods within the Project vicinity. Discussions of seismic safety issues will be an important topic addressed as part of this effort.

5.2.2 Field Visits and Surveys

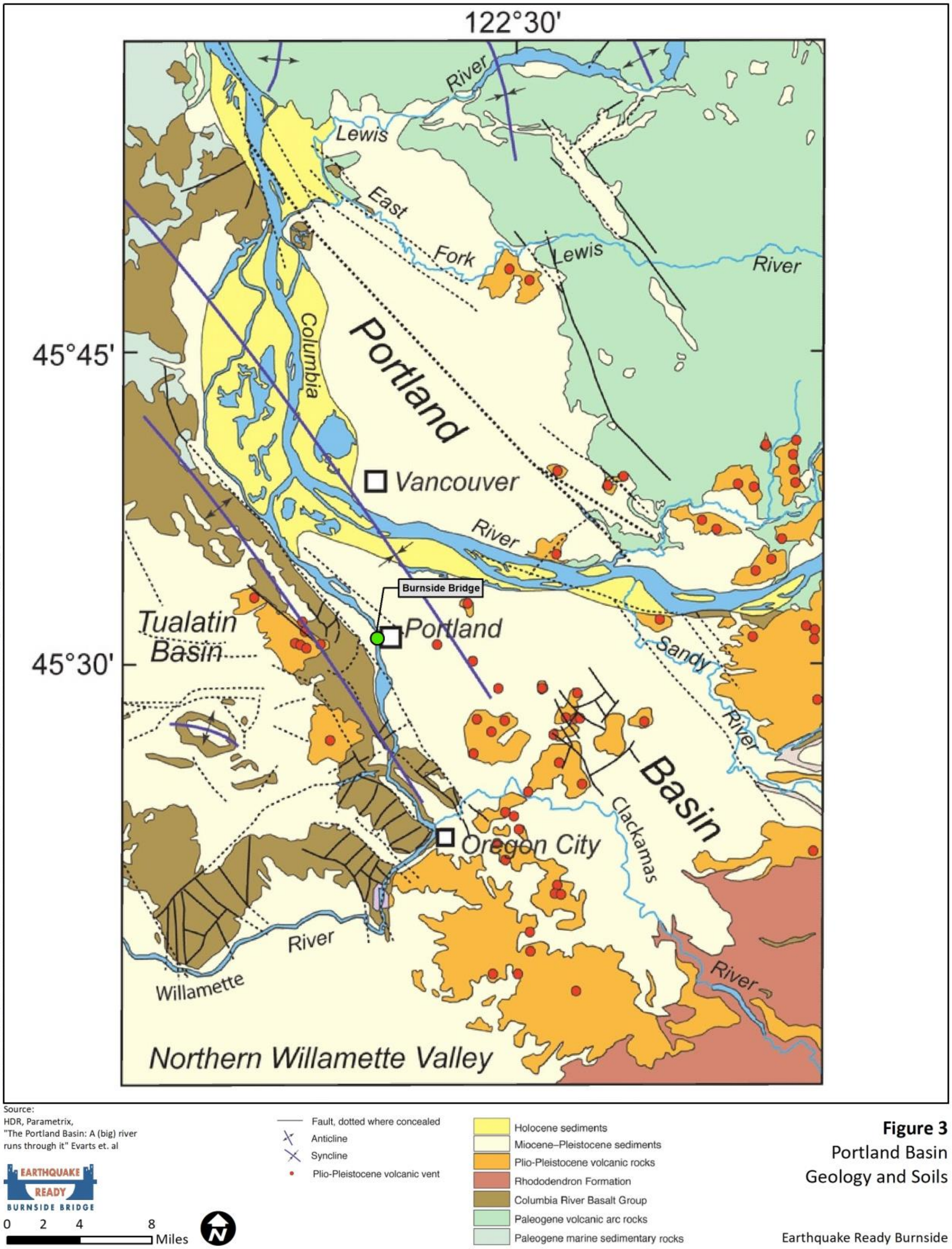
Belowground field exploration, including three mud rotary-drilled borings with associated soils testing, was conducted in 2016 during the preparation of the geotechnical report. No additional testing of soils or geologic conditions is proposed to be conducted as part of the preparation of the EIS.

5.3 Existing Conditions

5.3.1 Regional Geologic Setting

The City of Portland is centrally located in the Portland Basin, an approximately 1,300-square-mile area situated in northwestern Oregon and southwestern Washington (Figure 3). The basin is a northwest-southeast trending sediment-filled structural depression, approximately 45 miles long and 20 miles wide, bounded on the southwest by the Tualatin Mountains (also referred to as the Portland Hills) and the western Cascade Range on the east, north, and south (Swanson 1993). The Portland Basin is one of several topographic and structural depressions associated with the Puget-Willamette forearc trough of the Cascadia subduction system (Gannett 1998; Evarts 2009). The southwestern margin of the Portland Basin is a well-defined break along the base of the Tualatin Mountains and clearly fault-bound along its west edge from the Clackamas River through downtown Portland (Madin 1998). The northeastern margin of the basin is less clear or defined.

Figure 3. Portland Basin



Source: HDR, Parametrix, Evarts et al. 2009

The basement rock in the Portland Basin predominantly consists of lava flows associated with the Miocene Columbia River Basalt Group (CRBG) (Beeson 1991). The CRBG is thought to be the most extensive geologic unit in the basin. As the basin gradually subsided during the late Miocene and Pliocene, it was filled with fluvial and lacustrine sediments transported through the Cascade Range by the ancestral Columbia River with additional material carried in by tributaries draining the surrounding highlands (Swanson 1993; Evarts 2008). During Quaternary time, sediment deposition in the basin was influenced by alternating episodes of incision and aggradation associated with Quaternary climate change and glaciation, including multiple catastrophic flood events, leaving prominent gravel fills and terraces.

Early geologic mapping of the Portland Basin referred to the fill sediments as the Troutdale Formation, named after exposures near Troutdale, Oregon. Further work noted that a section of the Troutdale Formation consisted predominantly of fine-grained beds quite different from the coarse-grained sandstone and conglomerate typical of the Troutdale type area. This observation resulted in dividing the Troutdale Formation into informal lower and upper members based on the noted lithologic difference. The lower fine-grained member was formally named the Sandy River Mudstone by Trimble (1963) while retaining the name Troutdale Formation for the overlying sandstone and conglomerate. More recent studies have found that the stratigraphic relationships with the basin fill are more complex than portrayed by Trimble (1963) and Mundorff (1964).

The indirect effects of Quaternary glaciation and volcanism formed most of the present topography of the Portland Basin. Isolated hills represent eruptions that began in late Pliocene time and continued throughout the Quaternary associated with the Boring Lava Field (Madin 2009; Evart 2008). Episodic influxes of sand and gravel into the Portland Basin by the Columbia River occurred from late Pliocene to late Pleistocene time. Much of the modern land surface in the Portland Basin has been shaped by the cataclysmic late Pleistocene Missoula Floods. These floods were caused by repeated failure of an ice dam at Pleistocene Lake Missoula in western Montana. Each failure producing enormous floods that coursed down the Columbia River and into the Portland Basin. The sediment-laden floodwaters were hydraulically dammed by a constriction of the Columbia River valley at the north end of the Portland Basin, causing temporary ponding in the basin and tributary valleys to elevations below 400 feet (Gannett 1998). Associated with Quaternary glaciation was deposition of loess; silt deposits that blanket most upland surfaces above areas affected by the Missoula Floods (Madin 2009). These silt deposits are especially thick in the Tualatin Mountains and known as the Portland Hills Silt (Lentz 1981).

5.3.2 Project Area Topography

The topography of the Project vicinity reflects location in a depositional basin with the modern surface shaped by catastrophic flood events of the Columbia River. The dominant topographical features of the area include the north-south trending Tualatin Mountains to the west (the Portland Hills) and the Cascade Range to the east representing the western and eastern boundaries of the Portland Basin, respectively, and the convergence of the westward flowing Columbia River and the northwestward flowing Willamette River that flow into and subsequently out of the Portland Basin (Figure 3). The City of Portland lies within the Portland Basin. Development of the City of Portland has included extensive placement of fill in areas adjacent to the Willamette River and in catastrophic flood channels near the river.

The City of Portland is generally divided by the Willamette River that flows through the city from the south toward the north, creating a natural east-west division. The western portion is generally flat from the Willamette River to the west until the gradual incline of the Tualatin Mountains begins approximately one mile to the west of the Willamette River. The eastern portion of the city is generally flat with several buttes and outcroppings far east of the Willamette River. The API and Project Area straddle the Willamette River, and are relatively flat with the land on the east side of the river gently sloping west toward the river and the land on the west side of the river gently sloping east toward the river. Figure 4 shows the topography of the API based on Lidar.

5.3.3 Project Area Geologic Mapping

Deposits associated with the Troutdale Formation, the catastrophic Missoula Floods, alluvium, and artificial fill have been mapped in the Project vicinity (Figure 5). Beeson (1991) divided catastrophic flood deposits into three facies; channel facies (Qfch), fine-grained facies (Qff), and coarse-grained facies (Qfc). Along with the Troutdale Formation (Tt), alluvium (Qal), and artificial fill (Qaf), two of the three Missoula Flood alluvium facies are present in the Project Area. The following provides descriptions of these geologic units.

Troutdale Formation (Tt) – Miocene to Pliocene: Friable to moderately strong conglomerates with minor interbeds of sandstone, siltstone, and claystone. This unit is shown to be exposed adjacent to the eastern shore of the Willamette River at the north side of the API.

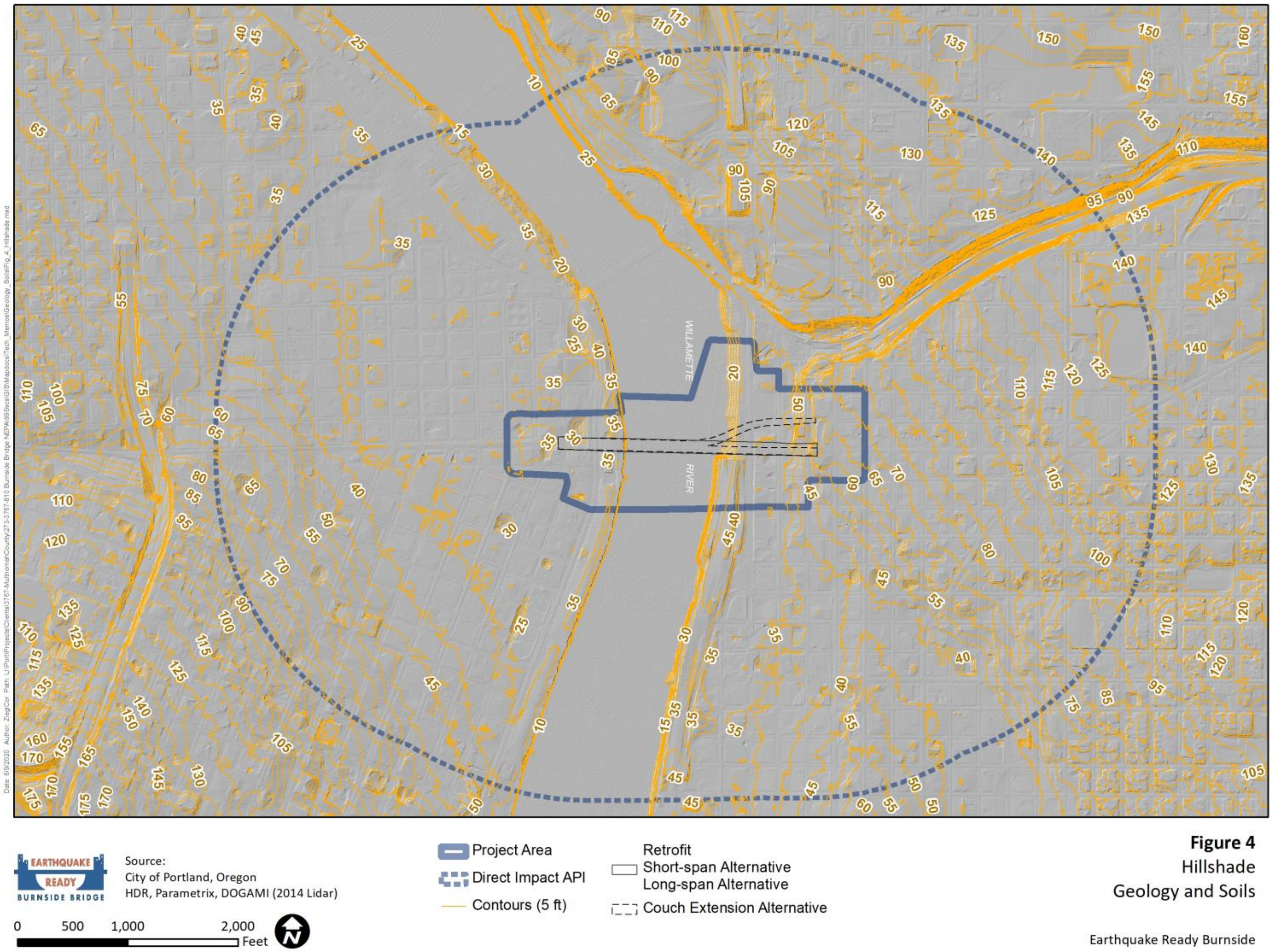
Catastrophic flood deposits – Pleistocene **channel facies** (Qfch): Complexly interlayered with variable amounts of silt, sand, and gravel deposited in major flood channels. Channels are cut in earlier and/or contemporaneous fine and coarse flood deposits (Qff and Qfc) and retain much of original morphology. This unit is shown to be present in the east API.

Catastrophic flood deposits – Pleistocene **fine-grained facies** (Qff): Coarse sand to silt deposited by catastrophic floods. Poorly defined beds approximately 1 to 3 feet thick. Modern soil development commonly introduced abundant clay and iron oxides into the upper approximately 6 to 10 feet of the deposit. This unit is shown to be present in the eastern Project Area and just beyond the western end of the API.

Alluvium (Qal) – Quaternary: River and stream deposits of silt, sand, and organic-rich clay with subordinate gravel of mixed lithologies. This unit is shown to be present in the west API.

