C. GEOLOGY, SOILS AND SEISMICITY

This section assesses the geotechnical conditions potentially affecting the development of industrial and commercial uses as part of the proposed Benicia Business Park Master Plan. The analysis is based on a review of published and unpublished reports on geologic, soils, and seismic conditions within the project site and a site-specific geotechnical investigation. This section includes an assessment of potential impacts from seismically-induced strong ground shaking, landslides, slope failure, lateral slope deformation, differential settlement, and unstable or expansive soils. Mitigation measures for identified significant impacts are provided.

1. Setting

This section describes the existing geologic and seismic conditions of the project site and its vicinity, and associated hazards.

a. Geologic Conditions. The geology, topography, and soils of the project site and the vicinity are described below.

(1) Regional Geology. The project site is located on the northern margin of the Carquinez Strait, which links Suisun Bay and the Sacramento River Delta to San Pablo Bay. The regional geologic setting is the Coast Range Geomorphic Province of California, a relatively geologically young and seismically-active region on the western margin of the North American plate. Within this broadly defined region between the Pacific Ocean to the west and the Central Valley to the east, the topography is characterized by a series of northwest-southeast trending uplands or low mountain ranges and intervening valleys. In general, the Coast Ranges are composed of sedimentary bedrock with layers of recent alluvium filling the intervening valleys.[1] The Carquinez Strait is a relatively narrow valley cut through an upland area underlain by resistant sedimentary bedrock of the Upper Cretaceous Great Valley Sequence and younger Tertiary sedimentary rocks.[2] The upland is bounded by tidal lowlands at the margins of Suisun Bay (to the east) and at the confluence of the Napa River and San Pablo Bay (to the west).

(2) Site-Specific Geology. Most of the eastern three-quarters of the project site are underlain by Cretaceous-age bedrock of the Great Valley Sequence (unnamed mudstone, siltstone, shale, sandstone, and conglomerates). The relatively flat highlands to the northwest and the southeast tip of the project site are underlain by older Pleistocene age alluvial fan deposits. Along most of the stream channels, younger Pleistocene alluvial deposits are present and frequently overlain by Holocene age deposits.[3] The bedrock is extensively fractured and weathered in outcrops (exposed bedrock) at the project site. The bedrock is mantled with unconsolidated sediments derived from physical and chemical weathering of the bedrock. These materials are transported downslope under the influence of gravity and are referred to as colluvium. The thickness of colluvium is variable but is typically thinner on upper portions of slopes and thicker at the base (or toe) of the slopes. The colluvium is locally thicker in swales that naturally form on the slopes as the natural surface water drainage system

[1] California Geographic Survey (CGS), 2002. *California Geomorphic Provinces, Note 36.*

[2] Dibblee, Thomas, 1980. *Geologic Map of the Benicia Quadrangle, California*, USGS Open File Map 80-400.

[3] Graymar, R.W., Jones, D.J., Brabb, EE., 1999. *Geology of the Cordelia and the Northern Part of the Benicia 7.5 Minute Quadrangles, California.* From the Digital Map Database, Open-File Report 99-162.

develops. The colluvium was found to range from 4 to 15 feet in thickness in geologic borings installed at the project site, and is considered to be highly expansive.[4]

Alluvium, a term referring to deposits associated with rivers or streams, occurs in relatively narrow bands in and adjacent to the drainage channels and in low-lying areas. The alluvial deposits at the project site consist of unconsolidated clay, silt, sand and gravel ranging in thickness from 4 to 21 feet. Based on laboratory testing, these deposits are considered to be moderately to highly expansive. Alluvial terrace deposits have been mapped in some of the relatively level areas in the eastern portion of the project site, and found to consist of interbedded silty and sandy clays, clayey sands, and gravelly sands.[5]

Much of the project site has been identified as being susceptible to landslide and debris flow. ENGEO has mapped eight landslides at the project site, typically consisting of shallow earth-flows and slump-type failures. Considered dormant, the depth of past movement associated with these landslides is 10 to 30 feet below the ground surface.[6]

In addition to the naturally-occurring geologic materials at the project site, artificial fills associated with historic grading and quarry operations have been placed at the project site. Fills were encountered in geologic borings in the low-lying areas in the southwestern and southeastern portions of the project site. Fills were also observed in the northeast corner of the project site. The fills appear to consist of soils from the project site, but may contain debris and other materials that may render them unsuitable for reuse. A closed sand quarry is located in the northeast corner of the project site.[7]

(3) Topography. The irregularly-shaped project site covers approximately 527.8 acres of hilly terrain generally consisting of rounded knobs and ridges separated by three main northeast to southwest trending valleys. Elevations range from about 25 feet above mean sea level (msl) in the eastern portion of the project site near I-680 to 280 feet above msl on a knoll in the north-central portion of the project site.[8] The project site contains several un-named drainage swales, intermittent streams, and stock ponds. The project site was historically used for livestock grazing.

(4) Soils and Minerals. Soil is generally defined as the unconsolidated mixture of mineral grains and organic material that covers the land surfaces of the earth. Soils can develop on unconsolidated sediments and weathered bedrock. The characteristics of soil reflect the five major influences on their development: topography, climate, biological activity, parent (source) material, and time. Most of the surface soil mapped throughout the project site is Altamont clay with lesser amounts of Corning gravelly loam and Dibble-Los Osos clay loam. These soils are developed in upland areas underlain by sedimentary rock. The shrink-swell potential is high for the Altamont clay and low to moderate in the Corning gravelly loam and Dibble-Los Osos. The erosion hazard within

[4] ENGEO Incorporated, 1998. *Preliminary Geotechnical Exploration, Lake Herman Road Industrial Park, Benicia, California*, submitted to West Coast Home Builders, Inc., Concord Ca., Project # 1708-V3. June 18.

