3.18 GEOLOGY AND SOILS

> ***Supporting Project Technical Document***
>
> Geological Resources Technical Report (CH2M HILL, 2012h)

This section discusses geologic resource concerns as they relate to the environment, public safety, and project design both during construction and after completion of the project. Landslides, earthquakes, and general soil suitability are prime considerations in the design and retrofit of structures as well as cut-and-fill slopes for roadway designs. The analysis of potential impacts included the following:

- Identifying critical areas of potential soil erosion
- Characterizing soils exposed in cuts and used for fills, identifying low-strength soils, and identifying zones subject to liquefaction in order to address slope stability and roadway and structure foundations.
- Identifying areas susceptible to flooding, channel migration, and streambank scour

Geologic hazard areas are identified to ensure that development in these areas, including highway construction, avoids these risks or makes use of appropriate design and construction techniques to minimize them. Erosion and landslides are functions of an area's soil types and topography—the steeper the slope and the finer or more layered the soil, the likelier both are to occur. Engineers can take precautions in highway design and construction to stabilize erosion- and slide-prone areas in order to maintain the integrity of the roadway.

The Geological Resources Technical Report (CH2M HILL, 2012h) provides additional information.

3.18.1 REGULATORY SETTING

A key federal law for geologic and topographic features is the Historic Sites Act of 1935 (16 U.S.C. 461–467), which establishes a national registry of natural landmarks and protects "outstanding examples of major geological features." The following regulatory and guidance documents apply to geology, soils, groundwater, and paleontological resources:

- Numerous federal statutes specifically address paleontological resources, their treatment, and funding for mitigation as part of federally authorized or funded projects (for example, Antiquities Act of 1906 [16 U.S.C. 431–433] and [20 U.S.C. 78]).
- The State of Oregon does not address the preservation of paleontological resources on State Lands except where they may occur in an archaeological context (ORS 358.880[4] and ORS 358.885[1-2]).
- The federal Clean Water Act (CWA; 33 U.S.C. 1251–1376) is the primary law covering groundwater quality

3.18.2 Affected Environment

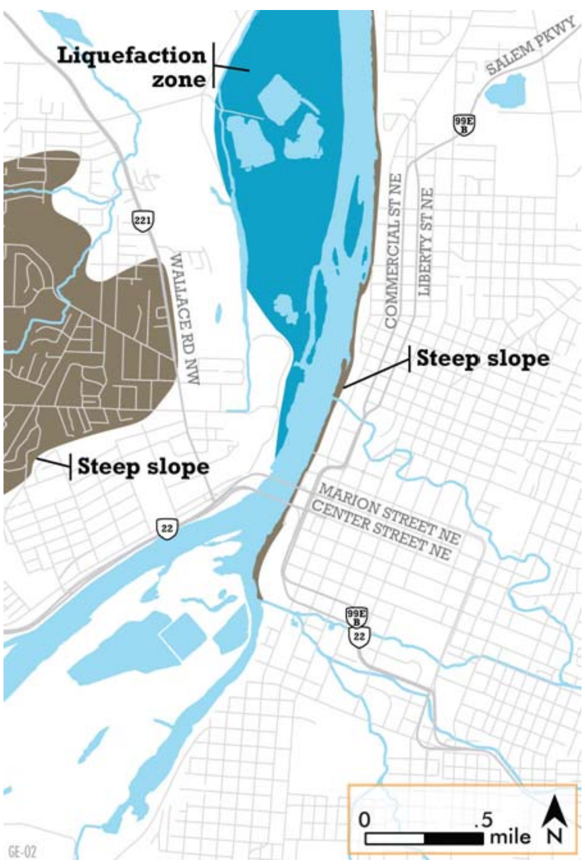
3.18.2.1 Soils

Soils information for the study area is summarized from Bela (1981) and the Natural Resources Conservation Service (NRCS) (USDA, 2008). The soil in and along the study area includes primarily silty loamy soils where groundwater is deeper than 80 inches.

