Chapter 5

Geology, Seismicity, and Soils

5.1 Introduction

This chapter provides a description of existing geologic, seismic, and soil conditions in the project area and evaluates the potential geologic-, seismic-, and soil-related impacts associated with project construction.

5.2 Affected Environment

For the purposes of this chapter, the affected environment (*affected area*) consists of

- the construction area,
- the short embankment located between the construction area and I-80, and
- the steep slope that adjoins the construction area on river left.

Defined as such, the affected environment encompasses all of the landforms, geologic materials, and soils that would affect or be affected by project construction. Operational geomorphological effects are described in chapter 4, "Water Quality."

5.2.1 Sources of Information

In 1998–1999, Black Eagle Consulting (Black Eagle) conducted extensive surface and subsurface geologic investigations in and adjacent to the construction area. The results of these investigations are presented in the geotechnical design report for the proposed project (Black Eagle Consulting 2000). Accordingly, the data, maps, physical descriptions, interpretations, and design recommendations contained in the Black Eagle report served as the primary source of information for this chapter and as the basis for most of the subsequent geology and soils impact analyses. Much of the information contained in the geotechnical report was corroborated during field surveys conducted in August 2000 by earth scientists from Jones & Stokes. Where appropriate, information in the Black

Eagle geotechnical report was supplemented with information from regional literature published by the California Division of Mines and Geology (CDMG) and the Tahoe National Forest (TNF).

5.2.2 Regional Setting

5.2.2.1 Geology

The large-scale geologic map prepared by Black Eagle (figure 5-1) indicates that there are at least 4 geologic formations in the affected area. Two of these 4 formations comprise glacial outwash deposits, 1 formation is made up of volcanic mudflow deposits, and 1 formation is quartz monzonite bedrock.

Most project structures, including the proposed diversion structure, the temporary diversion channel, and the proposed diversion conduit, would be constructed in or immediately adjacent to the Truckee River channel. The sites proposed for construction of these structures are underlain at the surface by the coarse-textured glacial outwash deposits of the River Outwash formation; the deposits have been reworked by the Truckee River since their initial deposition by glacial floodwaters. In general, the River Outwash deposits consist of rounded cobbles and boulders with minor amounts of gravel, sand, and silt. On river right, the River Outwash deposits are overlain in places by a relatively thick layer (up to 23 feet thick) of fill consisting of gravelly sands and clayey sands that contain various types of construction debris, including bricks, iron pipe, and fragments of concrete. On river left, the River Outwash deposits are overlain in places by varying amounts of granitic riprap.

A second formation of glacial outwash, referred to as Tahoe Outwash, was mapped above Old Highway 40 (figure 5-1). Like the River Outwash formation, it consists of coarse-textured till deposited during episodes of postglacial flooding. It differs from the River Outwash formation in that it is older, is characterized by a matrix of sand and fine gravels, and has not been reworked by the Truckee River.

Volcanic mudflow deposits are mapped above Old Highway 40, just north of the Tahoe Outwash formation (figure 5-1). The mudflow deposits consist of angular to subangular clasts of volcanic rock in a highly erodible matrix of volcanic ash.

Quartz monzonite bedrock was mapped on portions of the steep slope that adjoins the construction area on river left. Subsurface investigations indicated that this bedrock formation extends beneath the River Outwash on both sides of the Truckee River channel. The bedrock is moderately to highly weathered, extensively fractured, and has been moderately altered by hydrothermal fluids thought to have traveled along the unnamed, west-trending fault that traverses the affected area (described below) (figure 5-1).

Float material, which consists of rock fragments (e.g., gravels, cobbles, and boulders) originating from unstable upslope areas, has accumulated on the slope between the river and Old Highway 40, concealing the identity of underlying geologic formations (figure 5-1).

5.2.2.1.1 Rockfall and Slope Stability

Active mass movements and potential mass movement hazards were identified at several locations on the steep slope that adjoins the construction area on river left (Black Eagle Consulting 2000). The most severe of the mass movement hazards on this slope are associated with the poorly vegetated, oversteepened exposure of Tahoe Outwash located on National Forest property above Old Highway 40 (figure 5-2). Rockfalls occur year-round at this location, but occur most frequently during the spring when freeze-thaw processes are most active. Substantial rockfall debris piles have formed above, on, and below Old Highway 40 as a result. Although there was no evidence of past slope failures at this location, there is evidence of slope failures on similar glacial outwash deposits elsewhere in the Truckee River canyon (Black Eagle Consulting 2000). Future large-scale mass movements are possible on the oversteepened exposure of Tahoe Outwash that is present in the affected area (Johnson pers. comm.).