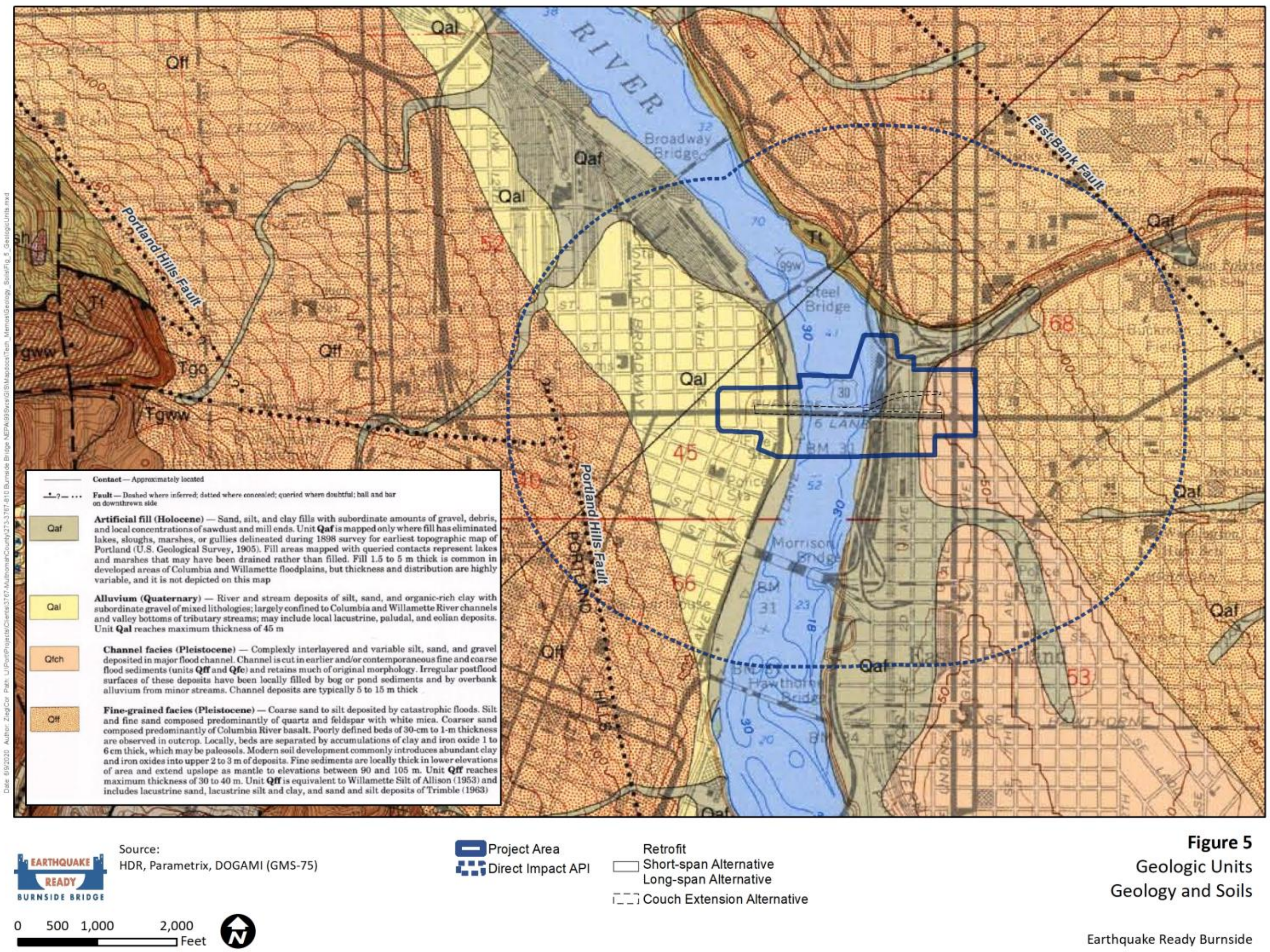
Artificial fill (Qaf) – Holocene: Sand, silt, and clay fills with subordinate amounts of gravel, debris, and local concentrations of sawdust and mill ends. This unit is shown to be present adjacent to both sides of the river in the API.

Figure 4. Hillshade



Source: City of Portland, HDR, Parametrix, DOGAMI (2014 Lidar)

Figure 5. Geologic Units



Source: HDR, Parametrix, DOGAMI (GMS-75)

Two structures (faults) are shown to be present west and east of the API. The fault to the west is known as the Portland Hills fault. The fault to the east is known as the East Bank Fault. The locations of both faults are shown on Figure 5 as a dotted indicating the location is concealed. The down-side of Portland Hills fault is shown to be on the east side; the down-side of the East Bank Fault is shown to be on the west side.

5.3.4 Project Area Earthquake-Hazard Geologic Mapping

Earthquake-hazard mapping in the Portland metropolitan area was initiated by DOGAMI in 1990 and has focused on Quaternary units shown to be present in the API. The following four geologic units in the Portland metropolitan area have been identified (Madin 1990) as potentially having high amplification or liquefaction potential: Quaternary loess, catastrophic flood fine-grained facies (Qff), fine-grained alluvium (Qal), and artificial fill (Qaf). Only Quaternary loess has not been mapped as present in the API.

The level of ground shaking at a given location may increase, or be amplified, by focusing seismic energy in response to the geometry of the depositional material. The effects of a seismic event vary with the softness and thickness of depositional material. As seismic waves travel through the ground, they move faster through hard rock than soft soil. When waves transition from hard to soft earth-material, they increase in amplitude, resulting in a bigger wave that causes stronger shaking. The thicker a soft depositional unit (e.g., sediment) is above a harder unit, the more material there is for the seismic waves to travel through. Soft soil means bigger waves and stronger amplification.

Liquefaction is the drastic loss of soil strength that can accompany shaking during a moderate or strong seismic event. During ground shaking, vibration or water pressure within a mass of soil can cause soil particles to lose contact with one another. As a result, the soil behaves like a liquid and is unable to support weight and can flow. Loose granular soils located below the water table are generally susceptible to liquefaction.

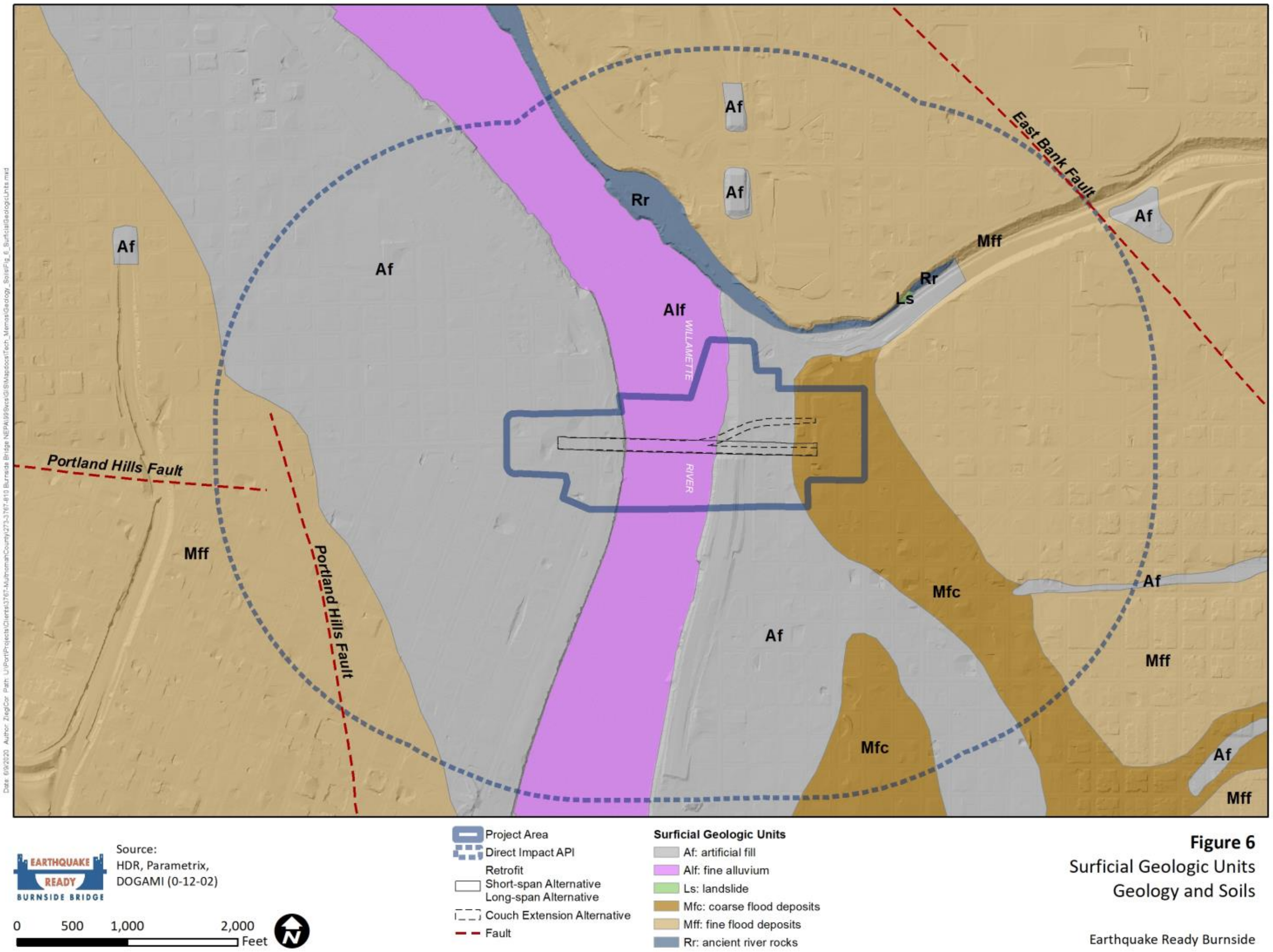
Since 2003, DOGAMI has been working with the USGS to develop digital geologic maps for the Portland metropolitan area to support earthquake and landslide hazard and risk studies for the region. One product of this effort is a Lidar-based surficial geologic map of the greater Portland area (Ma 2012). Figure 6 shows the surficial geologic map for the API. The following surficial geologic units are shown to be present in the API: ancient river rocks, fine and coarse Missoula Flood deposit facies, artificial fill, and fine alluvium. The following provide descriptions of these five units.

Ancient river rocks (Rr): This unit is shown to be present adjacent to the east side of the Willamette River and north of the API. The location of this unit corresponds with the Troutdale Formation (Tt) as mapped by Beeson (1991) and described in Section 5.3.2.

Missoula Flood deposits – **fine flood deposits** (Mff): This unit is shown to be present in the east API. The location of this unit corresponds with the catastrophic flood deposits fine-grained facies (Qff) as mapped by Beeson (1991) and described in Section 5.3.2.

Missoula Flood deposits – **coarse flood deposits** (Mfc): This unit is shown to be present in the east API. The location of this unit generally corresponds with the catastrophic flood deposits channel facies (Qfch) as mapped by Beeson (1991) and described in Section 5.3.2.

Figure 6. Surficial Geologic Units



Source: HDR, Parametrix, DOGAMI (0-12-02)

Artificial fill (Af): This unit is shown to be present throughout the west API and adjacent to and east of the Willamette River. The location of this unit generally corresponds with Quaternary alluvium (Qal) and artificial fill (Qaf) as mapped by Beeson (1992) and described in Section 5.3.2. As mapped by Ma (2002), the artificial fill unit extends further to the west compared with the extent of alluvium as mapped by Beeson (1991).

Fine Alluvium (Alf): This unit is shown to be present in the Willamette River channel in the API. This unit consists of sand, silt, clay, and small amounts of gravel. This deposit unit has formed since the end of the Missoula Floods and therefore younger than 12,000 years. This is a loose, water-saturated sediment identified as very susceptible to liquefaction during strong earthquake shaking.

The two faults mapped by Beeson (1991) as shown on Figure 5 are also shown on Figure 6. The time since last deformation (displacement) on the Portland Hills Fault and the East Bank Fault is less than 15,000 years ago (Wong 2001).

5.3.5 Project Area Boring Findings

The geotechnical report (Shannon & Wilson 2020) presents a summary of subsurface conditions based on review of existing geotechnical boring information, other borings (non-geotechnical) that have been completed in the Project Area, and three geotechnical borings located in the Willamette River completed during an earlier Project phase. The following primary geotechnical units were identified: fill, alluvium, catastrophic flood deposits, and Troutdale Formation. The presence of these identified units is consistent with previously mapped geologic units as described in Sections 5.3.3. and 0. With exception of fill, the identified primary geotechnical units were further divided. The following describe identified geotechnical units.

Alluvium is divided into fine-grained, sand/silt, sand, and gravel units. Fine-grained material consists of very soft to medium-stiff silt and clay with varying amounts of sand. Sand/silt material is very loose grading with depth to dense/very soft grading with depth to stiff. The unit consists of silty sand and sandy silt with trace gravel, trace silt and clay interbeds, and trace organic. Sand material is loose to medium dense, occasionally dense to very dense consisting of sand to gravelly sand with varying amounts of silt, lesser amounts of silty sand, some zones containing organics and wood debris. Gravel material is medium dense to very dense gravel with varying amounts of sand and fines including zones with cobbles and possible boulders including trace lenses of sand and silt.

Catastrophic flood deposits are divided into fine-grained facies and channel facies. The fine-grained facies are stiff to very stiff. The channel facies are dense to very dense interbedded sand and gravel deposits with varying amounts of fines, lesser layers of stiff sandy silt, and includes zones with cobbles and possible boulders.

The **Troutdale Formation** is divided into the Upper Troutdale Formation, Lower Troutdale Formation, and Sandy River Mudstone. The Upper Troutdale Formation is described as dense to very dense sand and gravel deposits with varying fines content, interbedded with hard silt and clay deposits containing varying amounts of sand with some zones of cementation. The Lower Troutdale Formation is described as very dense gravel with varying amounts of sand and fines, trace sand and fine-grained layers were also encountered along with some zones of cementation and cobbles likely present in some areas. The Sandy River Mudstone is described as consisting of hard clay with varying amounts of sand interbedded with very dense sand that contains varying amounts of fines.

The distribution of these geotechnical units is shown on west to east Interpretive Subsurface Profile A-A’ presented in the geotechnical report (Shannon & Wilson 2020). Profile A-A’ provides an interpretive subsurface profile from the west end to just beyond the east end of the Burnside Bridge. Based on this profile the general distribution of the geotechnical units in the Project Area are as follows.