[5] Ibid.

[6] Ibid.

[7] Ibid.

[8] Ibid.

the site ranges from slight to moderate on gentle slopes (2 to 9 percent) to moderate to high on steep (greater than 30 percent) slopes.[9]

Portions of the project site and surrounding area are classified by the California Division of Mines and Geology (CDMG) as Mineral Resource Zone-1 (MRZ-1) (areas where adequate information is available showing that no significant mineral resource exists) and MRZ-4 (areas where insufficient information is available to allow classification into other mineral resource classifications). A portion of the project site is beyond the boundaries of CDMG mapping.[10] The project site is not identified in the Benicia General Plan or the Benicia Mineral Resource Management Study as an area of mineral resource conservation.

b. Seismic Conditions. The following section includes a description of seismic conditions in and around the project site.

(1) Regional Seismicity. The entire San Francisco Bay Area is located within the San Andreas Fault Zone (SAFZ), a complex of active faults forming the boundary between the North American and Pacific lithospheric plates. Movement of the plates relative to one another results in the accumulation of strain along the faults, which is released during earthquakes. Numerous moderate to strong historic earthquakes have been generated in northern California by the SAFZ. The level of active seismicity has resulted in classification of the area as seismic risk Zone 4 (the highest risk category) in the California Building Code. The SAFZ includes numerous faults found by the California Geological Survey under the Alquist-Priolo Earthquake Fault Zoning Act (A-PEFZA) to be "active" (i.e., to have evidence of fault rupture in the past 11,000 years). Regional active faults are shown on Figure IV.C-1.

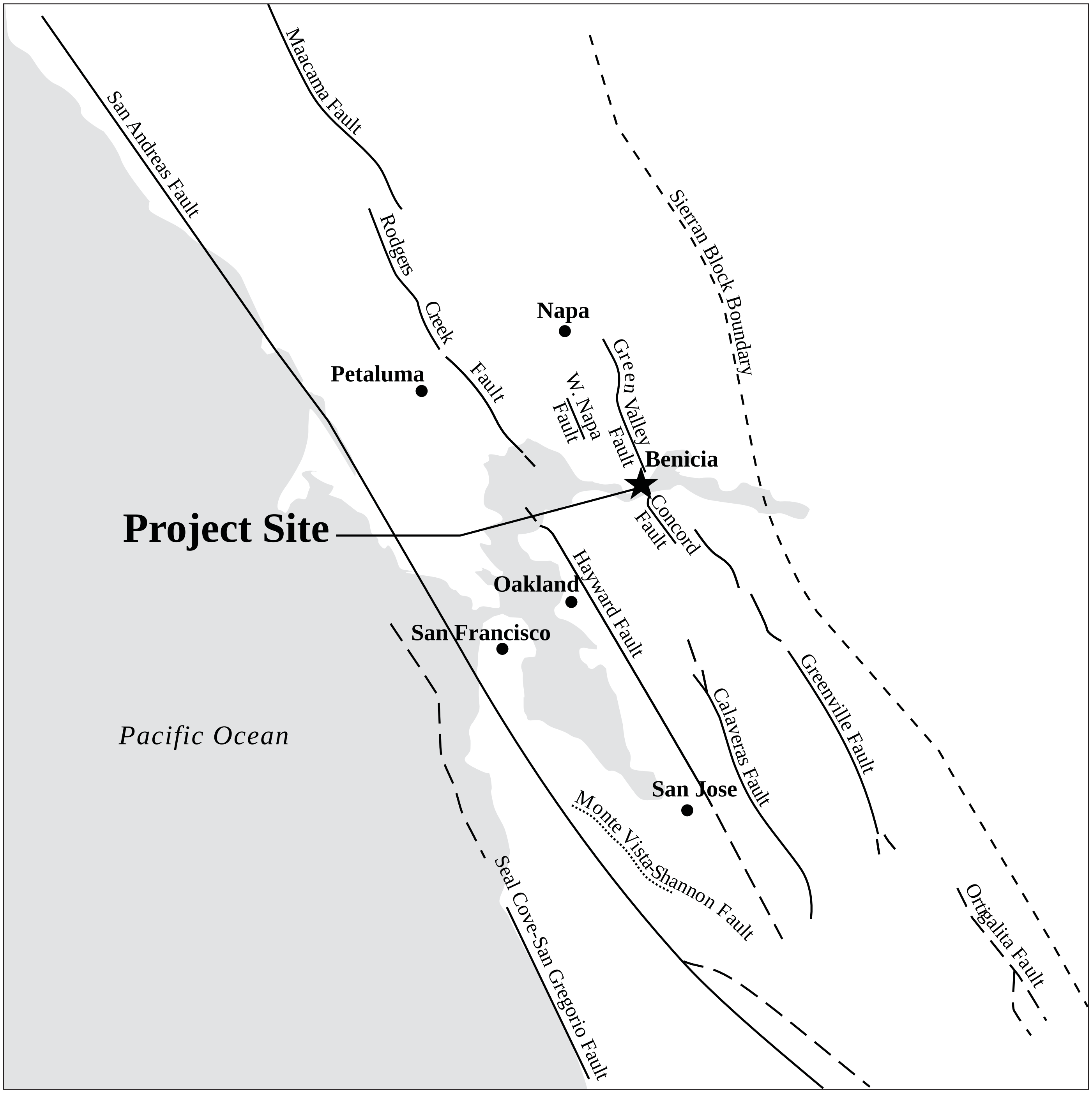
The U.S. Geological Survey's Working Group on California Earthquake Probabilities estimated that there is a 62 percent probability that one or more Moment Magnitude (M_w) 6.7 [11] or greater earthquakes will occur in the San Francisco Bay Area between 2002 and 2031. The probability of a M_W 6.7 magnitude or greater earthquake occurring along individual faults was estimated to be 21 percent along the San Andreas Fault, 27 percent along the Hayward Fault, 11 percent along the Calaveras Fault, 4 percent along the Concord-Green Valley Fault, 10 percent along the San Gregorio Fault, 3 percent on the Greenville Fault, and 3 percent for the Mt. Diablo Thrust fault. In addition, there is a cumulative 14 percent chance of a background (other earthquake source, either mapped or undiscovered) event occurring. When predictions are expanded to 100 years, it is estimated that about three M_W 6.7 or greater events could occur during that time. Thus the probability of at least one M_W 6.7 or greater magnitude earthquake rises to near certainty – about 96 percent – when calculated for a 100-year span.[12]