The outcroppings of quartz monzonite bedrock above Old Highway 40 also represent a considerable rockfall hazard. Rockfall of cobble- and boulder-size rocks occur at these outcroppings approximately 5 times per day. Weathering and extensive hydrothermal alteration of the bedrock has significantly reduced the strength of the quartz monzonite rock masses, rendering them potentially susceptible to larger mass movements when saturated with water and oversteepened by excavation (Black Eagle Consulting 2000).

With the exception of a small, sparsely vegetated slope segment located above the proposed diversion structure (figure 5-2), the existing rockfall hazard between Old Highway 40 and the river is relatively low. In addition, no active mass movements or mass movement hazards were identified on the embankment between the river and I-80.

5.2.2.2 Seismicity

5.2.2.2.1 Faults and Surface Fault Rupture Hazard

An unnamed, west-trending fault traverses the affected area just north of proposed diversion structure (figure 5-1). This fault shows no evidence of displacement during the last 1.6 million years (i.e., it is pre-Quaternary). There are no other known faults in the affected area, but at least 8 other known faults are located within a 1-mile radius of the construction area (Black Eagle Consulting 2000).

The State Geology and Mining Board (the Board), under the authority of the Alquist-Priolo Earthquake Fault Zoning Act, has established policies and criteria for the classification or "ranking" of known faults in California. According to the Board's policies, known faults are mapped and ranked by the state geologist with regard to their potential for surface rupture, based on the existence or absence of a detectable fault trace and recency of fault displacement.

Detectable fault traces that show evidence of displacement during the last 10,000–11,000 years (i.e., Holocene faults) are defined as *active* and are considered to have the greatest potential for surface rupture. Detectable fault traces that show evidence of displacement between 10,000 and 1.6 million years ago (i.e., Quaternary faults) are defined as *potentially active* and are considered to have less potential for surface rupture. The Board has not established an official category for faults that show no evidence of displacement during the last 1.6 million years (i.e., pre-Quaternary faults). Although such faults are not deemed *inactive* by virtue of being excluded from active and potentially active categories, they are considered to have a relatively low potential for surface rupture (Hart and Bryant 1997). Thus, the unnamed, pre-Quaternary fault that traverses the construction area can be considered to have a relatively low potential for surface rupture.

5.2.2.2.2 Seismic Ground Shaking Hazard

USGS and CDMG both have developed probabilistic seismic hazard (PSH) maps for California (Peterson et al. 1996, U.S. Geological Survey 2001). These PSH maps use isograms to depict the levels of earthquake ground motion that have a 10% probability of being exceeded in 50 years. The measure of earthquake ground motion depicted on both maps is *peak horizontal ground acceleration*, expressed as a proportion of the acceleration due to gravity *g* (9.8 ms^{-2}). The peak ground acceleration isograms depicted on these maps represent probabilistic estimates of the intensity of ground motion or "shaking" likely to occur as a result of reasonably foreseeable earthquake events on active faults. As such, the isograms can be used to evaluate seismic ground-shaking hazards in different regions of California.

According to the most current USGS and CDMG PSH maps, the affected area has a 10% probability of experiencing a peak horizontal ground acceleration that exceeds 0.3g–0.4g in 50 years. This peak ground acceleration value is low to moderate compared to those assigned to other areas in California. Black Eagle indicated that the maximum credible earthquake likely to occur in the general vicinity of the affected area would be a magnitude 6.5 earthquake (on the Richter scale) along the historically active Stampede Valley fault (described above). This statement suggests that a significant proportion of the seismic ground-shaking hazard in the affected area is associated with the Stampede Valley fault.

5.2.2.2.3 Liquefaction Hazard

Liquefaction is a natural process by which soils and sediments lose shear strength and fail during episodes of intense seismic ground shaking. *Shear strength* is resistance to rupture that would be caused by movement of parallel surfaces within a solid body. The susceptibility of a soil or sediment to liquefaction is primarily a function of local groundwater conditions and inherent soil properties such as texture and bulk density. Poorly consolidated, water-saturated, fine sands and silts located within 50 feet of the surface are typically considered to be the most susceptible to liquefaction. Soils and sediments that are not water saturated and that consist of coarser or finer materials are generally less susceptible to liquefaction.