Fill – Varying thickness present at ground surface on both east and west sides of the river. This is consistent with surficial geologic units shown on Figure 6. Fill thickness was found to be up to 25 feet or more.

Fine-grained alluvium – These deposits were encountered on both sides of the river. The unit is intermittently present below fill and as interbeds within and between other alluvial units. The thickest accumulation is found on the east side of the river where thicknesses up to 100 feet were observed.

Sand/silt alluvium – Encountered intermittently throughout the Project Area and interbedded with other alluvial units. The silt/sand alluvium unit is most prevalent on the east side of the river with thicknesses up to 100 feet. In the western and central portions of the site thicknesses range from 5 to 20 feet.

Sand alluvium – This unit has been interpreted to be an approximately 25- to 50-foot-thick layer situated at the bottom of the modern-day Willamette River. Lesser layers were also noted to be present in the subsurface below the banks of the river.

Gravel alluvium –This unit has been interpreted to be an approximately 10- to 40-foot-thick layer situated beneath the other alluvial deposits. The gravel alluvium unit is present from the western bank to the eastern bank of the river extending continuously beneath the river. The gravel alluvium is differentiated from the channel facies of the catastrophic flood deposits by having a more consistent composition and fewer interbeds of silt and sand.

Catastrophic flood deposits – fine-grained and channel facies – Material associated with the fine-grained facies and the channel facies of the catastrophic flood deposits were encountered on the east side of the Project Area, above the lower east riverbank. The approximately 10-foot-thick fine-grained facies deposit is situated on top of the approximately 20-foot-thick channel facies deposit.

Troutdale Formation – Material identified as associated with the upper section of the Troutdale Formation is present only in the western portion of the of the river and under the west riverbank. Material identified as associated with the lower section of the Troutdale Formation is identified present under the river and both the east and west riverbanks. The upper section is described as dense to very dense sand and gravel deposits with varying amounts of fine content interbedded with hard silt and clay deposits containing varying amounts of sand. Some cementation was reported present. The lower section is described as typically consisting of very dense gravel with varying amounts of sand and fines. Zones of cementation are noted throughout the unit.

Sandy River Mudstone – Presence of material associated with the Sandy River Mudstone was interpreted to be present below the lower section of the Troutdale Formation in three borings located in the western portion of the river and riverbank area. Material interpreted to represent Sandy River Mudstone deposits are described as a gray to green-mottled hard silty clay to clay with trace fine micaceous sand to very dense sand with some silt. Trace organics are present in section. Very dense interbeds of fine to medium sand are also present.

5.3.6 Project Area Mapped Soils

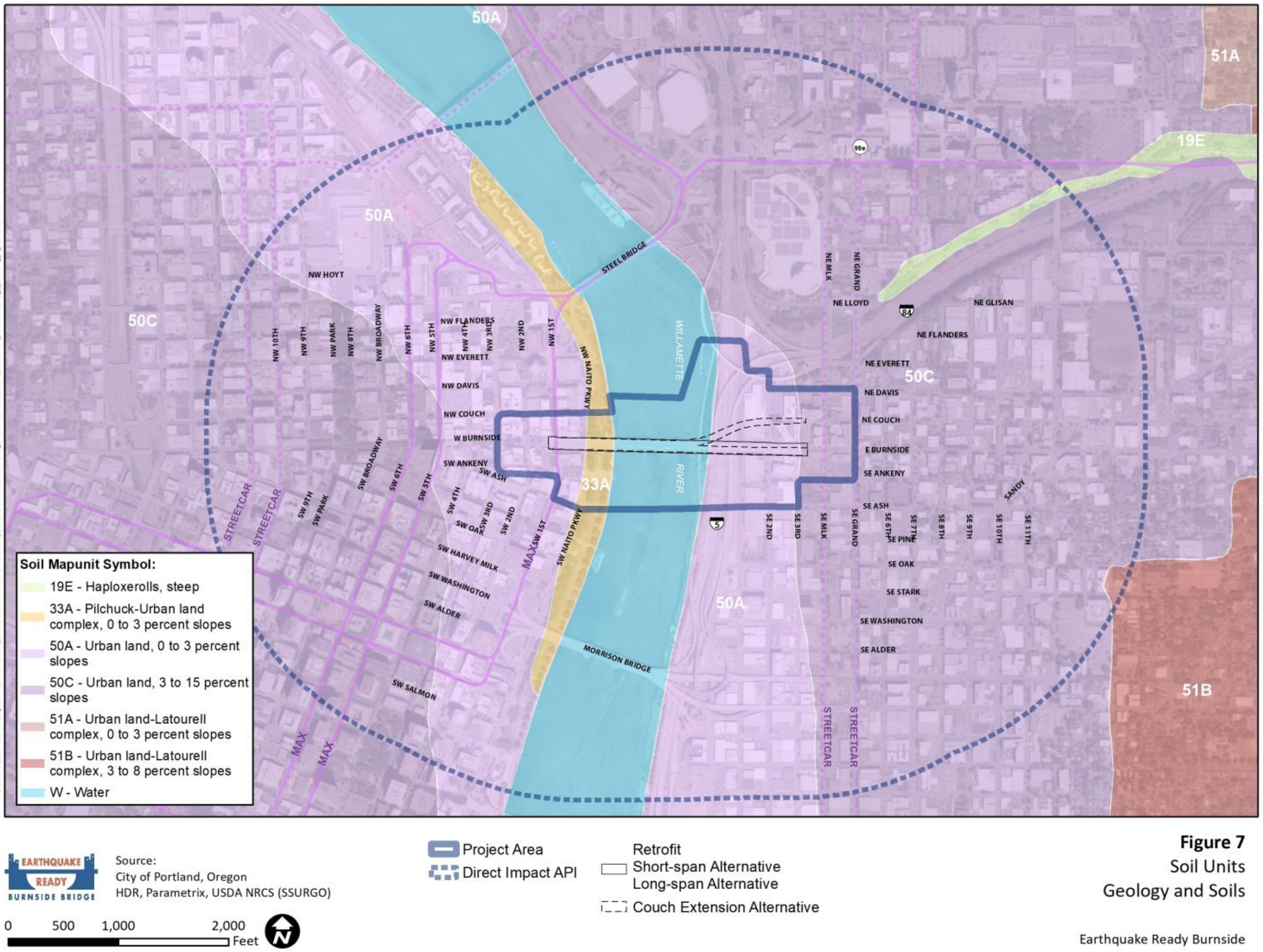
The NRCS soil map for Multnomah County Area identifies the presence of four soil types in the API. These soil types are Pilchuck-Urban land complex on 0 to 35 slopes (33A), Urban land on 0 to 3 percent slopes (50A), Urban land on 3 to 15 percent slopes (50C), and Haploxerolls, steep (19E). The distribution of these four soil types in the API is shown on Figure 7. Urban land-Latourell complex on 0 to 3 percent slopes are present southeast of the API. Urban land soil types 50A and 50C are the dominant soil types present in the Project Area. Soil type 33A is shown to be present only along the west riverbank area. Soil type 19E is only shown to be present only on the north slope of Sullivan's Gulch in the northeast corner of the Project Area.

A description of Urban land soils is not provided for soil types 50A and 50C. The NRCS manuscript for the soil survey of Multnomah County, Oregon, indicates that this map unit is used where 85 percent or more of the soils are covered with commercial and industrial buildings, streets and sidewalks, parking lots, railroads, and other works and structures. Some areas are not covered by works and structures, but soils present have been so altered during construction that to separate them was deemed not practical. The original soil type was loam ranging from a silty clay loam to a gravelly loam and was commonly situated over stratified sand and gravel at a depth of 4 to 6 feet.

The Pilchuck-Urban land complex soil on 0 to 3 percent slopes (33A) is described as a complex consisting of excessively drained soil on the flood plains of the Columbia and Willamette Rivers. This soil type formed in sandy alluvium or sandy dredge spoils. In most areas, this soil complex has been graded, cut, filled, or otherwise disturbed. Pilchuck soils and Urban land are typically together in such an intricate pattern that it is not practical to map them separately. About 35 percent of this soil complex is sandy material 20 feet or more in depth. In areas of undisturbed Pilchuck soil, permeability is very rapid.

The Haploxerolls steep (19E) soil is described as a well-drained to moderately well-drained soil located on long, narrow escarpments of drainages that have cut into the valley terrace and along major streams and rivers. This soil type is a mixture of silt and sand. The typical soil horizon consists of dark brown to brown sandy to silty clay loam. Permeability is moderate to moderately slow. Hazard of erosion is moderate to high. The soil is subject to slumping.

Figure 7. Soil Units



Source: HDR, Parametrix, USDA NRCS (SSURGO)

5.3.7 Project Area Groundwater Conditions

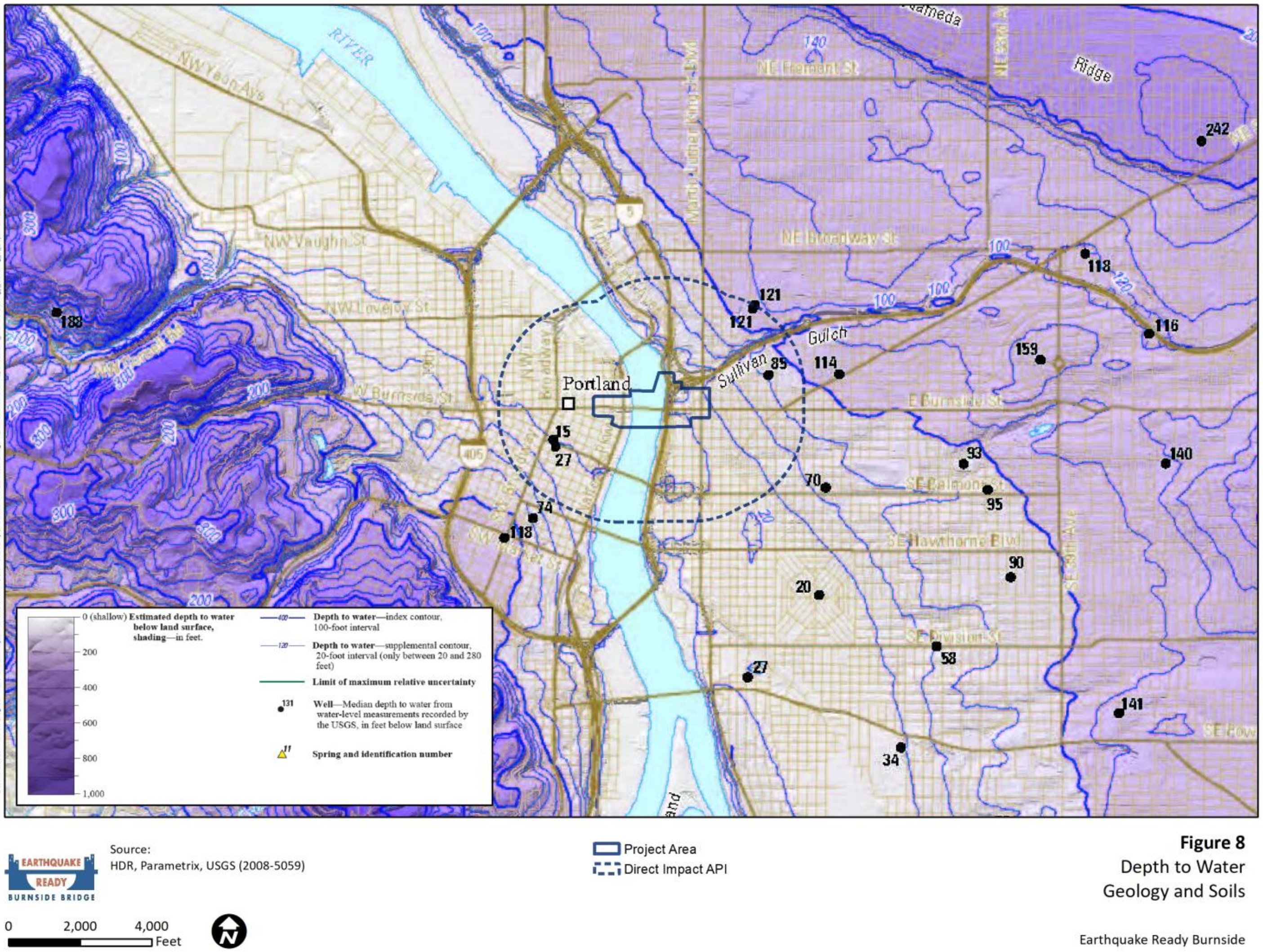
Mapping to provide information on the configuration of the water table in the Portland metropolitan area has been completed (USGS 2008). Figure 8 shows the configuration of the water table in the API based on the USGS (2008) analysis. This water table mapping effort was completed in response to recognition that construction of new infrastructures for diverting stormwater runoff have raised concerns regarding the protection of groundwater resources, particularly with the use of underground injection control systems (e.g., sumps, drywells, stormwater injection systems) and other systems designed to allow for the infiltration of stormwater. Information derived from the effort also can be used in the evaluation of aquifer susceptibility and the design of monitoring programs used in construction of buildings, roads, and infrastructure.

Development of estimated depth-to-water and water table elevation maps for the Portland area included estimation of the relative uncertainty and seasonal water-table fluctuations. The USGS (2008) mapping effort relied on water-level data collected from shallow wells during the effort and from previous USGS investigation. Range of seasonal water-level measurements was evaluated based on wells with multiple water-level measurements distributed throughout the seasons.

The water table in the API generally reflects the land surface. This condition is typically observed in humid areas with relatively thin unsaturated zones that are present in the Portland area. The configuration of the water table is a function of the geometry of the land surface, the rate and location of groundwater recharge and discharge, aquifer properties, and the extent, thickness, and shape of the aquifer and adjacent confining units, if present. Changes in depth-to-water level are influenced by seasonal precipitation patterns, but also can be influenced by human-induced modifications such as changes to impervious area or stormwater runoff into underground injection control systems.

In the API there are no publicly owned underground injection control systems (COP 2010; USGS 2008). With the exceptions of the river and vegetated areas of Waterfront Park, the area between the west side of the river and NW Naito Parkway, and the east side of the river and exposed unpaved surfaces to the east side of the railroad corridor, most of the ground surface consists of impervious surfaces. Most of the stormwater drainage in the Project Area flows into the combined sewer system which mostly flows to the City of Portland treatment plant. Stormwater in the east Project Area, from the river to east of SE 2nd Avenue, is served by a separate storm sewer system (COP 2010). This system carries stormwater runoff that flows through public and private pipes, drainages, and other stormwater conveyance systems.