The six geologic units mapped in the study area include loose unconsolidated river deposits that become increasingly sedimentary as one moves further away from the Willamette River. The study area is underlain by a very thick sequence of unconsolidated geologic materials, and bedrock is very deep. The hills west of the river are primarily Colombia River basalt, which is more compact than the river-deposited soils. The Geological Resources Technical Report (CH2M HILL, 2012h) contains detailed descriptions of the geologic units. Observations in the vicinity of the gravel extraction operation indicate that much of the site is underlain by sand, gravel, and clay that are more than 60 feet deep.

Loose gravelly soils associated with the Willamette River floodplain.

Figure 3.18-1. Liquefaction Potential



The Willamette River Floodplain is subject to major and local flooding, channel migration, ponding, and high groundwater. Scour and damage to the existing Marion Street Bridge piers has already occurred. Any new bridge embankments or retaining walls constructed near the river's edge or in flood-prone areas would be susceptible to scour and erosion from high water and channel migration, which could lead to slope failures.

Steep river banks along the east side of the Willamette River (Figure 3.18-1) are up to 30 feet high. These banks may be susceptible to local landslides and slope instability from streambank erosion and seismic shaking. The analysts observed bent and leaning trees on this slope (as shown in the photo), which could indicate long-term slope creep and potential failure. The west bank of the Willamette River, which is on the inside of the bend, should be subject to sediment transport and deposition. Conversely, because the east bank of the river is on the outside of the bend, it would be more subject to erosion and undercutting from channel migration.

Steep slopes of the east Willamette River bank near Center Street Bridge.

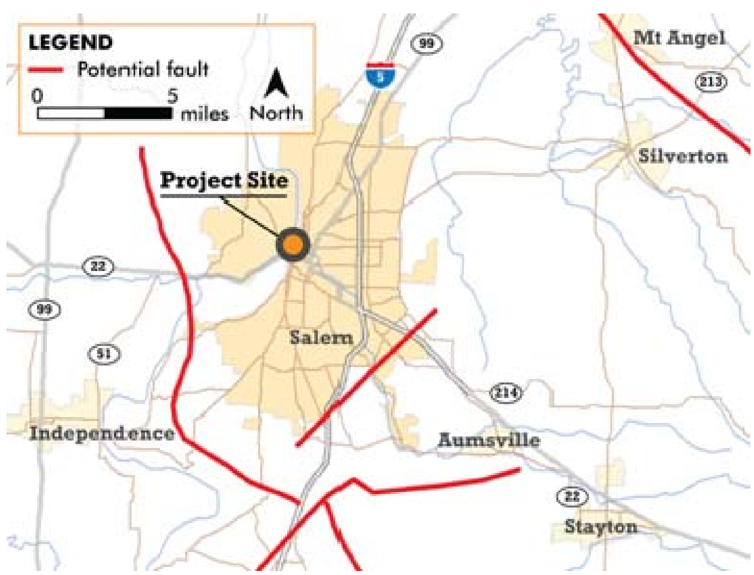
3.18.2.2 Seismicity

Western Oregon lies along the "ring of fire," the zone of earthquakes and volcanoes that encircles the Pacific Ocean. Off the Oregon coast, two tectonic plates are slowly colliding, with the Juan de Fuca plate pushing its way beneath the North American plate. Although movement of the plates is slow, the forces resulting from their motion are enormous. The collision of the plates causes stresses to build up in the earth's crust over long periods of time. When this stress is released, an earthquake occurs.

An earthquake's most characteristic physical effect is the passage of seismic waves, causing the ground to shake. The amount of ground motion varies with the magnitude of the earthquake, the distance from its source, and the type of soil through which the seismic waves are traveling. If it is strong enough, this motion can damage or destroy buildings, roads, bridges, and other facilities. Earthquakes can also cause permanent movement of the ground, through either slippage along fault lines and steep slopes or the way the shaking affects the soils.