[9] Natural Resources Conservation Service, 2006. *Web Soil Survey 1.1, for Solano County, California*. Website: websoilsurvey.nrcs.usda.gov. September 18

[10] California Division of Mines and Geology (CDMG), 1987. Mineral Land Classification, Aggregate Materials, San Francisco-Monterey Bay Area, CDMG Special Report 146, Part III.

[11] Moment magnitude (M_W) is now commonly used to characterize seismic events as opposed to Richter Magnitude. Moment magnitude is determined from the physical size (area) of the rupture of the fault plane, the amount of horizontal and/or vertical displacement along the fault plane, and the resistance to rupture of the rock type along the fault.

[12] USGS, 2003. *Earthquake Probabilities in the San Francisco Bay Region: 2002 to 2031 – A Summary of Findings*, Open File Report 03-214.



LSA

FIGURE IV.C-1

Legend

Active Fault -
Fault has evidence of surface displacement within the past 11,000 years (dashed where inferred)

Potentially Active Fault -
Fault has evidence of surface displacement in the past 1.6 million years, but not within the past 11,000 years

Seismic Source without Surface Rupture

N

0 10 20
MILES

Benicia Business Park EIR
Regional Faults

SOURCE: BASELINE, 2004

I:/CIB530 benicia bus park/figures/Fig_IVC1.ai (10/9/06)

The Coast Range-Sierran Block Boundary (CRSBB) forms the western geomorphic boundary of the Central Valley with the Coast Ranges to the west. This boundary is underlain by a seismically active fold and thrust belt. The CRSBB is generally defined as the range front at the western margin of the Coast Ranges. The project site is basically within this broadly-defined boundary. The CRSBB is currently recognized as a potential seismic source, capable of generating moderate earthquakes within the study area.[13] Recent evaluations of the CRSBB indicate that tectonic compression occurs across the boundary as the Coast Range Block is tectonically pushed beneath the Sierran Block. The result of this active compression is the development of folds and thrust faults within the CRSBB. The faults associated with this zone do not typically propagate to the surface and are, therefore, called "blind thrusts." Because the faults are not expressed at the surface, identification of the locations of the faults cannot, typically, be determined on the basis of geomorphic evidence. However, the compressional zone is considered capable of generating moderate to large earthquakes that could produce strong seismic shaking throughout the region, including the study area. Eleven moderate earthquakes (M_w 5.8 to M_w 6.8) have been documented along the CRSBB zone during the last 150 years, including the 1892 Winters earthquakes.[14] The 1983 Coalinga earthquake (M_w 6.7) is a recent example of an earthquake that occurred on a blind thrust within the CRSBB zone.

(2) Site-Specific Seismicity. The project is not within an Alquist-Priolo Earthquake Fault Zone (A-PEFZA); the project site is about 0.6 miles west of the Green Valley-Concord A-PEFZA fault zone.[15] The Green Valley-Concord fault is a right lateral strike-slip fault with a northwest-southeast axis,[16] and, as noted above, has a 4 percent chance of an M_w 6.7 earthquake occurring between 2002 and 2031. The project site has not yet been mapped as part of the Seismic Hazards Mapping Act. [17]

Other active faults in the vicinity of the project site that could affect proposed development include the San Andreas Fault Zone, and the Hayward, Calaveras, Rodgers Creek, Greenville, Cordelia, and the West Napa faults. These faults are considered active and capable of generating damaging earthquakes based on either historic fault rupture or on geologic evidence that clearly demonstrates faulting during Holocene time (within approximately the last 11,000 years).

Potentially active faults within 20 miles of the project site include the Lake Herman (just to the west of the project site), Sky Valley (immediately east of the project site) Antioch, Southampton, Livermore, Los Positas, and Midway faults. Faults that are considered to be potentially active do not have known Holocene displacement, but are young with respect to geologic time (evidence of activity in the last 2,000,000 years) and are considered to be possible earthquake sources.

[13] Wong, I.G., Ely, R.W., and Lollmann, A.C., 1988. Contemporary Seismicity and Tectonics of the Northern and Central Coast Ranges-Sierran Block Boundary Zone, California, Journal of Geophysical Research, V. 93, pp. 7813-7833.

[14] Wakabayashi, J. and Smith, D.L., 1994. Evaluation of Recurrence Intervals, Characteristic Earthquakes, and Slip Rates Associated with Thrusting along the Coast Range-Central Valley Geomorphic Boundary, California, Bulletin of the Seismological Society of America, Vol. 84, No. 6, pp.1960-1970.