Figure 8. Depth to Water



Source: HDR, Parametrix, USGS (2008-5059)

Primary surficial aquifers in the vicinity of the API consist of the unconsolidated sedimentary aquifer and the Troutdale gravel aquifer where the Troutdale is exposed or near the surface. These two aquifers supplied more than 80 percent of the volume pumped in 1987 and 1988 (Collins and Broad 1993). In the API, the unconsolidated sedimentary aquifer is present in catastrophic Missoula Flood deposits and Quaternary alluvium. Perched groundwater zones may also be present in the shallowest parts of the surficial aquifers. The Willamette River is understood to be in direct hydraulic contact and interact with groundwater. Water-table mapping completed by the USGS (2008) assumed that surface water features such as the Willamette River are considered characteristic of the water table at land surface. Fluctuation of Willamette River stage is reportedly between elevations of approximately 6 and 20 feet; a 14-foot range (Shannon & Wilson 2020). Identified seasonal water-table fluctuations in the vicinity of the Project Area appear to be in the range of 0 to 6 feet and may range up to 12 feet in certain locations (USGS 2008). The overall direction of groundwater flow is toward the major groundwater discharge areas consisting of the Columbia and Willamette Rivers.

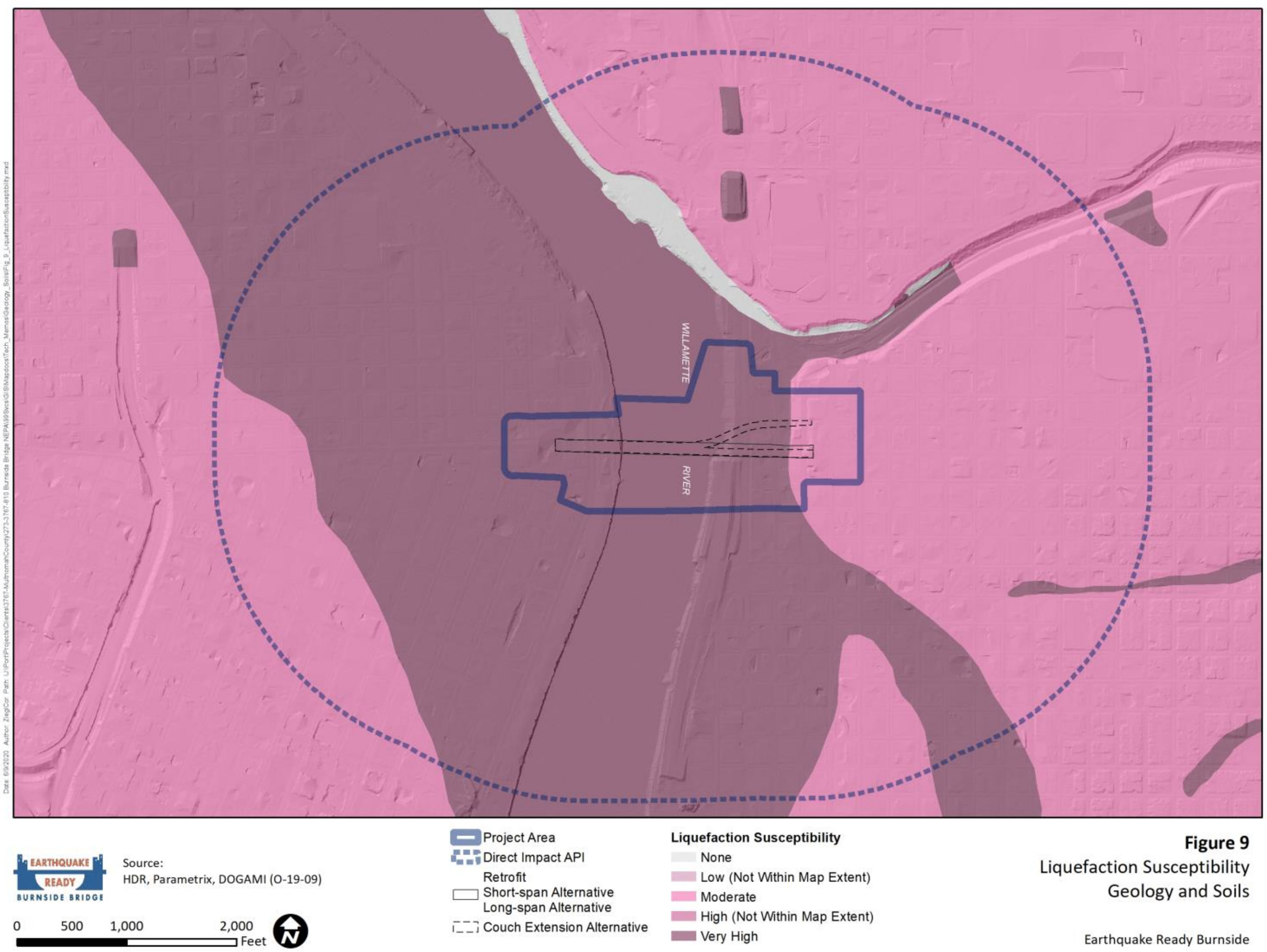
Estimated depth to groundwater in the Project Area as shown on Figure 8 (USGS 2008) is 15 feet or less. The Shannon & Wilson (2019) report noted that boring logs completed on the west side of the Willamette River for the Ankeny Pump Station and the west side combined sewer overflow reported groundwater elevations that range from approximately 6 to 10 feet (NAVD 88)[1] or approximately 20 to 24 feet below ground surface (bgs). A boring completed for the for the east side combined sewer overflow on the east side of the Willamette River reported a groundwater elevation of approximately 15 feet or approximately 29 feet bgs. The Shannon & Wilson report (2020) cited boring (ES-2005C) located approximately 865 feet east of the river while the cited west side borings are located within approximately 235 feet of the river. Borings completed for the Prosper Portland between E Burnside Street and NE Davis Street and NE 2nd Avenue and NE Martin Luther King, Jr. Boulevard indicate a groundwater elevation of 25 feet (Shannon & Wilson 2019). The presence of perched groundwater was identified in a boring located adjacent to the east side of this area. Depth to groundwater for the perched zone was 15 feet or an approximate elevation of 50 feet.

5.3.8 Project Area Seismic Mapping

To increase the resiliency of the Portland metropolitan region to seismic hazards, DOGAMI has been updating local geologic information in conjunction with current understandings of risks associated with a CSZ event and a Portland Hills earthquake event. A CSZ earthquake represents a regional event, and a Portland Hills earthquake represents a local event. The effort includes assessment and analysis of resulting ground motion and ground deformation associated with the two earthquake scenarios. This effort resulted in mapping updates associated with earthquake-induced landslide susceptibility, liquefaction susceptibility, and soil amplification classification. The most severe damage from earthquakes is often associated with amplification of ground shaking by soil, ground deformation due to liquefaction of water-saturated low cohesion deposits, and the triggering of landslides. These phenomena are referred to as coseismic hazards (Figure 9).

[1] North American Vertical Datum of 1988.

Figure 9. Liquefaction Susceptibility



Source: HDR, Parametrix, DOGAMI (0-19-09)

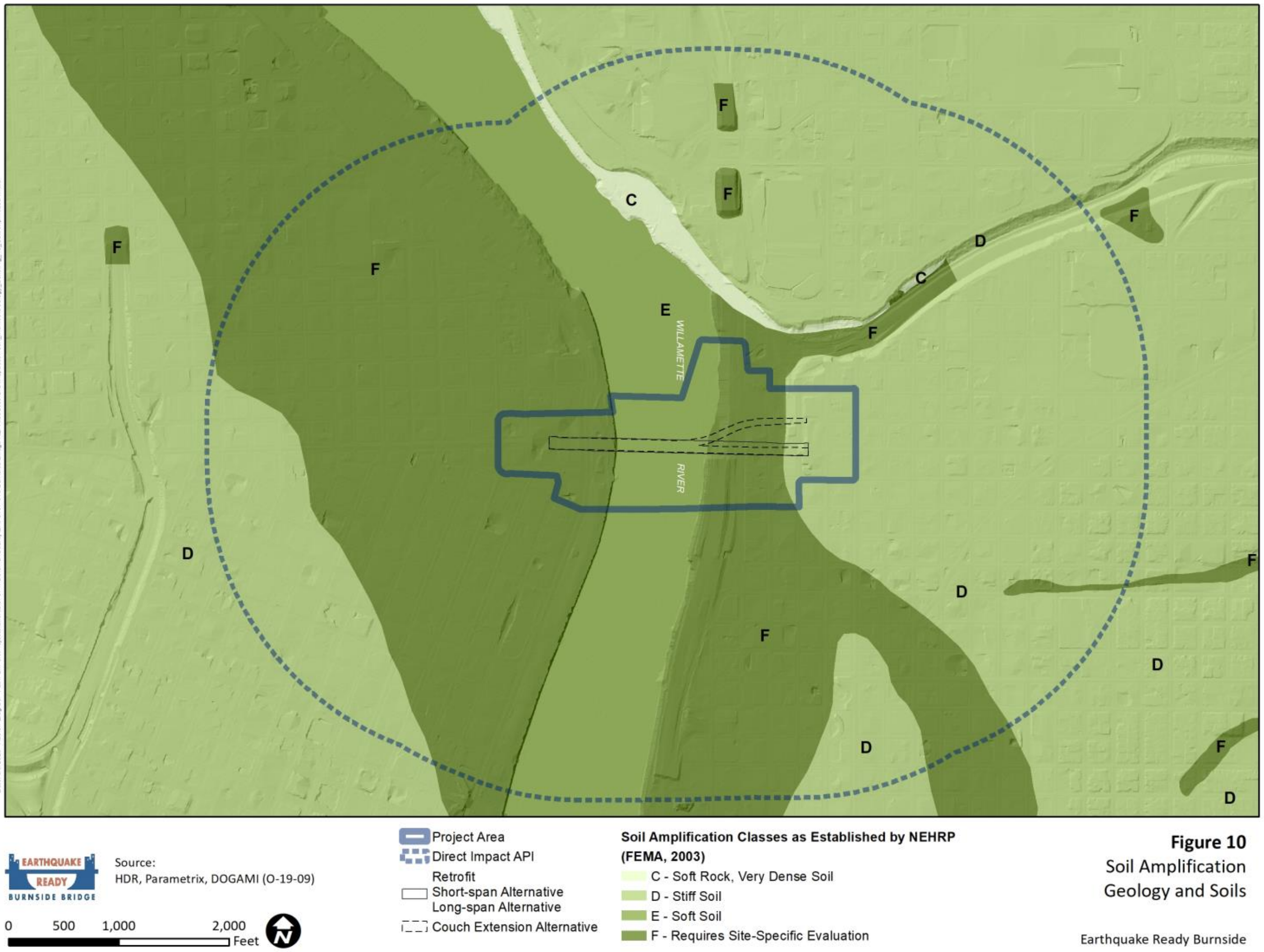
The geologic diversity present in the Portland Basin creates significant local variations in earthquake ground motion and in ground failure from earthquake-induced landslides and liquefaction. The evaluation completed by DOGAMI (2018) assumed a CSZ magnitude 9.0 earthquake and a magnitude 6.8 Portland Hills fault earthquake. The potential occurrence of a magnitude 6.8 Portland Hills fault earthquake event is described by Wong (2001). The DOGAMI (2018) analysis also examined an earthquake event occurring during saturated and dry soil conditions. A saturated soil condition event would more likely have earthquake-induced landslides and liquefaction. In contrast, a dry soil condition may have some earthquake-induced landslides, but a lower occurrence of liquefaction. The analysis completed by DOGAMI determined a higher damage and casualty estimate in the Portland metropolitan area resulting from a Portland Hills fault earthquake compared with a CSZ earthquake, primarily due to the location of the Portland Hills fault that is situated below a densely populated and heavily developed area. However, the likelihood of a Portland Hills fault earthquake is considerably less than a CSZ earthquake (DOGAMI 2018).

DOGAMI's recent efforts to evaluate and estimate damage and casualties resulting from a major earthquake used the Federal Emergency Management Agency's Hazus methodology and associated modelling. To evaluate ground motion at a structure's (building) location, the Hazus model requires the following four descriptors: peak ground acceleration, peak ground velocity, spectral acceleration at 1.0 second, and spectral acceleration at 0.3 second. Peak ground acceleration and velocity are the largest that can be expected at a specific site due to an earthquake. Based on these descriptors, DOGAMI (2018) evaluated two specific earthquake scenarios (magnitude 9.0 CSZ earthquake and a magnitude 6.8 Portland Hills fault earthquake) resulting in the following maps: site peak ground acceleration (for both earthquake scenarios); perceived shaking and damage potential (for both earthquake scenarios); potential permanent ground deformation due to earthquake-induced landslides or liquefaction lateral spreading (only for CSZ earthquake scenario with saturated soil assumption); and probability of earthquake-induced landslides or liquefaction (only for CSZ earthquake scenario with saturated soil assumption).

To further inform ground motion and ground deformation at a given location based on the surficial geology present, DOGAMI (2019) developed coseismic geohazard maps that can be utilized to assess impact of an earthquake at a neighborhood scale. Maps produced by DOGAMI (2019) associated with this analysis include the following: soil amplification classes; liquefaction susceptibility; coseismic landslide susceptibility (for both wet and dry soil conditions).

To establish appropriate seismic demands, consistent with the recommendation for soils within Site Class F shown in Figure 10, preliminary dynamic soil-structure interaction (DSSI) analyses were performed to develop site-specific design ground motions and to evaluate ground deformations from seismic shaking. These DSSI analyses estimate the seismic response of a site based on earthquake time histories applied to the base of the model. As a result of these analyses, largely due to the presence of the soft soils at the site, recommended preliminary seismic ground motions were developed that often exceed those derived from DOGAMI's typical methods. See the EQRB geotechnical report (Shannon & Wilson 2020).

Figure 10. Soil Amplification



Source: HDR, Parametrix, DOGAMI (0-19-09)

6 Impact Assessment Methodology and Data Sources

The effects of soil, geologic, and hydrogeologic conditions on the Project are dependent on the physical properties of soil and rock in the region and their responses to external forces. These forces include, but are not limited to, severe ground shaking, settlement, and/or liquefaction associated with a seismic event, expansion and/or contraction of soils, landslides from steep or altered slopes, scour, and erosion. A significant geologic impact would expose people and/or structures to potentially adverse effects including damage, loss, injury, or death.