Figure 3.18-2 shows the mapped potentially active faults within 20 miles of the project site (U.S. Geological Survey [USGS], 2008b). No known active faults have been mapped in the project vicinity. Therefore, impacts to the project from fault surface ruptures within the project boundaries are anticipated to be low. The geologic terrain that underlies the study area is generally low relief, but locally steep slopes are present along the east side of the Willamette River that could be subject to local slope failures.

Figure 3.18-2. Potentially Active Faults



One of the most damaging effects of earthquakes is liquefaction, which results when seismic shaking causes certain soils to act like liquids. As shown on Figure 3.18-1, several liquefaction zones are present in the project area relative to the underlying soils.

3.18.2.3 Groundwater

Within the floodplain areas of the study area, shallow groundwater occurs at depths ranging from approximately 5 to 15 feet below ground surface, and soils in the Willamette River floodplain are subject to seasonal high saturation levels (U.S. Department of Agriculture [USDA], 2008). Based on groundwater intercepted during the excavation of gravel, shallow ground water also occurs from approximately 20 feet beneath the terraces that adjoin the Willamette River floodplain. Groundwater levels vary based on the level and flows of the Willamette River. Groundwater beneath the Salem and West Salem benches and hills generally flows towards the Willamette River.

3.18.2.4 Paleontological Resources

No unique geologic features have been recognized within the study area. A review of the paleontological resources map (ODOT, 2009b) indicated that no recognized fossil localities are within the project area.

3.18.3 ENVIRONMENTAL CONSEQUENCES

The major impacts from the Build alternatives would be to the resources at the approaches and abutments. The primary geologic issues include the following:

- Potential for increased erosion because of excavations and fills
- Placement of structures and fills
- Seismic shaking and liquefaction
- Embankment foundation stability
- Flooding and scour of embankments near the river and piers in the river
- Instability of steep river banks
- Current and future gravel operations impacting the project by undermining fills or foundations

Managing Geologic Hazards

All the Build alternatives include supporting roadways on piers/columns, improving soils beneath bridge columns, designing bridge columns to withstand seismic motion, and/or excavating areas with vulnerable soils and replacing them with stronger materials.

3.18.3.1 Direct Impacts

No Build Alternative (Alternative 1)

With the No Build Alternative, local roadway projects would continue to take place in and around the study area. These modifications to the transportation system would include intersection widening, additional turn lanes, and ramp modifications. Although not on the Salem-Keizer Area Transportation Study Metropolitan Planning Organization (SKATS MPO) Regional Transportation Systems Plan (RTSP) Project List, the City of Salem is planning for the eventual construction of Marine Drive between the Marion Street Bridge and River Bend Road. This project would be similar to the Marine Drive construction included as part of some of the Build alternatives.

Build Alternatives

For all Build alternatives, project designers would include a number of features to reduce potential geologic hazards. Areas would be stabilized where soils are liquefiable and/or prone to settlement or landslide, including the floodplain and eastern banks of the Willamette River. Erosion, topographic modifications, and drainage pattern alterations are direct impacts expected to occur for all Build alternatives. The cut-and-fill slopes, retaining walls, and other structures would have the potential to create slope instability. Rock-cut slopes would be constructed along the west bridge approach as part of each Build alternative. The rock-cut slopes could also have a thick mantle of soil or weathered rock at their crests. Direct impacts from new rock cuts would include rockfall hazards, instability, costly construction, and ongoing maintenance.

A bridge constructed on the west side of the Willamette River would be built upon alluvial deposits that could potentially include zones of weak, soft silt, clay, and organic materials. These areas create a potential liquefaction zone, as seen on Figure 3.18-1.

Direct impacts could include settlement of the new bridge embankments constructed on weak, low-strength sediments. Embankment structures constructed on weak sediments could settle, which could endanger the roadway. While all Build alternatives would have similar risks within the Willamette River floodplain, some differences occur in the connections of local roads and ramps, and in the placement of piers. Potential scour and erosion of the bridge piers would need to be addressed and mitigated.