[15] California Division of Mines and Geology (CDMG), 1993. *State of California Special Studies Zones, Vine Hill Quadrangle Map.*

[16] Right-lateral: if the trace of the fault were viewed while standing on one side during an event, it would appear that the ground on the other side of the fault moved to the right. Strike-slip: the sides are moving laterally relative to each other with little or no vertical movement.

[17] California Geological Survey (CGS), 2006. *State of California Seismic Hazard Zone Mapping Act of 1991.*

c. Seismic and Geologic Hazards. The following section details seismic and other geologic hazards within the project site.

(1) Surface Rupture. Surface rupture occurs when the ground surface is broken due to fault movement during an earthquake. The location of surface rupture generally can be assumed to be along an active or potentially active major fault trace. No known active fault traces cross the project site; therefore, the potential for fault rupture at the project site is low.

(2) Ground Shaking and Peak Acceleration. Ground shaking is a general term referring to all aspects of motion of the earth's surface resulting from an earthquake, and is normally the major cause of damage in seismic events. The extent of ground shaking is controlled by the magnitude and intensity of the earthquake, distance from the epicenter, and local geologic conditions. The Modified Mercalli Intensity Scale (MMI) is the most commonly used scale for measurement of the subjective effects of earthquake intensity (See Table IV.C-1). A related concept, acceleration, is measured as a fraction or percentage of the acceleration under gravity (g).

Table IV.C-1: Modified Mercalli Intensity Scale

I	Not felt except by a very few under especially favorable circumstances.
II	Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.
III	Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration like passing of truck. Duration estimated.
IV	During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
V	Felt by nearly everyone, many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned. Disturbances of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop.
VI	Felt by all, many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight.
VII	Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motor cars.
VIII	Damage slight in specially designed structures; considerable in ordinary substantial buildings, with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Collapse of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving motor cars disturbed.
IX	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken.
X	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks.
XI	Few, if any, (masonry) structures remain standing. Bridges destroyed. Board fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.
XII	Damage total. Practically all works of construction are damaged greatly or destroyed. Waves seen on ground surface. Lines of sight and level are distorted.

Source: California Geological Survey, 2002, *How Earthquakes and Their Effects are Measured*: Note 32

The closest known active faults are the Concord and Green Valley faults (often referred to as the Concord-Green Valley fault system, since they may represent portions of one continuous fault on either side of the Carquinez Strait) about 1 mile east of the project site.[18]

The City of Benicia General Plan indicates that those areas approximately corresponding to the mapped areas of Quaternary alluvial deposits may be prone to a high level of ground shaking amplification.[19] Based on Association of Bay Area Governments (ABAG) studies, the estimated intensity for ground shaking at the project site during a magnitude 6.7 earthquake on the Concord-Green Valley Fault ranges from MMI VIII (very strong) to MMI X (very violent) depending on underlying geologic materials.[20] This would constitute a potentially significant hazard.

Estimates of the peak ground acceleration have been made for the Bay Area based on probabilistic models that account for multiple seismic sources. Under these models, consideration of the probability of expected seismic events is incorporated into the determination of the level of ground shaking at a particular location. The expected peak horizontal acceleration (with a 10 percent chance of being exceeded in the next 50 years) generated by any of the seismic sources potentially affecting the project area, including the project site, is estimated by the California Geological Survey as 0.56g.[21] This level of ground acceleration at the project site is a potentially significant hazard.

(3) Liquefaction and Lateral Spreading. Liquefaction is the temporary transformation of loose, saturated granular sediments from a solid state to a liquefied state as a result of seismic ground shaking. In the process, the soil undergoes transient loss of strength, which commonly causes ground displacement or ground failure to occur. Since saturated soils are a necessary condition for liquefaction, soil layers in areas where the groundwater table is near the surface have a higher liquefaction potential than those in which the water table is located at greater depths.

The City of Benicia General Plan indicates that the areas in the southwestern corner of the site, the southeastern margin of the site, and a portion of the western quarter of the site (west of Reservoir Road) may be prone to liquefaction, lateral spreading and/or settlement hazards.[22] However, the liquefaction hazard at the project site is rated as "very low" by the Association of Bay Area Governments (ABAG).[23] Based on the types and densities of the granular materials encountered in the borings conducted at the project site, the site-specific Preliminary Geotechnical report rates the risk of liquefaction at the project site to be low.[24]

Lateral spreading is a form of horizontal displacement of soil toward an open channel or other "free" face, such as an excavation boundary. Lateral spreading can result from either the slump of low cohesion unconsolidated material or more commonly by liquefaction of either the soil layer or a

[18] California Geological Survey, 1999. Special Publication 42: Fault Rupture Hazard Zones in California.

[19] Benicia, City of, 1999. *City of Benicia General Plan, Community Health and Safety Maps.* Adopted June 15.

[20] Association of Bay Area Governments (ABAG), 2004. Earthquake Shaking Scenario. Website: quake.abag.ca.gov

[21] California Geological Survey, 2006. *Probabilistic Seismic Hazards Mapping Ground Motion Page*, Peak Horizontal Ground Acceleration 10% Probability in 50 Years, Soft Rock Site Condition.

[22] Benicia, 1999. op. cit.

[23] Association of Bay Area Governments (ABAG), 2001. *Liquefaction Hazard Map: Concord-Green Valley M6.7 Earthquake.* Website: www.abag.ca.gov. September 19.

[24] ENGEO, 1998, op. cit.

subsurface layer underlying soil material on a slope.[25] The lateral spreading hazard tends to mirror the liquefaction hazard for a project, and by definition needs an open channel or "free" face to expand into; this can include temporary excavations resulting from the construction process.