The geologic and soil conditions identified to be present in the Project Area are evaluated with emphasis of potential geologic and/or soil hazards that may impact the Project. The effects of geologic and hydrogeologic conditions on the Project are dependent on physical properties of soil and rock in the API. The impact assessment evaluation considers the conditions identified, then applies professional judgment to assess the level of concern that these geologic conditions may pose on the Project Alternatives. A more detailed geotechnical evaluation will be developed as design efforts advance through the Final EIS and into final design.

6.1 Long-Term Impact Assessment Methods

Long-term effects are defined as those lasting beyond the construction period, and can be either effects on the completed Project from geologic hazards, or the effects from the completed Project on geologic resources. Geologic hazards include seismic events (earthquakes), liquefaction, landslides, steep slopes, and soil erosion. Geologic resources include rock and aggregate, and groundwater resources. For the purpose of this summary, these potential effects are placed in context with respect to the No-Build Alternative.

6.1.1 Geology and Material Resources

Geology and material resources were assessed using DOGAMI's surface mining permit database that lists active and closed private quarry and borrow material sites. Other information for the assessment includes review of surficial geology as delineated by aerial photography interpretation, Lidar, ground reconnaissance techniques, existing published geologic information, and findings presented in the geotechnical report (Shannon & Wilson 2020). Direct long-term impacts were assessed by evaluating what potential resources would be affected.

Review of DOGAMI's surface mining permits database indicated that there are no active or closed surface mining (quarry) sites located in the API or near the Project Area. The closed Curry Street Plant site adjacent to the east side of the Willamette River is located approximately 1.2 miles north (down-river) of the Project Area. The closed Ross Island Sand & Gravel site, the next closest identified permitted surface mining site, is located approximately 2.3 miles south (upriver) of the Project Area on Ross Island. The permittee of the closed Curry Street Plant site was Northwest Aggregates Company. The site is now operated by CalPortland that provides various building materials such as cement, concrete, aggregates, and asphalt. The permittee of the closed Ross Island site is Ross Island Sand & Gravel. Ross Island Sand & Gravel operated a concrete plant adjacent to the northeast side of the Ross Island bridge. However, they closed this concrete plant in early 2019.

Review of recent aerial images in and near the Project Area indicated that there are no borrow material sites. Building construction occurring in the Project Area has resulted in various amounts of related excavation work. It is not known where material excavated during new building construction has been disposed.

6.1.2 Groundwater Hydrology

Groundwater hydrology impacts are based on location and definition of groundwater resources. Information was obtained through a literature search of existing hydrology publications and documents. Direct long-term impacts were assessed by evaluating how operation of the Alternatives and Options would affect groundwater quality.

Historically, groundwater in the Project vicinity has been used for industrial purposes, primarily for thermal heat exchange associated with heating and cooling of buildings in downtown Portland (Brown 1963). Drinking water in the Project vicinity is provided by the City of Portland, sourced from the Bull Run River, and augmented with groundwater produced from wells located near the Columbia River in east Portland.

The principal aquifers in the Project vicinity are found in the CRBG and in the Troutdale Formation. Other aquifers or water-bearing zones are found in the catastrophic flood and alluvial deposits mapped in the Project Area. Historically, most of the wells located in the westside City of Portland business district tapped the CRBG or the Troutdale Formation for water (Brown 1963).

An DEQ assessment of the former East Portland Gas Works site, located in the southeast corner of the Project Area, noted there are records for 10 production wells within 0.5 mile of the subject site (DEQ 2012). Current use of 8 wells was not determined but they appear to be for industrial purposes (thermal heat exchange). Two wells are located in and adjacent to the east boundary of the API, that in addition to providing thermal heat exchange, also appear to be used as a drinking water source. The two wells are associated with a transient water supply system (public water supply OR4195347) that reportedly provides drinking water to an average daily population of 110. The location of these two wells is understood to be located up-gradient of the Project Area.

6.1.3 Seismic Hazards

Seismic hazards considered in this study include ground shaking, slope failure, liquefaction, ground surface fault rupture, and associated effects (e.g., flow failure, lateral spreading, and settlement).

The seismic ground-shaking hazards analysis considered in the Project design study are the full-rupture CSZ earthquake event and the probabilistic-based 1,000-year return ground motion level. The full-rupture CSZ event is associated with the full operation seismic design criteria. The 1,000-year ground motion level is associated with the limited operation seismic design criteria. The EQRB Seismic Design Criteria define the design-level earthquake and identify the ODOT peak ground acceleration for the full-rupture CSZ event and the 1,000-year return period event. A probabilistic-based 1,000-year return period event represents a 7 percent probability of exceedance in 75 years event.

The potential for fault rupture in the Project Area appears low as the closest known fault, the Portland Hills fault, is located approximately 2,000 feet west of the Project Area. The understood location of the East Bank Fault is located approximately 2,700 feet east of the Project Area. As shown on Figure 5 and Figure 6, the Portland Hills fault is located in the western portion of the API while the East Bank Fault is located adjacent to the east side of the API. The understood subsurface geometry of the Portland Hills fault is that it dips to the west and the East Bank Fault dips to the east (Wong 2001). If one of these faults were to rupture, it is assumed it would occur in the area where the faults are mapped or outward and away from the API. Movement on these faults appears to be on the order of several thousand years (Wong 2001) and therefore much longer than the 1,000-year return period seismic design assumption (Shannon & Wilson 2020).

The primary hazards in the Project vicinity that may result from earthquake ground shaking are soil liquefaction and liquefaction-related effects which include lateral spreading, flow failure, ground surface settlement, and reduction or complete loss of strength in the soils supporting the bridge and the bridge access foundations.

The seismic hazards analysis evaluates how soil and rock conditions in the API behave when subjected to earthquake ground motions. This seismic evaluation was based on current standards of practice, design codes, and levels of risk developed specifically for this Project. Direct long-term impacts were assessed by evaluating the relative earthquake hazard of the API.

Seismic ground-shaking hazard maps that include the Project Area have recently been published by DOGAMI (2018, 2019). Seismic ground-shaking analysis for the Project Area was also completed as presented in the geotechnical report (Shannon & Wilson 2020). Review of DOGAMI maps and findings presented in the geotechnical report provides information regarding how soil and rock conditions in the API will potentially behave when subjected to earthquake-sourced ground motions and their susceptibility to earthquake-induced shaking. The analysis examined in the DOGAMI mapping effort and the geotechnical report included ground acceleration and amplification, perceived shaking and damage potential, ground deformation, and liquefaction. The analysis completed by DOGAMI provides information on a more regional scale whereas analysis presented in the EQRB geotechnical report is specific to the response of existing Burnside Bridge foundations (bents and piers) to Project-defined ground-shaking events.

Seismic ground-shaking elements and related seismic hazards in the API based on DOGAMI mapping results are described below. Conversely, the geotechnical report (Shannon & Wilson 2020) recognizes the same hazards and identifies bridge-specific mitigation strategies. The primary seismic-associated hazards identified by both DOGAMI and the geotechnical report are ground shaking, liquefaction, and liquefaction-related effects such as ground deformation.

Ground Acceleration and Amplification

Peak ground acceleration associated with a simulated CSZ magnitude 9.0 earthquake (DOGAMI 2018 Plate 4) is identified to be 0.25 – 0.30 g in the API. An exception is in the eastern portion of the API where a slightly lower peak acceleration range of 0.20 – 0.25 g is identified. For a simulated Portland Hills fault 6.8 magnitude earthquake (DOGAMI 2018 Plate 5) the identified peak ground acceleration in the API is 0.45 – 0.50 g on the west side of the river and 0.50 – 0.60 g on the east side of the river.

The National Earthquake Hazards Reduction Program has developed classes of geologic units defined by the average speed at which a shear wave propagates through the upper 30 m (98 feet) of a unit. Shear-wave velocity is a key parameter used to quantify the behavior of soil in the shallow subsurface. DOGAMI (2019) developed a map showing soil amplification classes in the Portland Basin. The DOGAMI (2019) Soil Amplification Classes map indicates that the soil class present in the API is Site Class F. This site class is described as consisting of soils requiring site-specific evaluations. Areas composed of artificial fill, landslides, and unconsolidated deposits were classified as F. These types of deposits or units are considered potentially highly complex heterogeneous soils that may experience ground movement or liquefaction. Figure 10 shows soil amplification classes in the API as presented in the DOGAMI (2019) report.

Consistent with DOGAMI's findings, recommended seismic design spectral accelerations were developed for the CSZ and 1000-year design earthquakes. See the geotechnical report (Shannon & Wilson 2020) for these values.

Perceived Shaking and Damage Potential

For a simulated CSZ magnitude 9.0 earthquake, as shown on DOGAMI (2018) Plate 6, in the API, perceived shaking is identified as severe with damage potential moderate to heavy and VIII on the Modified Mercalli Intensity scale. This scale is based on observed effects on people, objects, and buildings. For a simulated Portland Hills fault magnitude 6.8 earthquake, as shown on DOGAMI (2018) Plate 7, perceived shaking is violent, damage potential is heavy, and IX on the Modified Mercalli Intensity scale.

Ground Deformation and Liquefaction

Potential permanent ground deformation due to earthquake-induced landslides or liquefaction lateral spreading associated with a simulated CSZ magnitude 9.0 earthquake saturated soil scenario (DOGAMI 2018 Plate 8) in the API is identified as being very high. The range of permanent ground deformation for the very high category is 39 to 173 inches (3.3 to 14.4 feet). The probability of earthquake-induced landslides or liquefaction associated with a CSZ magnitude 9.0 earthquake saturated soil scenario is presented on DOGAMI (2018) Plate 9. For the API, Plate 9 indicates the probability of permanent ground deformation is high. The probability range for the high category is 16 to 30 percent.

A liquefaction susceptibility map for the Portland Basin was developed by DOGAMI (2019) using qualitative classes developed by Youd and Perkins (1978). This classification system considers the general distribution of cohesionless sediments in deposits (i.e., the depositional process and unit history) and the likelihood that cohesionless sediments when saturated would be susceptible to liquefaction by the age of the deposit. Characteristics that influence liquefaction susceptibility considered by the DOGAMI (2019) mapping effort include cohesion, sorting, depth, grain-size, density, and grain-shape, which are lithologic characteristics that relate to the Youd and Perkins (1978) classification scheme. As a result of this classification approach, DOGAMI's (2019) liquefaction susceptibility map reflects susceptibility based only on unit lithology and not on the water table. In contrast, DOGAMI's (2018) earthquake-induced landslide and liquefaction map described above is based on a specific modeled earthquake event with soils assumed to be fully saturated.

As shown on Figure 9, DOGAMI's (2019) liquefaction susceptibility map indicates that in the API, liquefaction susceptibility is very high. An exception is the east end of the API where liquefaction susceptibility is shown to be high. Active channels and recent deposits, including floodplains of major rivers in the Portland Basin, are classified as very high with older river terraces and alluvial deposits classified as moderate or high.

Consistent with DOGAMI's findings, liquefaction-induced lateral spreading and flow failures were calculated on each side of the river for the existing condition using DSSI analyses. On the west riverbank, flow failure with displacements in excess of approximately 14 feet is anticipated. On the east riverbank, flow failure with displacements in excess of approximately 25 feet is anticipated. Estimated settlements of up to approximately 4 feet are anticipated, subject to the support location under consideration. See the geotechnical report (Shannon & Wilson 2020) for more information on ground deformations and liquefaction-induced displacements.

6.1.4 Soil Hazards

Soil in the API was noted in Section 5.3.6 to consist primarily of material identified as Urban land; soil that has been so altered during construction of works and structures that mapping the various types present has not been completed except for a section along the west riverbank area. The west riverbank soil type, Pilchuck-Urban complex, was noted to also represent a typically disturbed soil type and is closely associated with Urban land area soil. Both the Urban land area and the Pilchuck-Urban complex soil are described as a loam overlying stratified sand and gravel deposits or a soil type formed in sandy alluvium and sandy dredge spoils. These soil descriptions are consistent with cited mapping describing the presence of alluvium and artificial fill in the API that consist of silt, sand, and clay deposits or fills with subordinate amounts of gravel and, in places, artificial fill associated debris material types.

Geotechnical subsurface investigations (Shannon & Wilson 2020) have found that the soil profile near the surface is composed of fill and fine-grained alluvium material that are highly susceptible to liquefaction. The conditions observed suggest that the presence of competent material may not be reached until depths beyond 50 feet bgs (see the EQRB Bridge Replacement Technical Report [Multnomah County 2021a]). Geohazard mapping completed by DOGAMI (2019) supports the geotechnical findings as they indicate soil present in the API has very high liquefaction susceptibility. The potential for permanent ground deformation due to an earthquake-induced liquefaction spreading associated with a simulated CSZ magnitude 9.0 earthquake assuming saturated soil condition is very high. Permanent ground deformation of the very high category ranges from 39 to 173 inches; up to 14.4 feet.

6.2 Short-Term Impact Assessment Methods

This assessment evaluates direct short-term impacts that could arise during Project construction. Direct short-term impacts associated with soils and geology in the API are based on their understood geotechnical conditions and considered to be primarily those related to impacts caused by geologic hazards on the Project Area.

Short-term impacts are primarily associated with construction-related activities, including the Build Alternatives with and without a temporary detour bridge. Construction of new temporary and permanent bridge piers or "bents" would occur in the Willamette River and on both banks of the river. Use of cofferdams and dewatering strategies or other isolation methods would likely be required (Shannon & Wilson 2020) Deep shafts in-water and on the west and east riverbank areas would likely need to be drilled. Proper design and construction measures must be employed to avoid undesirable impacts.

Identified ground stabilization improvement methods include excavation and replacement, soil densification, drainage, soil cementation, or a combination of these methods. Based on identified Project Area site conditions, soil cementation by the method of jet grouting has been identified as a preliminary recommended ground improvement method (Shannon & Wilson 2020). Proper design and implementation of ground stabilization improvement actions must be employed to avoid undesirable impacts such as settlement and soil upheaving.

A short-term impact could occur if a large quantity of earth-material would need to be removed to create new bridge structures and if construction material would be needed to build new bridge structures. These construction-related materials used to address ground improvement such as soil densification, soil drainage, soil cementation, or a combination of these methods could represent an impact on shallow groundwater flow and water quality.