The Build alternatives would modify the existing drainage patterns and topography from the cut-and-fill slopes and retaining walls. However, culverts and drainage ditches would be incorporated at the base of cut-and-fill slopes and along new roads. These ditches would convey stormwater away from the project site to prevent ponding or flooding. Drainage layers under retaining walls and culverts through embankment fills would move runoff under or through these structures to ensure drainage and prevent saturation.

Three areas of concern (extension of Marine Drive, a potential gravel extraction hazard, and OR 22 scour) are noted in the Geologic Resources Technical Report and are shown on Figure 3.18-3. The following subsections describe how these areas of concern would affect the Build alternatives.

Extension of Marine Drive (Alternatives 2A, 2B, 4B, 4C, 4D, and 4E)

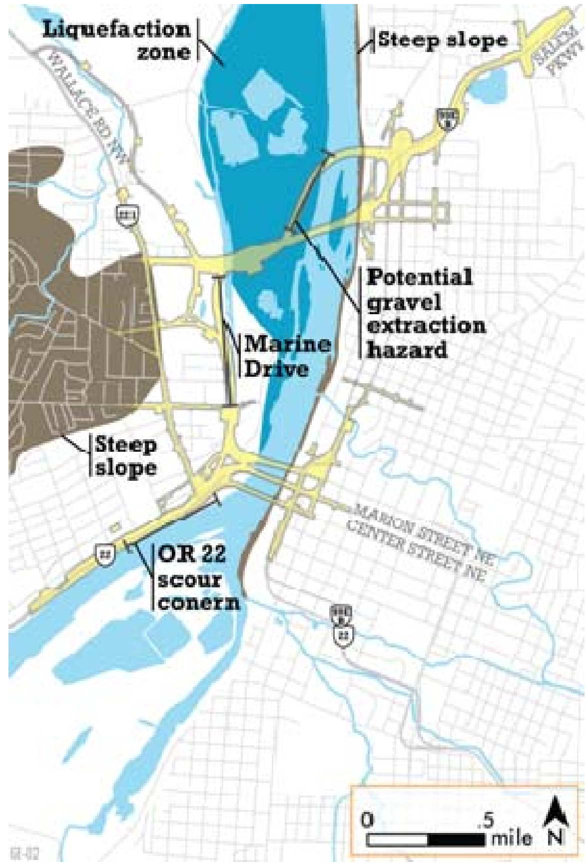
With Alternatives 2A, 2B, 4B, 4C, 4D, and 4E, Marine Drive would be extended, crossing an abandoned Willamette River channel and an unnamed slough. This area contains deposits from the Willamette River that are subject to repeated flooding. Settlement and compaction of soils could potentially impact construction of a new road, either at ground level or on piers.

Gravel Extraction Hazards (Alternatives 3, 4A, 4B, 4C, 4D, and 4E)

Alternatives 3, 4A, 4B, 4C, 4D, and 4E propose construction of a bridge on a strip of land adjacent to and immediately south of the active gravel pits and border the western shoreline of the Willamette River. Potentially loose, unstable slopes border this strip of land. (The slopes of the gravel pits have not been designed or engineered to handle a surface use.) During an earthquake, lateral movement and liquefaction could reduce the stability of the land in either direction, and, with very deep pier foundations, result in increased pier loading. In addition, this area could be subject to channel migration and bank erosion. Therefore, because of potential impacts, a bridge across this strip of land would require special investigations and design considerations.

The alignment of Alternative 3 would locate the piers in the most sensitive geologic areas (as described previously). Alternative 3 would require special additional mitigation and design considerations.

Figure 3.18-3. Geologic Areas of Concern



Alternatives 4A, 4B, 4C, 4D, and 4E would require additional design considerations for piers located south of the gravel pit, but these Build alternatives would not cross the narrow strip of land with the potentially unstable slopes.