Regional mapping provided by ABAG indicates the risk of liquefaction for the general area of the project site to be low. Therefore the risk of lateral spreading is considered to be low during the construction/excavation period unless site-specific investigations result in different conclusions.[26] The site-specific Preliminary Geotechnical Report also rates the risk from lateral spreading to be low.[27]

(4) Expansive Soils. Expansion and contraction of volume can occur when certain soils undergo alternating cycles of wetting (swelling) and drying (shrinking). During these cycles, the volume of the soil changes markedly. As a consequence of such volume changes, structural damage to buildings and infrastructure may occur if the potentially expansive soils are not considered in project design and during construction.

The site-specific Preliminary Geotechnical Report concludes that the presence of moderate to highly expansive soil (residual soils, alluvium, colluvium and landslide debris) and moderately to highly expansive bedrock (claystone) which are susceptible to significant volume changes (swell and compression) when subjected to varying moisture content is an area of concern. The preliminary study notes that the recommendations regarding risk in the report should be refined by a Geotechnical Engineer once final grading plans have been developed.[28]

(5) Slope Stability. Slope failure can occur as either rapid movement of large masses of soil ("landslide") or slow, continuous movement ("creep"). The primary factors influencing the stability of a slope are: 1) the nature of the underlying soil or bedrock, 2) the geometry of the slope (height and steepness), 3) rainfall, and 4) the presence of previous landslide deposits. In addition to these general factors, slope stability is also influenced by human activities, including placement of loads (e.g., buildings and other improvements) and excavation activities. While all slopes respond to the force of gravity by some amount of downslope movement of materials, it is the relatively rapid slope failures that present engineering challenges for developments on slopes.

The City of Benicia General Plan indicates that the entire project site has a potential for landslide and debris flow hazards.[29] A wide range of slope conditions exist in the hills that separate the valleys of the project site. Slope stability in these areas is controlled predominantly by the type of bedrock underlying the slope, the aspect of the slope relative to the dip of the underlying rock, the steepness of the slope, and the thickness and distribution of colluvial soils that mantle the slope. The slopes at the project site are underlain by fine-grained sedimentary bedrock and are generally classified as moderately unstable to unstable where the slope steepness is greater than 15 percent.[30] Reconnaissance of

[25] Rauch, Alan F., 1997. EPOLLS: An Empirical Method for Predicting Surface Displacements due to Liquefaction-Induced Lateral Spreading in Earthquakes, Ph. D. Dissertation, Virginia Tech, Blacksburg, VA.

[26] ABAG, 2003. op. cit.

[27] ENGEO, 1998. op. cit.

[28] Ibid.

[29] Benicia, 1999. op. cit.

[30] Nilsen, T.H. and Wright, R.H., 1979. Relative Slope Stability and Land-Use Planning, U.S. Geological Survey Professional Paper 944, 96p. + Maps.

the project site identified eight slope failures, typically consisting of shallow earthflows and slump-type failures.[31]

A potential unstable slope condition could exist in areas of the project site where thick colluvial deposits have accumulated in shallow swales on hill slopes. These swales form incipient drainage channels on the upper portions of the slopes. The swales, known as colluvial hollows, concentrate runoff and subsurface groundwater flow during storm events and periods of prolonged rainfall. Increased groundwater levels and corresponding increases in pore water pressure are the major influence on initiation of debris flows in colluvial hollows. Colluvial hollows may generate debris flows, shallow complex landslides that form a fluid, fast-moving landslide mass. A major series of rainstorms in January 1982 induced over 18,000 landslides in the San Francisco Bay region. Though several of these landslides occurred in the vicinity of the project site north of Lake Herman Road in 1982, none were identified at the project site.[32]

(6) Settlement and Differential Settlement. Differential settlement or subsidence could occur if buildings or other improvements were built on low-strength foundation materials (including imported non-engineered fill) or if improvements straddle the boundary between different types of subsurface materials (e.g., a boundary between native material and fill). Although differential settlement generally occurs slowly enough that its effects are not dangerous to inhabitants, it can cause significant building damage over time. Portions of the project site that may contain loose or uncontrolled (non-engineered) fill may be susceptible to differential settlement. Where structures cross boundaries between native bedrock and engineered fill, differential settlement can occur due to differences in density and strength of sub-grade materials after loads are emplaced. Generally, it is required that building pads be constructed by a process of over-excavation and emplaced engineered fill to achieve stable support for footing- or slab-based foundation systems.

The project site consists of knobs, ridges and valleys with little flat terrain. The proposed project includes extensive changes to the topography by means of cuts and fills to develop building pads and roadways. An estimated 9 million cubic yards of materials would be excavated at the project site. The applicant proposes to balance the cuts and fills on-site to minimize the need to import or export materials. Cuts would be up to 100 feet deep where hills are removed and fills, mostly in swales, would be 30 to 50 feet deep. Maximum slopes in the developed portion of the project site would be approximately 3 percent. A 30 percent maximum slope is proposed for construction along East 2nd Street and would consist of some cut and some fill slopes. Some imported fill material would be required for utility backfill, roadbed and similar uses, particularly where engineering concerns dictate specific performance thresholds.[33]

d. City of Benicia General Plan. The General Plan includes several goals, policies and programs that are related to protecting people and property from potential or known geologic and seismic hazards.

[31] ENGEO, 1998. op. cit.

[32] Wieczorek, G.F., Harp, E.L., Mark, R.K., and Bhattacharyya, A.K., 1988. Debris Flows and Other Landslides in San Mateo, Santa Cruz, Contra Costa, Alameda, Napa, Solano, Sonoma, Lake, and Yolo Counties, and Factors Influencing Debris-flow Distribution, U.S. Geological Survey Professional Report 1434, pp. 133-162 + map (Plate 10).