Short-term impacts could also include settlement of new bridge embankments constructed on weak, low-strength sediments and soil. Potential scour and erosion of bridge piers would need to be addressed and mitigated. Existing drainage patterns would be modified to some extent requiring new stormwater conveyance and management systems to prevent erosion, ponding, and undesired saturation.

6.3 Indirect Impact Assessment Methods

Indirect impacts occur later in time (after Project completion) or are farther removed in the distant, but still reasonably foreseeable future. Indirect Project-related impacts from geology and soils may arise during future Project operation. The evaluation and discussion of indirect impacts is qualitative.

Indirect impacts could include long-term erosion damage, future large precipitation events, climate change effects, and future earthquakes. Erosion damage can occur on slopes that are too steeply graded or highly exposed. Large precipitation events could lead to flooding, scouring of walls and structures, slope failures, and erosion on slopes.

No reasonably foreseeable indirect Project-related effects that would increase the vulnerability of other structures or resources to soil or geology have been identified.

6.4 Cumulative Impact Assessment Methods

The cumulative impacts analysis considered the Project's impacts combined with other past, present, and reasonably foreseeable future actions that would have environmental impacts in the Project vicinity. Based on the list of foreseeable transportation and other development projects that are anticipated to occur in the Project vicinity within the same time frame, as well as relevant past actions that have defined the Project vicinity, a qualitative analysis examined potential cumulative effects for soils and geologic impacts.

The analysis of potential cumulative soils and geologic impacts examined both near-term construction effects, as well as long-term operational impacts. Cumulative impacts were qualitatively assessed, but include known locations and types of issues or effects of soils and geology on both near-term construction and long-term operational impacts.

A cumulative impact is associated with alteration to the Willamette River. Both temporary and permanent bridge construction associated with the Project would add to flood and/or scour potential by the Willamette River in conjunction with other projects that might alter the hydraulics of the river, place fill in the floodway, constrict the river channel opening, and increase the amount of impermeable area resulting in an increase in the volume of stormwater runoff (see the EQRB Hydraulic Impact Analysis Technical Report [Multnomah County 2021e]).

7 Environmental Consequences

7.1 Introduction

The description of long-term impacts is divided into (1) pre-earthquake impacts, based on each Alternative's footprint and its day-to-day operations, and (2) impacts that would occur after the next CSZ earthquake, including how each Alternative affects resiliency, emergency response, and longer-term recovery.

7.2 Pre-Earthquake Impacts

With respect to soils and geology, pre-earthquake long-term impacts are thought to occur in two general categories: (1) disturbance of earth-material during construction; and (2) effects to earth-material from construction and operation. These potential impacts are assessed qualitatively for each Alternative based on the current understanding of the natural and built environments.

7.2.1 No-Build Alternative

Soils and geology, representing earth-material, and groundwater throughout the Project Area would not be disturbed under the No-Build Alternative; therefore, it would not be different from existing conditions. The existing earth-materials would remain in place except where disturbed by other non-related EQRB Project activities such as construction of new buildings or other works. There is some potential that future maintenance in the Project footprint could negatively affect earth-material present that may be associated with implementation of EQRB Project construction.

7.2.2 Enhanced Seismic Retrofit Alternative

The following identified activities of the Retrofit Alternative would impact existing earth-material (see the EQRB Enhanced Seismic Retrofit Technical Report [Multnomah County 2021d] for more information).

- At Bent 1, a reinforced concrete thickening of the bent wall is proposed by drilling and doweling reinforcement into the existing wall. Increasing the footing width with a reinforced concrete section is also proposed.
- At Bents 2 through 16, enlargement of the spread footings with a reinforced concrete section is proposed by drilling and doweling reinforcement into the side

of the footing. In addition, it is proposed that the footing be thickened to allow for a top mat of reinforcement and for anchorage of the new column reinforcement.

- At Bents 17 to 19, a large post-tensioned grade beam is proposed that would carry the loads from the existing columns to new large-diameter drilled shafts constructed on each side of the existing bridge. The new shafts would be constructed outside of the existing bridge deck extents and would extend through the liquefiable soil to suitable material for carrying the vertical and lateral loads.
- At Bents 2 through 16, cellular soil-cement ground improvement is proposed under the footings. An approximately 60-foot-deep zone of cellular soil-cement ground improvement is also proposed between Bent 19 and Pier 1.
- Four zones of cellular soil-cement ground improvement ranging from 80 to 130 feet deep are proposed at the following locations: (1) near existing Bent 4; (2) near new Bent 23; (3) between new Bent 24 and existing bent 25; and (4) near existing Bent 26.
- At existing Spans 20 to 24, it is proposed that they are replaced with a three-span steel-plate girder structure on modern reinforced concrete bents. The bents would be supported by large-diameter drilled shafts that extend through the liquefiable material to suitable material for carrying vertical loads.
- At Bent 35, a reinforced concrete thickening of the bent wall is proposed by drilling and doweling reinforcement into the existing wall. Increasing the footing width with a reinforced concrete section is also proposed.
- At Bents 28 to 34, enlargement of the spread footings with a reinforced concrete section is proposed by drilling and doweling reinforcement into the side of the footing. In addition, it is proposed that the footing be thickened to allow for a top mat of reinforcement and to allow for anchorage of the new column reinforcement.
- At Bents 25 to 27, a large post-tensioned grade beam is proposed that would carry the loads from the existing columns to new large-diameter drilled shafts constructed on each side of the existing bridge. The new shafts would be constructed outside of the existing bridge deck extents and extend through the liquefiable soil to suitable material for carrying the vertical loads.
- At each of the in-water piers, existing revetment would be removed to enable the foundation enlargement. Following the retrofit construction, new revetment would be placed to minimize future scour holes.

The Retrofit Alternative notes that geotechnical subsurface investigations have determined that the soil near the surface in the Project Area consists of artificial fill and fine-grained alluvium that are highly susceptible to liquefaction. These conditions suggest that the presence of competent material may not be reached until depths beyond 40 feet (on the west) to 140 feet bgs(on the east). To address this issue for the Retrofit Alternative, construction of deep foundation structures that include drilled shafts is identified at many support locations. These deep foundation structures would be embedded into the Troutdale Formation subsurface layer to provide sufficient support for the Retrofit Alternative.

Based on the current design strategy, the movable spans associated with the proposed Retrofit Alternative would be augmented with a group of large-diameter shafts encased in a large footing cap on both the upstream and downstream locations. These would be connected to the existing pier using post-tensioning. The use of a seal course for cofferdam dewatering would be needed for these bents. An analysis indicates that each bascule bridge pier could require twelve 12-foot-diameter shafts spaced at a minimum of three shaft diameters (see the EQRB Enhanced Seismic Retrofit Technical Report [Multnomah County 2021d]). Combined with the existing footing, this results in a 69-foot by 264-foot footing cap size for the bascule bents.

The following shafts have been identified for the Retrofit Alternative.

Table 1. Bridge Bent Shaft Foundations – Retrofit Alternative

Support Location	Number of Shafts	Shaft Diameter (feet)	Column Diameter (feet)
Bent 17	2	8	N/A
Bent 18	2	8	N/A
Bent 19	2	8	N/A
Pier 1	6	7	N/A
Pier 2	24	12	N/A
Pier 3	24	12	N/A
Pier 4 (new)	4	10	8
Bent 23 (new)	4	10	4
Bent 24 (new)	4	10	4
Bent 25	2	8	N/A
Bent 26	2	8	N/A
Bent 27	2	8	N/A

For the Retrofit Alternative, Bents 1 through 19 are located west of the Willamette River, Piers 1 through 4 are located in the river, and Bents 23 through 35 are located east of the river.

The total number of shafts associated with bridge bent foundations for the Retrofit Alternative is 78. As indicated in Table 1, shaft diameters would range from 7 to 12 feet; most of the shafts would be 8 feet or greater in diameter. A total of 52 shafts would be drilled in the Willamette River. The shafts would need to be advanced down to Troutdale Formation material, representing seismically competent material, which is typically at depths greater than 40 (on the west) to 140 feet bgs (on the east) at the Project Area.

Potential direct and indirect earth-material impacts associated with the Retrofit Alternative are summarized below.

Direct

The Retrofit Alternative would increase and improve bridge foundations at locations identified as having poor soil strength and potential for liquefaction in response to a seismic event. To complete the identified proposed enhancement elements would require excavation of poor-strength soils or completion of improved ground stabilization measures. The identified means to excavate for the construction of improvements is drilling. Identified drilling includes large-diameter shafts on each side of the existing bridge. The control and management of poor-strength soils during drilling and associated construction work to increase bridge foundation strength represents a direct impact on soils and geology (earth-materials) in the Project Area.

Indirect

Potential indirect impacts associated with identified Retrofit Alternative elements that impact earth-materials may include damage caused by long-term erosion, scouring of piers, bents, walls, and other structures, and ground settlement in or adjacent to areas where excavation work was completed.

7.2.3 Replacement Alternative with Short- or Long-Span Approach

The Short-span and Long-span Alternatives would replace the existing structure on the existing alignment with a movable span over the primary navigation channel. The Short-span Alternative uses slab-on-girder fixed bridge spans for the east and west approaches. The Short-span Alternative consists of three separate segments of bridge: the west approach spans, movable span, and east approach spans. The Long-span Alternative would replace a few of the spans on either side of the movable span with a single long span that would extend just west of Naito parkway (on the west) and between the Union Pacific Railroad (UPRR) tracks and NE 2nd Avenue (on the east). (See the EQRB Bridge Replacement Technical Report [Multnomah County 2021a] for more information on each design alternative.)

The EQRB Bridge Replacement Technical Report (Multnomah County 2021a) notes that the soil profile near the surface in the Project Area consists of artificial fill and fine-grained alluvium materials that are highly susceptible to liquefaction. These conditions suggest that the presence of competent material may not be reached until depths beyond 40 feet (on the west) to 140 feet (on the east) bgs. To address this issue for the Replacement Alternatives, construction of deep foundation structures that include drilled shafts is identified. These deep foundation structures would need to be embedded into the Troutdale Formation subsurface layer to provide sufficient support for the replacement bridge.

Short-Span Alternative

Based on the current design strategy, the proposed approach spans for the Short-span Alternative would be supported on multi-column concrete bents founded on large drilled shafts (see the EQRB Bridge Replacement Technical Report [Multnomah County 2021a]). Each of the intermediate bents for the west and east approaches would be supported on a four-column/shaft configuration. Link beams between columns at the top of shaft elevation for select bents would reduce displacements and moments in the bents. Additionally, cross bracing for the columns of Bent 9 would increase stiffness and brace the significantly tall columns at this bent.

Based on the current design strategy, the movable spans associated with the Replacement Alternatives would be supported on a group of large-diameter shafts encased in a large footing cap. These bents would need a seal course for cofferdam dewatering. Analysis indicates that each bascule bridge pier could require eighteen

12-foot-diameter shafts spaced at a minimum of three shaft diameters (see the EQRB Bridge Replacement Technical Report [Multnomah County 2021a]). This would result in a 106-foot by 175-foot footing cap size for the bascule bents. The movable lift bridge is slightly lighter than the bascule spans and, therefore, could have a slight decrease in the foundation size. Each lift bridge pier foundation would require fourteen 12-foot-diameter shafts and approximately an 80-foot by 140-foot footing cap.

Table 2 lists the proposed shafts for the Short-span Alternative.

Table 2. Bridge Bent Shaft Foundations – Short-Span Alternative

Support Location	Number of Shafts	Shaft Diameter (feet)	Column Diameter (feet)
Bent 1	10	3	--
Bent 2	4	7	5
Bent 3	4	7	5
Bent 4	4	8	6
Bent 5	4	10	8
Bent 6	4	10	8
Bent 7	18 (Bascule Bridge) 14 (Lift Bridge)	12	--
Bent 8	18 (Bascule Bridge) 14 (Lift Bridge)	12	--
Bent 9	4	12	10 x 16 pier
Bent 10	4	10	8
Bent 11	4	10	8
Bent 12	4	10	6
Bent 13	4	7	5
Bent 14	13	3	--

For the Short-span Alternative, Bents 1 through 6 are west of the Willamette River, Bents 7 through 9 are in the river, and Bents 10 through 14 are east of the river.

The number of shafts associated with bridge bent foundations for the Short-span Alternative as listed for the bascule bridge option is 99. For the lift bridge option, the number of shafts is 91. As indicated in Table 2, shaft diameters would range from 3 to 12 feet; most of the shafts would be 7 feet or greater in diameter. For the bascule bridge option, 40 shafts would be drilled in the Willamette River. The lift bridge option would require 32 shafts drilled in the river. The shafts would need to be advanced down to Troutdale Formation material, seismically competent material, which is typically at depths greater than 40 feet (west side) to 140 feet (east side) bgs at the Project Area.

Proposed east approach improvements would possibly include a volume of cementitious grouting extending well beyond the bridge width, thereby creating a “dam” to hold back east bank flow failures during a seismic event at two locations (proposed Bents 10 and 11), or include ground improvements extending down to the Troutdale Formation subsurface layer at Bents 9 through 12 to increase stability and withstand large-scale soil displacements that would occur during a seismic event.

Long-Span Alternative

Based on the current design strategy, the proposed approach spans for the Long-span Alternative would be supported on multi-column concrete bents founded on large drilled shafts (see the EQRB Bridge Replacement Technical Report [Multnomah County 2021a]). Link beams between columns at the top of shaft elevation for select bents would reduce displacements and moments in the bents.

The movable spans would be supported on a group of large-diameter shafts encased in a large footing cap. The use of a seal course for cofferdam dewatering would be needed for these bents. Analysis indicates that each bascule and lift bridge pier would be the same as the Short-span Alternative: requiring eighteen 12-foot-diameter shafts spaced at a minimum of three shaft diameters (see the EQRB Bridge Replacement Technical Report [Multnomah County 2021a]). This results in a 106-foot by 175-foot footing cap size for the bascule bents. The movable lift bridge is slightly lighter than the bascule spans, and, therefore, could have a slight decrease in the foundation size. Each lift bridge pier foundation could require fourteen 12-foot-diameter shafts and approximately an 80-foot by 140-foot footing cap.

Table 3 lists the proposed shafts for the Long-span Alternative.