Quartz monzonite bedrock and the coarse glacial deposits of the River Outwash formation, neither of which are susceptible to liquefaction, underlie the entire construction area. Consequently, the potential for liquefaction to occur in the construction area is extremely low.

5.2.2.3 Soils

Soils in the affected area were mapped and described by the U.S. Forest Service (USFS) as part of the Tahoe National Forest soil survey (Tahoe National Forest 1981). The survey indicates that soils of the Kyburz and Aldi series occupy most of the affected area. The soils of these series are shallow, well drained, and typically consist of a thin layer of loam or gravelly loam topsoil and less than 20 inches of clay loam or cobbly loam subsoil underlain by slightly weathered volcanic bedrock.

Field surveys conducted by Jones & Stokes and Black Eagle revealed that the types of soil parent materials (i.e., geologic formations) present in the affected area differ considerably from those described in the soil survey, and that native soils in the affected area have been substantially altered by erosion, mass movements, and human activities, such as road construction, road maintenance, and the placement of uncontrolled fill.

Based on the findings of the field surveys and geologic investigations conducted by Jones & Stokes and Black Eagle, soils in the affected area were determined to consist of a mixture of native soils, fill materials, and rockfall debris of varying size and composition.

5.2.2.3.1 Erosion Hazard

The existing erosion hazard in the affected area ranges from slight to very severe. The erosion hazard is greatest on the very steep and poorly vegetated slope that adjoins the construction area on river left, and on the short embankment between

the construction area and I-80. The erosion hazard is considerably less on the coarse River Outwash deposits that form the banks of the Truckee River.

5.2.3 Regulatory Setting

5.2.3.1 National Pollutant Discharge Elimination System

The regulatory setting for NPDES requirements for geology and soils is the same as described in chapter 4, "Water Quality."

5.2.3.2 Nevada County Grading Permit

Nevada County requires that the proponents of projects involving land grading within 20 feet of a watercourse obtain and comply with the requirements of a grading permit issued and administered by the Nevada County Building Department. Because the proposed project would involve substantial land grading in and immediately adjacent to the Truckee River channel, it would be subject to the conditions and requirements of a Nevada County grading permit, which are described in Chapter V of the Nevada County Land Use Code. Preparation of an erosion and sediment control plan would be a major component of permit compliance. The erosion and sediment control plan can be prepared as a separate document or included with the project grading plan, and would describe in detail the temporary and permanent BMPs that would be implemented to prevent accelerated erosion and sedimentation during and after project construction. It is expected that the SWPPP that would be prepared for the project would meet these requirements. Detailed techniques for minimizing erosion and sedimentation, as well as key elements of the SWPPP, are described in chapter 2, "Description of Project Alternatives."

5.3 Impact Assessment Methodology

5.3.1 Analytical Approach

This section provides an evaluation of the potential seismic-, geologic-, and soil-related impacts that could result from project construction and operation. This evaluation was based on field surveys conducted by Jones & Stokes in August 2000, a thorough review and analysis of the site-specific geotechnical report prepared by Black Eagle during the planning and design stages of the project, and a review of other regional literature describing geologic, seismic, and soil conditions in the affected area. For discussion of the effects that the proposed project could have on the water quality and fluvial geomorphology of the Truckee River system, see chapters 3 and 4, respectively.

5.3.2 Criteria for Determining Impact Significance

The criteria used for determining the level of significance for potential geologic-, seismic-, and soil-related impacts associated with project construction and operation were developed based on the State CEQA Guidelines and on professional judgement The project would result in a significant impact if it would

- expose people or structures to seismic hazards, including surface fault rupture, seismic ground shaking, liquefaction, and seismically induced mass movements;
- be located on a geologic unit or soil that is unstable, or that would become unstable as a result of the project, and potentially result in an on- or offsite mass movement;
- be located on an expansive soil that could create a substantial risk to human life or property;
- result in substantial soil erosion or the loss of topsoil;
- create a substantial change in topography or ground-surface relief features.

5.4 Impacts and Mitigation Measures of Alternative A: Proposed Project

Impact 5-1: Exposure of People or Structures to Surface Fault Rupture

A portion of the proposed diversion conduit would be constructed over the west-trending, pre-Quaternary fault that traverses the affected area immediately northwest of the I-80 bridge. Although the Board does not technically classify pre-Quaternary faults as inactive, such faults are considered to have a relatively low potential for surface rupture. Furthermore, the proposed diversion conduit would not be used to store large quantities of water, nor would the project significantly increase human use or habitation of the affected area. Therefore, this impact is considered ***less than significant.*** No mitigation is required.