[33] ENGEO, 1998. op. cit.

Responses to Hazards

- *Community Hazards Goal 4.11:* Minimize harm from geologic hazards.
    - *Community Hazards Program 4.11.A:* Require geotechnical engineering reports to address project site stability and building foundation integrity for projects involving substantial grading.[34]
    - *Community Hazards Program 4.11.C:* Require peer review of geotechnical engineering reports if it is determined that City staff does not have the technical expertise to review such reports.
    - *Community Hazards Program 4.11.D:* Prepare a planning-level geologic hazards map of the Planning Area as needed.
    - *Community Hazards Program 4.11.E:* Update the geologic hazards map as new information becomes available.

2. Impacts and Mitigation Measures

This section analyzes the impacts related to geology, soils, and seismicity that could result from implementation of the proposed project. The section begins with criteria of significance which establish the thresholds for determining whether a project impact is significant. The latter part of this section presents the potential geology, soils and seismicity impacts associated with the proposed project. Mitigation Measures are provided as appropriate.

a. Criteria of Significance. The project would have a significant geologic, soils, or seismicity impact if it would:

- Expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving:
    - Rupture of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map issued by the State Geologist for the area or based on other substantial evidence of a known fault? Refer to Division of Mines and Geology Special Publication 42;
    - Strong seismic ground shaking;
    - Seismic-related ground failure, including liquefaction; or
    - Landslides.
- Result in the loss of availability of a known mineral resource that would be of value to the region and the residents of the State; or
- Result in the loss of availability of a locally-important mineral resource recovery site delineated on a local general plan, specific plan or other land use plan.

b. Less-than-Significant Geology, Soils and Seismicity Impacts. The development of the proposed project would not be subject to, or contribute to, on- or off-site fault rupture, as there are no

[34] To grade property or install drainage improvements within the City of Benicia, sponsors must obtain a grading permit. In addition, sponsors need a zoning permit from the City Planning Department. Plans and related information for the proposed grading operation must be submitted to the Engineering Division. Grading work requires the installation of erosion control measures and may require a storm water discharge permit from the State Water Resources Board as determined by the Engineering Division. For major grading work, submittal of a soils (geotechnical) report prepared by a licensed engineer will be required. Submittal of grading plans and the soils report are required with the grading permit application. Accessed September 19, 2006 at: www.ci.benicia.ca.us/grading.php.

known active faults crossing the project site. The proposed project would not contribute to aquifer related subsidence, because groundwater would not be extracted.[35, 36] The proposed project would not hinder energy reserve development, as the project site is not located over a known gas, oil or geothermal field.[37] Implementation of the proposed project would not result in the loss of a known mineral resource; as noted in the setting section, portions of the project site and surrounding area are classified by the California Division of Mines and Geology (CDMG) as Mineral Resource Zone-1 (MRZ-1) (areas where adequate information is available showing that no significant mineral resource exists) and MRZ-4 (areas where insufficient information is available to allow classification into other mineral resource classifications). A portion of the project site is beyond the boundaries of CDMG mapping.[38] The project site is not identified in the Benicia General Plan or the Benicia Mineral Resource Management Study as an area of mineral resource conservation.[39] Potential impacts associated with erosion and loss of topsoil are discussed in Section IV.D, Hydrology and Water Quality of this EIR.

c. Significant Geology, Soils and Seismicity Impacts and Mitigation Measures. The following five significant impacts associated with the project have been identified.

Impact GEO-1: Seismically-induced ground shaking at the project could result in damage to life and/or property. (S)

All structures in the Bay Area could be affected by ground shaking in the event of an earthquake. The amount of ground shaking depends on the magnitude of the earthquake, the distance from the epicenter, and the type of earth materials in between. Violent to very violent ground shaking is expected at the project site during expected earthquakes on regional faults. This level of seismic shaking could cause extensive structural damage in buildings at the project site; most masonry and frame structures, and some well-built wooden structures would be destroyed. Implementation of the following mitigation measure would reduce this impact to a less-than-significant level:

> Mitigation Measure GEO-1: Prior to the issuance of any site-specific grading or building permit a final design-level geotechnical investigation report shall be prepared and submitted to the City of Benicia Planning and Building Department for review and confirmation that the proposed project fully complies with the California Building Code (Seismic Zone 4). The report shall determine the project site's geotechnical conditions and address potential seismic hazards such as seismic shaking. The report shall recommend foundation techniques appropriate to minimize seismic damage. In addition, the geotechnical investigation shall conform to the California Division of Mines and Geology (CDMG) recommendations presented in the *Guidelines for Evaluating Seismic Hazards in California*, CDMG Special Publication 117.
>
> All subsequent parcel-specific development and building plans shall comply with the California Building Code (Seismic Zone 4) requirements, or requirements superceding

[35] Morton & Pitalo, Inc., 2005. *Preliminary Sewer and Water Plan for Benicia Business Park*, Job# 970096. April.

[36] Water system improvements are specified to be based on recommendations of the 1996 City of Benicia Water System Master Plan.

[37] CDC, 2000. *Energy Map of California, Third Edition,* Division of Oil, Gas or Geothermal Resources.

[38] California Division of Mines and Geology (CDMG), 1987. Mineral Land Classification, Aggregate Materials, San Francisco-Monterey Bay Area, CDMG Special Report 146, Part III.

[39] EIP Associates, 1990. *Benicia Mineral Resource Management Study,* January.

California Building Code requirements. In addition, future development plans shall comply with the requirements of the final design-level geotechnical investigation report unless superseded by a parcel-specific design-level geotechnical investigation report.