Table 3. Bridge Bent Shaft Foundations – Long-Span Alternative

Support Location	Number of Shafts	Shaft Diameter (feet)	Column Diameter (feet)
Bent 1	10	3	--
Bent 2	4	7	5
Bent 3	4	7	5
Bent 4	4	8	6
Bent 5	8	10	Pier Wall
Bent 6	18 (Bascule Bridge) 14 (Lift Bridge)	12	--
Bent 7	18 (Bascule Bridge) 14 (Lift Bridge)	12	--
Bent 8	8	10	Pier Wall
Bent 9	4	7	5
Bent 10	13	3	--

For the Long-span Alternative, Bents 1 through 5 are located west of the Willamette River, Bents 6 and 7 are located in the river, and Bents 8 through 10 are located east of the river.

The number of shafts associated with bridge bent foundations for the Long-span Alternative bascule bridge option is 91. For the lift bridge option, 83 shafts would be needed. Shaft diameters would range from 3 to 12 feet; most of the shafts would be 7 feet or greater in diameter. For the bascule bridge option, 36 shafts would be drilled in the Willamette River. The lift bridge option would require 28 shafts drilled in the river. The shafts would need to be advanced down to Troutdale Formation material, seismically competent material, which is typically at depths greater than 40 to 140 feet bgs at the Project Area.

Proposed east approach improvements would include a volume of cementitious grouting extending well beyond the bridge width, thereby creating a dam to hold back east bank flow failures during a seismic event at two locations (proposed Bents 8 and 9), or include ground improvements extending down to the Troutdale Formation subsurface layer at Bent 8 to increase stability and withstand large-scale soil displacements that would occur during a seismic event at each bent. Retaining and buttressed walls are also proposed for the Replacement Alternatives. Buttressed walls would be located immediately adjacent (and open) to existing buildings. A new retaining wall would be installed directly south of the buttressed wall, allowing those voids to be backfilled and new sidewalk to be built on retained fill. At each of the in-water piers, new revetment would be placed to minimize future scour holes.

Direct

The Replacement Alternatives would sustain negligible or minimal damage immediately after an earthquake event. To address earth-material in the Project Area identified as having poor strength and the potential for liquefaction in response to a seismic event, extensive foundation works have been identified which would require drilling through poor-strength earth-material to construct new shafts. The shafts would range from 3 to 12 feet in diameter and extend more than 40 to 140 feet bgs.

Indirect

Potential indirect impacts could include damage from long-term erosion; scouring of piers, bents, walls, and other structures; and ground settlement in or adjacent to areas where excavation work was completed.

7.2.4 Replacement Alternative with Couch Extension

Long-term impacts for the Couch Extension Alternative are summarized below. Impacts related to soils and geology are not significantly different than with the Short-span Alternative described above in Section 7.2.3, with the exception that the Couch Extension Alternative would require additional bent foundations and additional shafts. Table 4 lists the number of shafts for the east approach leg that extends to Couch Street. Table 5 lists the number of shafts for the east approach leg that extends to Burnside Street. The number and size of shafts for Bents 1 through 8 for the Couch Extension Alternative are the same as for Short-span Alternative (see Table 2).

Table 4. East Approach Bent Shaft Foundations: Couch Extension – North Leg to Couch Street

Support Location	Number of Shafts	Shaft Diameter (feet)	Column Diameter (feet)
Bent 9	4	12	10x16 pier
Bent N10	2	10	8
Bent N11	2	10	8
Bent N12	2	8	6
Bent N13	2	8	6
Bent N14	2	6	4
Bent N15	6	3	--

Table 5. East Approach Bent Shaft Foundations: Couch Extension – South Leg to Burnside Street

Support Location	Number of Shafts	Shaft Diameter (feet)	Column Diameter (feet)
Bent S10	3	10	8
Bent S11	3	10	8
Bent S12	3	10	8
Bent S13	3	7	5
Bent S14	8	3	--

For the Couch Extension, Bents 1 through 7 are located west of the Willamette River, Bents 7 through 9 are located in the river, Bents N10 through N15 are located east of the river to Couch Street, and Bents S10 through S14 are located east of the river to Burnside Street.

The Couch Extension Alternative bascule option would require 106 shafts for the bent foundations; the lift option would require 98. As indicated in Table 2, Table 4 and Table 5, shaft diameters would range from 3 to 12 feet in diameter; most of the shafts would be 7 feet or greater in diameter. For the bascule option, 40 shafts would be drilled in the Willamette River. The lift option would require that 32 shafts be drilled in the river. The shafts would need to be advanced down to Troutdale Formation material, representing seismically competent material, which is typically at depths greater than 40 feet (west side) to 140 feet (east side) bgs at the Project Area.

Direct

The Couch Extension Alternative would provide a bridge and bridge access that would sustain negligible or minimal damage immediately after a CSZ earthquake event. To address earth-material in the Project Area identified as having poor strength and the potential for liquefaction in response to a seismic event, additional shafts would need to be drilled and columns installed as part of the Couch Extension Alternative. This increases the seismic performance risk as compared to the Short-span Alternative. The identified foundation works would require excavation of poor-strength earth-material primarily by drilling to construct new shafts. The control and management of poor-strength earth-material during drilling and associated construction work for a replacement bridge foundation represents a direct impact on soils and geology in the Project Area.

Similar to the Retrofit Alternative and the Short- and Long-span Alternatives, drilling activities would need to address how to manage and control poor-strength soil and generally saturated earth-material while the enhanced foundation elements are constructed. Drilling activities would also need to be managed so that contaminants are not introduced into the ground and potentially to groundwater or surface water. Potential contaminants could be sourced from equipment used for excavating (drilling) or from other sources such as stormwater that is allowed to discharge into an excavation. Site control measures would be needed to ensure that open excavations are secure and do not pose a risk to human health or ecological health.

Indirect

Potential indirect impacts associated with the Couch Extension Alternative that impact earth-materials could include damage from long-term erosion and ground settlement in or adjacent to areas where excavation work was completed. However, most of the area under and adjacent to the proposed Couch Extension Alternative consists of impermeable surfaces, which limit the potential for erosion. Due to the proximity of additional buildings along the Couch Extension, there is an increased potential of building structures impacting the Couch Extension Alternative as compared to the other Build Alternatives.

7.3 Post-Earthquake Impacts

Post-earthquake impacts on soils and geology were evaluated for each of the Build Alternatives. In all cases, the next major earthquake is expected to cause permanent ground deformation in the API and Project Area. Ground deformation will primarily be in the form of liquefaction lateral spreading. In the Project Area, this type of ground deformation is expected to include riverbank embankment landslides and permanent lateral spreading resulting in the displacement of shallow earth-material. Localized lateral movement due to liquefaction and localized slope failure due to poor-strength soils has the potential to damage the new bridge and associated bridge approaches if they exceed the specified seismic design criteria (see EQRB Seismic Design Criteria).

Subsurface conditions determined by recent Portland metropolitan geohazard mapping, historical and recent geotechnical data, and DSSI analysis performed for the EQRB Project all indicate that the potential for liquefaction and liquefaction-related effects are high in the API and in the Project Area. Investigations indicate that liquefaction and liquefaction-induced permanent ground deformations will occur at the west and east approach embankments in response to seismic shaking.

7.3.1 Enhanced Seismic Retrofit Alternative

The Retrofit Alternative would both minimize the changes to the existing bridge while also achieving a seismically resilient Burnside Street crossing over the Willamette River that would remain fully operational and accessible for vehicles immediately following a major CSZ earthquake. To achieve this objective, seismic enhanced foundation and structure elements would be completed including specific ground improvements to increase the strength of soils identified as highly susceptible to failure and located in critical foundation-associated areas.

Analysis by DOGAMI (2018) indicates permanent ground deformation due to liquefaction lateral spreading under saturated soil conditions in the Project Area could be 7 to 8 feet. An exception is in the eastern end of the Project Area where coarse-grain facies catastrophic flood deposits are present. The permanent ground deformation of this deposit has been determined to be less than a foot.

The DSSI analysis findings anticipate that the east riverbank area would have ground failures, such as embankment landslides, on the order of 25 feet and permanent lateral spreading displacements of approximately 3 feet or more. On the west riverbank area, ground surface movements are expected to be up to 14 feet and permanent lateral displacements greater than one foot could occur.

Flow failures and large permanent ground displacements of these magnitudes could result in significant damage to drilled shafts of any practical dimension. Therefore, hazard mitigation through ground improvements has been recommended.

Direct

Direct impacts for a post-earthquake condition depend on the magnitude of the earthquake and the extent of liquefaction-induced effects. Assuming that the seismic event falls at or below the level of the design earthquake, there would be minimal direct impacts. If the actual earthquake exceeds the design earthquake, then greater soil displacements than anticipated could occur. As such, Build Alternatives with the fewest number of supports within the geotechnical hazard zones, such as the Long-span Alternative, may perform better than the Retrofit Alternative.

Indirect

Because it is understood that infrastructure adjacent to the Burnside Bridge may not be designed to withstand seismic events, modal service to the bridge may be vulnerable and interrupted outside the Project vicinity. This includes the I-5 and I-84 bridges below the Burnside Bridge, the Waterfront Park seawall and Ankeny Pump Station, nearby TriMet MAX and UPRR rail lines, and nearby buildings.

7.3.2 Short- and Long-Span Replacement Alternatives

The Short- and Long-span Alternatives would achieve a seismically resilient Burnside Street crossing over the Willamette River that would remain fully operational and accessible for vehicles immediately following a major CSZ earthquake. To achieve this, a seismically enhanced foundation and structure elements would be completed, including specific ground improvements to increase the strength of soils identified as highly susceptible to failure that are located in critical foundation-associated areas.

Direct

Direct impacts for the Replacement Alternatives are the same as those identified for the Retrofit Alternative. An exception is for the Long-span Alternative, which would avoid piers and bents in the area on west end that is subject to lateral spreading, and it would avoid almost all of the area on the east side this is vulnerable to lateral spreading. It would, therefore, avoid/greatly reduce the need for extensive ground improvements, and avoid/greatly reduce the risk associated with bents and piers in these areas.

Indirect

Indirect impacts for the Short- and Long-span Alternatives are the same as identified for the Retrofit Alternative.

7.3.3 Replacement Alternative with Couch Extension

The Couch Extension Alternative would provide a seismically resilient Burnside Street crossing over the Willamette River that would remain fully operational and accessible for vehicles immediately following a major CSZ earthquake. To achieve this objective, seismically enhanced foundation and structure elements would be completed including specific ground improvements to increase the strength of soils identified as highly susceptible to failure that are located in critical foundation-associated areas.

Direct

The Couch Extension Alternative would have the same direct impacts as would the Short-span Alternative, but also would include an alignment split and northern bents that would require additional locations for ground improvements. Ground improvement zones would be needed at all bent locations with inadequate soil conditions.

Indirect

Indirect impacts for the Couch Extension Alternative would be the same as those identified for the Retrofit Alternative.

7.4 Construction Impacts

This section discusses potential construction impacts of the Project specific to soils and geology. The analysis of construction impacts is based on the current understanding of existing conditions described in Section 5, anticipated construction methods, and the Project footprint. The construction impacts were assessed for the Build Alternatives considering two different conditions, (1) construction without a temporary bridge, and (2) construction with a temporary bridge.

The control and management of poor-strength earth-material during drilling and associated construction work for a replacement bridge foundation would be needed while proposed enhanced foundation elements are constructed. Drilling activities would also need to be managed in a manner such that contaminants are not introduced into the ground and potentially to groundwater or surface water. Potential contaminants can be sourced from equipment used for excavating (drilling) or from other sources such as stormwater allowed to discharge into an excavation. Site control measures would also be needed to ensure open excavations are secure and do not pose a risk to human health or ecological health.

7.4.1 Without Temporary Bridge

The Burnside Bridge would be closed to all modes of transportation for the duration of construction. Detour routes would be established to route multimodal traffic to adjacent river crossings. For all Build Alternatives, temporary construction access (aka, work) bridges and platforms would be required to provide access for the contractor's bridge demolition and construction equipment. Temporary piles and supports would be needed throughout the bridge extents for this purpose. (See the EQRB Construction Approach Technical report [Multnomah County 2021b] for more information.)

Enhanced Seismic Retrofit Alternative

Drilling and doweling would be completed to reinforce the existing bridge foundation structures. Construction impacts would also include ground stabilization improvements at existing bridge foundation locations using cellular soil-cement methods.

Replacement Alternative with Short- or Long-Span Approach

Drilling would be completed for construction of new bridge foundation columns. Construction impacts would also include installation of new retaining and buttressed walls and some cementitious grouting extending beyond the bridge width.

Replacement Alternative with Couch Extension

In addition to construction impacts associated with the Short- and Long-span Alternatives, this Alternative would require additional drilling for construction of new columns associated with the Couch Extension.

7.4.2 With Temporary Bridge

A temporary bridge could be constructed to provide access for multimodal traffic around the existing bridge during construction. A temporary bridge could function to provide construction traffic management for all transportation modes or be limited to transit, bicycles, and pedestrians, or just bicycles and pedestrians. Temporary bents and other associated bridge foundation structures would be installed for the temporary detour bridge. The temporary bridge would be located sufficiently south to allow for construction access for the replacement bents for the conventional approaches or for the Long-span Alternative approach. The temporary bridge could consist of fixed spans along the east and west approach, and a movable lift span within the river navigation channel. (See the EQRB Construction Approach Technical report [Multnomah County 2021b] for more information.)

Enhanced Seismic Retrofit Alternative

While most impacts associated with soils and geology would begin during construction, they could continue long after construction is completed and are, therefore, included in the discussion of long-term impacts in Sections 7.2 and 7.3. Soils and geology impacts associated with the temporary bridge would be similar in type to those identified for the main bridge in Section 7.3, but with additional volume and magnitude due to the added columns and foundation work that would need to be completed to construct the temporary bridge.

Replacement Alternative with Short-Span Approach

Construction impacts for a temporary bridge would be similar to those described for the Retrofit Alternative.

Replacement Alternative with Long-Span Approach

Construction impacts for a temporary bridge would be similar to those described for the Retrofit Alternative.

Replacement Alternative with Couch Extension

Construction impacts for a temporary bridge would be similar to those described for the Retrofit Alternative.

7.4.3 Off-Site Staging Areas

The construction contractor may use one or more off-site staging areas, outside the bridge study area to store and and/or assemble materials that would be transported by barge to the construction site. Off-site staging could occur with any of the Alternatives. Whether, where, and how to use such sites would be the contractor's decision, and, therefore, the actual site or sites cannot be known at this time.