Impact 5-2: Exposure of People or Structures to Strong Seismic Ground Shaking

The probabilistic seismic hazard assessment maps developed by CDMG and USGS indicate that there is a 10% probability that the affected area will experience seismic ground motions of low to moderate intensity (0.3g–0.4g) during the next 50 years. However, all project structures would be designed and

constructed according to appropriate Uniform Building Code standards, which are intended to prevent or minimize structural damage resulting from seismic ground shaking of this intensity. Furthermore, the project would not be used to store large quantities of water, nor would it significantly increase human use or habitation of the affected area. Therefore, this impact is considered ***less than significant***. No mitigation is required.

Impact 5-3: Exposure of People or Structures to Liquefaction

All proposed project structures would be founded on or anchored to bedrock or coarse glacial outwash deposits, neither of which are susceptible to liquefaction. Therefore, there would be ***no impact***. No mitigation is required.

Impact 5-4: Creation of On- or Offsite Mass Movement, or Exposure of People or Property to Adverse Effects Resulting from an On- or Offsite Mass Movement

All of the mass movement hazards that currently exist in the affected area are located on the steep slope that adjoins the construction area on river left. The most severe of these hazards are associated with the poorly vegetated, oversteepened exposure of Tahoe Outwash. The outwash is on U.S. Forest Service property above Old Highway 40 (figure 5-2). Rockfalls occur daily on the poorly consolidated glacial deposits that compose the Tahoe Outwash formation, and the deposits are also susceptible to large mass movements such as landslides (Johnson pers. comm.). The altered quartz monzonite bedrock, which lies above and below Old Highway 40, constitutes a substantial but less severe mass movement hazard. There, rockfalls occur on a daily basis, and the bedrock may be susceptible to large mass movements when saturated with water and oversteepened by excavation (Black Eagle Consulting 2000).

Rockfall

With the exception of the shallow V-ditch that would be constructed along the western edge of Old Highway 40, project construction would occur entirely below Old Highway 40. Therefore, the project would have no direct, long-term effects on the amount or rate of rockfall originating from areas upslope of Old Highway 40. Furthermore, the project would not substantially increase human safety hazards associated with rockfalls, as it would not increase long-term use or habitation of the affected area. For these reasons, the project design does not include any permanent measures to control rockfalls. However, rockfalls originating from the steep slope on river left could potentially damage the proposed diversion conduit and could also be extremely hazardous to work crews during the construction period. Large rock riprap would be placed on top of the

diversion conduit to protect it from rockfall impact during project operation, whereas the following temporary measures would be implemented to minimize the exposure of workers to rockfalls during the construction period:

- Wire netting would be installed on the steep, poorly vegetated slope segment between Old Highway 40 and the river, above the general location of the proposed intake structure (figure 5-2). Once installed, the netting would contain rockfalls and significantly reduce the rockfall hazard during construction.
- Concrete K-rail would be installed in combination with rock fencing along the western edge of Old Highway 40. Both the rail and the rock fencing would intercept rockfall debris before it reaches the construction area below. These structures may be left in place and maintained during project operation if deemed necessary by the project proponent.

Large Mass Movements

The potential for the project to induce large mass movements, such as landslides and earthflows, or to create new mass movement hazards, is a direct function of the type and extent of the ground disturbances and topographic alterations that would result from project construction. As mentioned above, the project would not directly alter existing conditions on the slope above Old Highway 40—where the most severe mass movement hazards exist—but would substantially alter portions of the slope between Old Highway 40 and the river, a well as the embankment between the river and I-80. Specifically, construction of the proposed temporary diversion channel, the diversion conduit, and the northern and southern access roads would require deep excavations (more than 5 feet deep), which would form steep and potentially unstable cutslopes that could potentially fail and thereby compromise the stability of adjoining slopes. In addition to these extensive excavations, a small section of bedrock would be blasted from the toe of the slope between Old Highway 40 and the river to make room for the proposed intake structure.