All mitigation measures, design criteria, and specifications set forth in the geotechnical reports shall be followed. (LTS)

It is acknowledged that seismic hazards cannot be completely eliminated even with site-specific geotechnical investigations and advanced building practices (as provided in the mitigation measure above). However, exposure to seismic hazards is a generally accepted part of living in the San Francisco Bay Area and therefore the mitigation measure described above reduces the potential hazards associated with seismic activity to a less-than-significant level.

Impact GEO-2: Damage to structures or property related shrink-swell potential of project soils could occur at the project site. (S)

Many of the soils underlying the project site have a moderate to high shrink/swell potential. Shrinking and swelling of soils occurs when expansive soils undergo alternate cycles of wetting (swelling) and drying (shrinking). During these cycles, the volume of the soil changes significantly. Structural damage, warping, and cracking of roads and sidewalks, and rupture of utility lines may occur if the potential expansive soils were not considered during design and construction of improvements. On moderate to steep slopes, the shrink-swell potential of soils can exacerbate a process know as “soil creep.” Soil creep causes the surface soil mantling the slope to move downslope very slowly. Although the movement is slow, structures on and within the soil can deform in response to the movement, resulting in tilted fences, cracked pavement or building foundations.

The preliminary geotechnical report for the project includes several recommendations for mitigating potential problems associated with expansive soils, including:

- Placement of moderate to highly expansive soils and bedrock at a depth of 15 feet below grade;
- Placement of low to moderately expansive materials within the upper 15 feet;
- Proper moisture condition and compaction of fill materials;
- Re-excavation, backfill, and compaction of materials used to fill test pits and trenches; and
- Finished grades adjacent to improvements should provide a slope gradient of 3 to 5 percent to drain surface water away from structures.

Implementation of the following two-part mitigation measure would reduce the potential impacts associated with the moderate to high shrink-swell potential to a less-than-significant level.

Mitigation Measure GEO-2a: Prior to the issuance of a site-specific grading permit, a final design-level geotechnical investigation, to be prepared by licensed professionals and approved by the City of Benicia Planning and Building Department, shall include measures to ensure potential damages related to expansive soils are minimized. Mitigation options may range from removal of the problematic soils and replacement, as needed, with properly conditioned and compacted fill, to design and construction of improvements to withstand the forces exerted during the expected shrink-swell cycles and settlements.

Mitigation Measure GEO-2b: Prior to the issuance of any site-specific ~~grading or~~ building permit, designs of all common landscaped areas shall be reviewed and approved by the City of Benicia Community Development ~~Planning and Building~~ Department. The designs of all common landscaped areas shall incorporate low water-need plantings to minimize the potential for damage associated to pavements, utilities, and structures from expansive soils. The use of similar landscaping shall be encouraged at individual parcels by providing information to new tenants regarding the relationship between irrigation and subsequent property damage. A document which describes the potential for damage from expansive soils from over-irrigation and includes solutions such as drought-tolerant plant material and drip irrigation systems shall be prepared by the applicant and provided to all occupants of the proposed commercial and industrial facilities. (LTS)

Impact GEO-3: Potential long-term deformation related to construction of deep fills and cut slopes could occur as a result of proposed development. (S)

The proposed construction of deep fills at the project site (in some areas up to 50 feet in thickness) could result in the development of adverse soil conditions that could cause deformation of the fills. This deformation could affect the performance of foundations and other project site improvements, including roadways and utility lines. Although the fills would be designed and constructed under the requirements of an approved grading plan, the potential for settlement of the fills and related subsidence of the land surface may occur in localized areas of the project site.

Minor settlement of properly constructed deep fills may be caused by primary compression that would typically occur soon after construction. However, over the last decade, investigation of settlement of old deep fills has raised concern amongst geotechnical professionals regarding the long-term performance of these features.[40,41] Older deep fills appear to be susceptible to a phenomenon typically referred to as "hydrocompression." Under this process, the water content in soils within the deeper portions of the fill increases through time and, ultimately, the soil becomes saturated. The source of water has mainly been attributed to over watering of landscaped areas, leaking water conveyance structures, and collection of groundwater. When these deeper portions of the fill become saturated, the compacted soil can lose strength and experience consolidation. In many cases this process will not occur until more than ten years after construction of the fill. This delayed consolidation can result in significant settlement of the ground surface. Such settlement can cause damage to improvements (structures, utilities, and pavements) which are constructed on the fills.

The preliminary geotechnical report for the project includes several recommendations for mitigating potential problems associated with cut and fill, including:

- Remove colluvial material or weathered rock that may be subject to consolidation under the load of proposed fills;
- Minimize the variability of fill thickness within fills that underlie structures or other improvements at the project site. When cut and fill transitions occur under building sites,

[40] Brandon, T.L., Duncan, M., and Gardner, W.S., 1990. *Hydrocompaction Settlement of Deep Fills*, Journal of Geotechnical Engineering, Vol. 116. pp. 1536-1547.

[41] Rodgers, J.D., 1991. *Long Term Behavior of Urban Fill Embankments*, presented at the University of California-Berkeley Symposium on Foundation Conditions. July. 16 p.

additional excavation of cut areas should be conducted and backfilled with engineered fill to minimize fill thickness variability;

- Differential fill thickness should not exceed 15 percent; and
- For slopes greater than 30 vertical feet in height, debris benches not less than eight feet wide should be constructed, with concrete v-ditches to control surface water runoff.