The types of impacts to soils and geology that could occur due to off-site staging could be similar to the short-term construction-related impacts discussed previously in this report. It is currently assumed that an off-site staging area would be located adjacent to the Willamette River to allow for transport of materials by barge to and from the construction site. This type of off-site staging location would have a similar soil profile and geologic condition as described for the API. The locations would also be highly susceptible to liquefaction.

It is uncertain how an off-site staging area would be used. For example, use could be limited to just staging and then moving construction materials to the bridge construction site or use may include temporary storage of excavated earth-material from the bridge construction site. It is assumed that use of an off-site staging and/or storage area would be temporary with all material removed at completion of the Project. Consequently, a short-term impact could occur if a large quantity of earth-material would need to be removed to create new bridge structures and if construction material would be needed to build new bridge structures. Short-term storage of large quantities of earth-material and/or construction material needed to build new bridge structures could result in temporary compression of shallow soil and geologic deposits located beneath the temporarily stored material. Following removal of temporarily stored materials, it would be anticipated that rebound would occur.

Similar to construction activities at the bridge site, management of temporarily stored excavated earth-material and construction materials at an off-site staging area would also need to be managed in a manner such that contaminants are not introduced into the ground and potentially to groundwater or surface water. Potential contaminants can be sourced from equipment used for bridge construction or from other sources such as stormwater that is allowed to come in contact with temporarily stored earth-materials or staged construction materials.

7.5 Cumulative Effects

Cumulative impacts are the accumulation of impacts from past, present, and reasonably foreseeable actions. They are analyzed so that impacts from actions over time that add up to affect a resource are considered. The cumulative impacts analysis was performed as described in the EQRB Cumulative Effects Methodology Memo for the No-Build and all Build Alternatives.

7.5.1 No-Build Alternative

No cumulative impacts have been identified for the No-Build Alternative on soils and geology in the API.

7.5.2 Build Alternatives

Changes to soils and geology in the Project Area would be primarily limited to areas associated with new bridge-related foundation structures. This would primarily be caused by drilling of new shafts down to seismically competent deposits and ground improvements to increase the strength of soils identified as highly susceptible to failure that are located in critical bridge-related foundation areas. The extent of this work in the API represents a relatively minor change in current soils and geology conditions and would have little or no meaningful impact to existing, long-term geologic, hydrogeologic, or soil conditions and are not expected to contribute to significant cumulative impacts.

7.6 Compliance with Laws, Regulations, and Standards

As noted in Section 4.1, there are no specific regulations and laws pertaining to soils or geology that are specifically applicable to the Project. However, construction of new bridge-related foundations, specifically drilling associated with construction of new shafts, is regulated under OAR Chapter 690 Division 240 (Construction, maintenance, alteration, conversion and abandonment of monitoring wells, geotechnical holes and other holes in Oregon). The following are regulations specific to the drilling and construction of new bridge foundation structures; specifically drilling new shafts. The drilling of shafts associated with new bridge foundation structures represent “other holes.” As listed on Table 240-1, and as cited below, a construction hole, a piling hole, and a trench are regulated as other holes. The following paragraphs present OAR Chapter 690 Division 240 regulations relevant to other holes.

> OAR 690-240-0005(2) Holes other than monitoring wells, water supply wells, or geotechnical holes which are drilled, excavated, or otherwise constructed in the earth's surface can also provide an avenue for deterioration of ground water quality. Improper construction, maintenance, use, and abandonment of other holes can pose a significant risk to ground water. Table 240-1 lists common subsurface borings and indicates which administrative rule governs the construction, conversion, maintenance, alteration, and abandonment of the boring.
>
> OAR 690-240-0005(9) To protect the ground water resource, the Commission has the authority, under ORS 537.780(1)(c)(A), to regulate any hole through which ground water may be contaminated. Construction of holes other than water supply wells and monitoring wells does not require a license and licensing fee, bond, examination, well report, start card, and start card fee.
>
> OAR 690-240-0010(53) "Other Hole" means a hole other than a water supply well, monitoring well, or geotechnical hole, however constructed, in naturally occurring or artificially emplaced earth-materials through which groundwater can become contaminated. Holes constructed under ORS Chapters 517, 520, and 522 are not subject to these rules. Examples of other holes are listed in OAR 690-240-0030.

Specific regulations associated with other holes as presented in OAR 690-240-0030 are as follows.

> 690-240-0030 Other Holes: General Performance and Responsibility Requirements

> (1)(a) Other holes are constructed for a variety of purposes which may or may not encounter ground water. Other holes are constructed using a wide variety of equipment and are not typically designed to access water in order to collect subsurface information. Other holes include but are not limited to temporary (abandoned within 72 hours) wetland delineation holes, gravel pits, pits for removal of underground storage tanks (UST), pilings, tunnels, post holes, excavation and construction holes, elevator shafts, and trenches.
>
> (b) Although enforcement actions may be exercised against other parties, the landowner of the property where the other hole is constructed is ultimately responsible for the condition and use of the other hole.
>
> (2)(a) In order to protect ground water, all other holes shall be constructed, operated or used, maintained, and abandoned in such a manner as to prevent contamination or waste of ground water;
>
> (b) In order to protect ground water, all other holes, when abandoned, shall be abandoned in such a manner that water cannot move vertically in them with any greater facility than in the undisturbed condition prior to construction of the other hole;

As indicated in OAR 690-240-0005(9) the construction of other holes does not require a license and licensing fee, bond, examination, well report, start card, and start card fee.

7.7 Conclusion

All of the Build Alternatives involve design elements resulting in bridge and bridge access foundations to be situated in seismically competent earth-material. Regional and Project-specific investigations have identified that earth-materials near the surface in the Project Area consist of material that have poor soil strength and are highly susceptible to liquefaction and earthquake-induced ground deformation. Construction of a seismically resilient Burnside Bridge would therefore require existing bridge foundations to be enhanced or replaced such that they are situated on seismically competent earth-material. The Replacement Alternative with Long-span Approach minimizes the seismic performance risk by avoiding most of the geotechnical hazard zones. Drilling, excavating, and improving poor-strength earth-material would be required. These actions would result in various degrees of impact on existing soils and geology in the Project Area.

8 Mitigation Measures

The current designs and proposed construction assumptions for the Build Alternatives incorporate measures to meet the seismic design criteria established for the Project. Bridge foundations and other bridge elements would be improved (Enhanced Seismic Retrofit Alternative) or constructed (Replacement Alternatives), and soil improvements would be implemented to address identified poor soil strength and potential for liquefaction in response to a seismic event. These design and construction measures are summarized in Chapter 7 and described in detail in the various design reports.

As the Project advances, subsequent geotechnical investigations and advanced design analysis would be used to further develop and design more specific mitigation measures to minimize seismic, scour, and erosion impacts.

Excavation activities would address how to manage and control poor-strength soil and generally saturated earth-material while proposed enhanced foundation elements are constructed. Excavation (drilling) activities would also need to be managed in a manner such that contaminants are not introduced into the ground, to groundwater, and surface water. Potential contaminants can be sourced from equipment used for excavating (drilling) or from other sources such as stormwater allowed to discharge into an excavation. Site control measures would also be needed to ensure open excavations are secure and do not pose a risk to human health or ecological health. Prior to the start of construction, an approved erosion and sediment control plan would be required. During construction, best management practices listed in the current version of the City of Portland Erosion, Sediment, and Pollutant Control Plan would be implemented to prevent runoff with sediment or other pollutants from reaching drainage systems or the Willamette River. Measures for minimizing impacts are assumed to be part of Project planning and are described in the EQRB Construction Technical Report (Multnomah County 2021b) and the EQRB Wetlands and Waters Technical Report (Multnomah County 2021g).

9 Contacts and Coordination

Project work will include an extensive public involvement and agency coordination effort including local jurisdictions and neighborhoods within the Project Area.

Agencies and organizations will be notified of the intent to prepare an EIS through the Federal Register and other Project outreach activities. Interested organizations will have the opportunity to review and comment on the hazardous materials analysis throughout the duration of the Project, including during the public comment period for the Draft EIS.

10 Preparers

Name	Professional Affiliation	Education	Years of Experience
Rick Malin	Parametrix	Registered Geologist	25

11 References

Appleby,C.A., Burns, W.J.,Hairston-Porter, R.W., and Bauer, J.M.

2019. Coseismic Landslide Susceptibility, Liquefaction Susceptibility, and Soil Amplification Class Maps, Clackamas, Multnomah, and Washington Counties, Oregon. DOGAMI Open-File Report O-19-09.

Bauer, J.M., William, J.B., and Madin, I.P.

2018. Earthquake Regional Impact Analysis for Clackamas, Multnomah, and Washington Counties, Oregon. DOGAMI Open-File Report O-18-02.

Beeson, M.H., Tolan, T.L., and Madin, I.P.

1991. Geologic Map of the Portland Quadrangle, Multnomah and Washington Counties and Clark County, Washington. DOGAMI Geological Map Series GMS-75.

Brown, S.G.

1963. Problems of Utilizing Ground Water in the West-Side Business District of Portland, Oregon. USGS Water-Supply Paper 1619-O.

Collins, C.A. and Broad, T.M.

1993. Estimated Average Annual Ground-Water Pumpage in the Portland Basin, Oregon and Washington, 1987-1988. USGS Water-Resources Investigations Report 91-4018.

COP (City of Portland).

2010. Portland Watershed Management Plan, Potential Benefit of Green Infrastructure Improvements. COP Environmental Services, Systems Analysis, Spatial Analysis and Modeling. March, 24, 2010 print date.

DEQ (Oregon Department of Environmental Quality).

2012. DEQ Site Assessment Program – Strategy Recommendation: East Portland Gas Works (former). DEQ ECSI Number 4426. August 9, 2012.

Evarts, R.C. and O'Connor, J.E.

2008 Geologic Map of the Camas Quadrangle, Clark County, Washington, and Multnomah County, Oregon. USGS Scientific Investigations Map 3017. 2008.

Evarts, R.C., O'Connor, J.E., Wells, R.E., and Madin, I.P.

2009. The Portland Basin: A (big) river runs through it. GAS Today, V. 19, no.9, September 2009.

Gannett, M.W. and Caldwell, R. R.

1998. Geologic Framework of the Willamette Lowland Aquifer System, Oregon and Washington. USGS Professional Paper 1424-A.

Green, G.L.

1983. Soil Survey of Multnomah County, Oregon. U.S. Department of Agriculture, Soil Conservation Service and Forest Service, in cooperation with Oregon Agricultural Experiment. Original text issues on August 1983.

Lentz, R.T.

1981. The Petrology and Stratigraphy of the Portland Hills Silt – A Pacific Northwest Loess. Oregon Geology, v.43, no.1, p.3-10.

Ma, L., Madin, I.P., Duplantis, S., and Williams, K.J.

2012. Lidar-Based Surficial Geologic Map and Database of the Greater Portland Area, Clackamas, Columbia, Marion, Multnomah, Washington, and Yamhill Counties, Oregon and Clark County, Washington. DOGAMI Open-File Report O-12-02.

Madin, I.P.

1990. Earthquake-Hazard Geology Maps of the Portland Metropolitan Area. DOGAMI Open-File Report O-90-02.

1998. Eathquake Hazard Geologic Maps of the Portland, Oregon, Metropolitan Area. In Rogers, A.m., Walsh, T.J., Kockleman, W.J., and Priest, G.R., eds., Assessing Earthquake Hazards and Reducing Risk in the Pacific Northwest, Vol.2: USGS Professional Paper 1560, p. 355-370.

2009. Geologic Map of the Oregon City 7.5' Quadrangle, Clackamas County, Oregon. DOGAMI Geologic Map 119.

Multnomah County.

2021a. EQRB Bridge Replacement Technical Report. https://multco.us/earthquake-ready-burnside-bridge/project-library.

2021b. EQRB Construction Approach Technical. https://multco.us/earthquake-ready-burnside-bridge/project-library

2021c. EQRB Description of Alternatives Report. https://multco.us/earthquake-ready-burnside-bridge/project-library

2021d. EQRB Enhanced Seismic Retrofit Technical Report. https://multco.us/earthquake-ready-burnside-bridge/project-library

2021e. EQRB Hydraulic Impact Analysis Technical Report. https://multco.us/earthquake-ready-burnside-bridge/project-library

2021f. EQRB Seismic Design Criteria. https://multco.us/earthquake-ready-burnside-bridge/project-library

2021g. EQRB Wetlands and Waters Technical Report. https://multco.us/earthquake-ready-burnside-bridge/project-library

Mundorff, M.J.

1964. Geology and Ground-Water Conditions of Clark County and a Description of Major Alluvial Aquifer Along the Columbia River. USGS Water-Supply Paper 1600.

Roe, W.P., and Madin, I. P.

2013. 3D Geology and Shear-Wave Velocity Models of the Portland, Oregon Metropolitan Area. DOGAMI Open-File Report o-13-12.

Shannon & Wilson.

2017. Draft Geotechnical Report: Burnside Bridge Seismic Feasibility Study. September 13, 2017.

2020. Draft Geotechnical Report: Burnside Bridge Environmental Impact Study, Portland, Oregon. January 2020.

Snyder, D.T.

2008. Estimated Depth to Ground Water and Configuration of the Water Table in the Portland, Oregon Area. USGS Scientific Investigations Report 2008-5059.

Swanson, R.D, McFarland, W.D, Gonthier, J.B., and Wilkinson, J.M.

1993. A Description of Hydrogeologic Units in the Portland Basin, Oregon and Washington. USGS Water-Resources Investigations Report 90-4196.

Trimble, D.E.

1963. Geology of Portland, Oregon and Adjacent Areas. USGS Bulletin 1119.

Wong, I., Silva, W., Bott, J., Wright, D., Thomas, P., Gregor, N., Li, S., Mabey, M., Sojourner, A., and Wang, Y.

2000. Earthquake Scenario and Probabilistic Ground Shaking Maps for the Portland, Oregon, Metropolitan Area. DOGAMI. Interpretive Map Series IMS-16.

Youd, T.L. and Perkins, D.M.

1978. Mapping of Liquefaction Induced Ground Failure Potential. Journal of the Geotechnical Engineering Division, American Society of Civil Engineers, v. 104, no.4, p 433-446.