Scour and Erosion at OR 22 Piers (Alternatives 2B, 4B, 4C, 4D, and 4E)

The potential exists for slope failures due to scour on the western bank of the Willamette River at OR 22. The roadway for these alternatives would be widened on piers with additional piers placed adjacent to the Willamette River channel. Bridge-embankment retaining walls constructed near the river's edge are more susceptible to scour and erosion from high water and channel migration. Potential scour and erosion of the widened bridge piers would need to be addressed and mitigated.

3.18.3.2 Indirect Impacts

Changes in topography from adding infrastructure could affect drainage patterns and erosion, which could, in turn, increase the potential for future landslides. Therefore, indirect impacts to bridges from the Build alternatives might occur from long-term erosion, flood events, and future earthquakes that would not occur with the No Build Alternative.

3.18.3.3 Construction Impacts

Construction impacts primarily relate to soil and erosion concerns and soil compaction. Potential construction impacts could include the following:

- Construction of foundations or footings within the Willamette River floodplain or in areas with shallow groundwater would require dewatering. Proper design and construction measures must be employed to avoid impacts.
- Areas cleared of vegetation for highway construction would leave soils exposed during construction. Proper erosion and sediment control measures would be applied to limit exposed areas subject to soil erosion from wind and precipitation runoff.
- Small landslides or slumps could occur during construction activities such as grading, excavating, changing drainage that would lead to saturation, altering existing slopes, or surcharging slopes by constructing embankments.

ODOT design and construction standards and best management practices (BMPs) would address these construction impacts.

3.18.3.4 Summary of Potential Impacts

All of the Build alternatives would require mitigation measures to ensure safe construction and long-term performance. The Build alternatives with the largest amount of roadway and bridge construction, and therefore the greatest potential to encounter geologic hazards and require the most mitigation at the greatest expense, would be Alternatives 3, 4C, 4D, and 4E. Alternatives 2A and 2B would have the least impacts on geological resources of all the Build alternatives, requiring the least mitigation.

3.18.4 Avoidance, Minimization, and Mitigation Measures

3.18.4.1 Drainage and Erosion

As outlined in the *Erosion Control Manual* (ODOT, 2005), standard erosion control techniques (including stormwater and erosion best management practices such as the development and implementation of a comprehensive erosion and sediment control plan) would be used in construction zones to minimize erosion. These would include stormwater and erosion BMPs such as the development and implementation of a comprehensive erosion and sediment control plan. For the long-term, erosion could be controlled by hydroseeding and establishing vegetation as soon as possible. Other measures would include diverting stormwater runoff away from cuts and fills and constructing erosion retention basins.

3.18.4.2 Seismic Hazards

The Pacific Northwest is a geologically active region that experiences large and small earthquakes, as well as landslides and erosion along vulnerable slopes. Careful consideration of design, location, and construction techniques improves the safety of transportation structures during seismic events and increases stability in areas prone to erosion and landslides. Mitigation for seismic hazards to bridges, structures, and retaining walls would include evaluating the level of loading to be expected during design and performing structural design to withstand the anticipated loads. Foundation design would consider liquefaction, and the structure would be founded on rock or more stable ground (such as the Troutdale formation), if encountered at depth. Slope stabilization measures (such as installing drilled shafts or micropiles and increasing soil strength) would also provide mitigation for seismic hazards.

3.18.4.3 Other Mitigation Measures

Mitigation would be required for scour, settlement, and other foundation issues, and for landslides and other slope-stability issues. Proper impact identification and mitigation design will require subsurface testing prior to final design. Because the project impact area would be so large, and the Build alternatives would vary so substantially with respect to the impacted area, these tests have not been conducted yet. Structural elements exposed to water flow can be designed to minimize scour and armored to protect against the results of scour. Most of the techniques mentioned previously to mitigate seismic hazards would also apply to foundation and slope-stability issues.