Relatively high south-facing cut slopes along the northern portion of the project site (in excess of 100 feet) would be required to accomplish the proposed grading plan. Each of the parcels within the project site would benefit from the cut slopes (allowing gentler finished grades elsewhere at the project site), but may unduly burden parcels adjacent to these features with slope failure risk and routine maintenance. The preliminary geotechnical report states that slope maintenance and clearing of v-ditches and debris benches would be required, but does not provide a mechanism for ensuring the maintenance. The City of Benicia would not accept maintenance responsibility for these slopes. Implementation of the following two-part mitigation measure would reduce potential impacts associated with cut and fill for the proposed project to a less-than-significant level:

> <u>Mitigation Measure GEO-3a:</u> Prior to the issuance of any site-specific grading or building permit, a final design-level geotechnical investigation, to be prepared by licensed professionals, and approved by the City of Benicia ~~Planning and Building~~ <u>Public Works</u> Department, shall include measures to ensure potential damages related to long-term deformation and deep cuts and fills are minimized <u>or eliminated by adoption of best industry practices as related to these conditions. In addition, the geotechnical investigation shall make a determination as to the effect such work may have on the stability of materials underlying the proposed 1,000,000- gallon water tanks and the offsite water tank and other facilities of the City of Benicia Water Treatment Plant.</u> The applicant shall incorporate all recommendations of the final geotechnical investigation report regarding mitigation of potential effects associated with cut and fill into the project design.

> <u>Mitigation Measure GEO-3b:</u> Prior to the issuance of any site-specific grading or building permit, the applicant shall establish a self-perpetuating slope maintenance program (to be managed by a project site business owners association or similar entity), to be reviewed and approved by the City of Benicia ~~Planning and Building~~ <u>Public Works</u> Department. The self-perpetuating slope maintenance program shall include annual inspections of slopes, debris benches, and v-ditches. Any accumulation of slope detritus on the benches or in the v-ditches shall be promptly removed. The association would also be responsible for repair of any slope failures that may occur on the cut slopes ~~along the northern portion~~ of the project site. An annual report documenting the inspection and any remedial action conducted shall be submitted to the Planning and Building Divisions of the Community Development Department and the Engineering Division of the Public Works Department for review and approval. <u>Approval by the City of Benicia City Engineer is required with respect to the Grading and Erosion control requirements of the City of Benicia Municipal Code Section 15.28.040 – Hazards (or its successor). (LTS)</u>

<u>Impact GEO-4</u>: Damage to structures or property could occur at the project site due to existing or induced slope instability resulting in landsliding. (S)

The upland areas of the project site include relatively steep slopes on which landslides have occurred.

Construction of buildings or site improvements within or adjacent to landslides or slopes prone to landsliding could result in damage during new or continued slope movement. Reconnaissance of the project site has identified eight slope failures, typically consisting of shallow earthflows and slump-type failures.[42] The potential for slope failure is increased during the expected very strong to very violent seismic shaking (particularly if the causative earthquake occurs during the rainy season when groundwater levels are high).

The preliminary geotechnical report for the project includes several recommendations for mitigating potential slope instability problems, including:

- When grading activities are conducted in identified landslide areas, the entire slide mass should be excavated to a level below the failure plane;
- Minimization of accumulation of water in the fill slopes (which could reduce slope stability) by installation of subdrains;
- Cut and fill slopes greater than 15 feet in height should be no steeper than 3:1; slopes up to 15 feet in height no greater than 2:1;
- All cut slopes should be inspected by the Engineering Geologist for conditions that may affect slope stability; and
- Regular maintenance of debris benches below slopes, including removal of accumulated material that has migrated down the slope onto the bench.

Implementation of the following three-part mitigation measure would reduce potential slope instability impacts to a less-than-significant level:

> <u>Mitigation Measure GEO-4a:</u> Prior to the issuance of any site-specific grading or building permit, final design-level geotechnical investigation report shall be prepared and submitted to the City of Benicia Planning and Building Department for review and confirmation that the proposed project fully complies with the California Building Code (Seismic Zone 4). The applicant shall incorporate all recommendations of the final geotechnical investigation report regarding mitigation of slope instability into the project design.
>
> <u>Mitigation Measure GEO-4b:</u> All grading plans, cut and fill slopes, compaction procedures, and retaining structures shall be designed by a licensed professional engineer and inspected during construction by a licensed professional engineer (or representative) or Certified Engineering Geologist (or representative). All designs shall be submitted to, and approved by, the City of Benicia prior to implementation.
>
> <u>Mitigation Measure GEO-4c:</u> The 40-scale grading plans, when prepared, shall be reviewed by a registered professional engineer, to ensure that the detailed plans conform to the intent of the preliminary geotechnical report. (LTS)

<u>Impact GEO-5</u>: Accidental or earthquake-induced overflows from the Water Treatment Plant and proposed water tank reservoirs could result in flooding hazards on the project site. (S)

[42] ENGEO, 1998. op. cit.

Development of business park uses on the project site could expose persons and structures to flooding hazards associated with accidental or earthquake-induced spills at the City's Water Treatment Plant, which is up-gradient from the site. In addition, flooding could occur if the proposed tank reservoirs were to rupture. Implementation of the following mitigation measure would reduce this impact to a less-than-significant level:

> Mitigation Measure GEO-5: The project shall be designed so ~~to ensure~~ that the proposed development will accommodate the potential ~~would not be subject to~~ flooding associated with accidental or earthquake-induced release of water from ~~rupture at~~ the Water Treatment Plant or water tank reservoirs. Prior to issuance of a building or grading permit, the project sponsor shall retain a hydrologist to review final project grading and drainage plans to ensure that flooding would not endanger human health or property on the project site. The hydrologist's findings shall be reviewed and approved by the City of Benicia Public Works Department.