The proposed project includes several temporary measures and permanent design provisions that would be implemented to ensure that the activities identified above do not induce large mass movements or create new mass movement hazards. All blasting operations would be conducted according to a preapproved blasting plan. In the blasting plan, the potential effects of the blasting activity on slope stability in surrounding areas would be considered. Blasting operations would also be closely monitored, even though the momentary ground motions generated by the blasting activity would be relatively small and extremely unlikely to induce large-scale slope failures in the affected area (Johnson pers. comm.). Oversteepened and potentially unstable cutslopes would be stabilized using soil-nail walls and MSEs. Detailed descriptions of these cutslopes and specifications for the soil-nail walls and MSEs that would be implemented to stabilize them are provided in the geotechnical design report for the project

(Black Eagle Consulting 2000). A summary of the conditions under which the soil-nail walls and MSEs would be used is provided in table 5-1.

The temporary construction measures and permanent design provisions included in the project description and summarized in the paragraphs above and table 5-1 would be sufficient to

- control rockfall during construction,
- protect potentially vulnerable project structures from rockfall during project operation,
- ensure that project-related construction activities do not induce landslides or other types of large-scale mass movements, and
- ensure that project-related construction activities do not destabilize slopes adjoining the construction and create new mass movement hazards.

Furthermore, the project would not exacerbate the consequences of mass movements induced by other activities (i.e., activities not associated with the proposed project) because it would not substantially increase human use of the project area or involve the storage of substantial quantities of water. Therefore, this impact is considered ***less than significant***. No mitigation is required.

Table 5-1. Summary of Conditions under which Soil-Nail Walls and Mechanically Stabilized Earthwalls Would Be Used

Project Feature for which Soil-Nail Walls or MSEs Would be Implemented	Description of Implementation of Soil-Nail Walls or MSEs
Temporary diversion channel	A cutslope with a gradient of 0.3–0.5:1 would form a small segment of the temporary diversion channel's eastern bank. A temporary soil-nail wall would be installed on this cutslope during excavation to stabilize the embankment between I-80 and the temporary diversion channel. Constructed cutslope gradients on the remainder of the channel's eastern bank would not exceed 1.5:1 and would be stabilized and armored with large rock riprap.
Portage trail	A permanent MSE with architectural rock facing would be installed on the embankment between the proposed portage trail and I-80.
Concrete diversion conduit	A cutslope with a gradient of 0.5:1 would be created on the upslope side of the diversion conduit during its construction. Temporary soil-nail walls would be installed to stabilize this slope until the conduit is complete and the trench adjacent to the conduit is backfilled. Portions of the temporary soil-nail walls that remain exposed above the diversion conduit backfill will be upgraded and left in place for use as permanent soil-nail walls.
Northern and southern access roads	MSEs would be installed along portions of the downslope side of the northern and southern access roads on river left. Additionally, a permanent soil-nail wall would be installed along portions of the upslope side of the southern access road.

Impact 5-5: Location on an Expansive Soil that Would Create Substantial Risks to Life or Property

All project structures would be founded on or anchored to bedrock or coarse glacial outwash deposits, neither of which are expansive. Therefore, there would be ***no impact.*** No mitigation is required.

Impact 5-6: Increase in Erosion and Sedimentation Rates during the Project Construction Period

Project construction would disturb a considerable amount of soil, sediment, and vegetation in and adjacent to the Truckee River channel. Disturbances could potentially increase erosion and sedimentation rates and thereby adversely affect water quality in the Truckee River. The project description (chapter 2) contains several procedural and design provisions that are intended to minimize the potential for project-related disturbances to have such an effect.

Implementation of the design and procedural provisions contained in the project description, in combination with the temporary BMPs that would be prescribed in the erosion control plan or the SWPPP for the project, would be sufficient to substantially reduce the potential for accelerated erosion and sedimentation to occur during construction. Therefore, this impact is considered ***less than significant***. No mitigation is required.

Impact 5-7: Increase in Short- and Long-Term Erosion and Sedimentation Rates

Some of the areas disturbed during construction would continue to have the potential to erode and contribute sediment to the Truckee River at an accelerated rate once construction is complete. However, the project design contains provisions that would effectively limit the potential for postproject accelerated erosion and sedimentation, as would the SWPPP and erosion control plan that would be prepared for the project.

Implementing the permanent design provisions, revegetation program, and postconstruction BMPs prescribed in the project description, SWPPP, and erosion control plan would substantially reduce the potential for postconstruction erosion and sedimentation rates to exceed preconstruction levels. Therefore, this impact is considered ***less than significant.*** No mitigation is required.