# 3.1 Geology and Soils

This section describes the existing geology, soil conditions, and seismicity in the action area and the state and local regulations that would apply to the North Bay Water Recycling Program (NBWRP). In general, this section provides an assessment of local geological and seismic conditions that could have an effect on the NBWRP. The Setting describes existing conditions in terms of local topography, geologic substrate, soil resources, and regional seismicity. In the context of the action area, the setting section also identifies local geologic and seismic hazards that could affect structures associated with the project. The Regulatory Framework describes pertinent state and local laws related to geologic and seismic considerations of the NBWRP. The Impacts and Mitigation Measures section defines significance criteria used for the impact assessment and presents a discussion of potential project-related impacts. Determination of significance of impacts in this EIR/EIS apply only to CEQA, not to NEPA.

## 3.1.1 Affected Environment/Setting

### Regional Setting

#### *Geology*

The action area is located within the geologically complex region of California referred to as the Coast Range Geomorphic Province. Much of the Coast Range Province is composed of marine sedimentary deposits and volcanic rocks that form northwest trending mountain ridges and valleys, running subparallel to the San Andreas Fault Zone. Bedrock geology in this region consists primarily of graywacke, shale, greenstone (altered volcanic rocks), basalt, chert (ancient silica-rich ocean deposits), and sandstone that originated as ancient sea floor sediments. The Franciscan units are overlain in areas by volcanic cones and flows of the Quien Sabe, Sonoma and Clear Lake volcanic fields.

The Coast Range Province is divided into a northern and southern half with the San Francisco Bay as the dividing boundary. The San Francisco Bay lies within a broad depression created from an east-west expansion between the San Andreas and the Hayward fault systems. The San Andreas fault zone runs roughly parallel to the Pacific coastline in western Marin County.

#### *Seismicity*

The seismic environment in Northern California and the San Francisco Bay Area is characterized by the San Andreas Fault system, which formed due to major forces occurring at the boundary of shifting tectonic plates. This fault system, and its northwest-trending folds and faults, control much of the geologic structure within the northern Coast Ranges. The U.S. Geological Survey (USGS) Working Group on California Earthquake Probabilities estimated that there is a 21 percent chance of the San Andreas Fault experiencing an earthquake of magnitude 6.7 or greater in the next 30 years (USGS, 2008).

### *Regional Faults*

The San Francisco Bay Area region contains both active and potentially active faults and is considered a region of high seismic activity.[1] Throughout the action area there is a potential of damage from movement along any one of a number of the active Bay Area faults. The USGS estimates that there is a 63 percent probability of at least one moment magnitude 6.7 or greater earthquake occurring in the San Francisco Bay region over the next 30 years.[2] Within the 63 percent probability, the Hayward-Rodgers Creek and San Andreas fault systems are the two most likely to cause such an event (USGS, 2008).[3]

**Figure 3.1-1** depicts active faults in the vicinity of the NBWRP, including the Rodgers Creek fault zone. **Table 3.1-1** lists these faults along with other potentially active fault systems, and identifies the dates of their most recent activity and the estimated maximum moment magnitude of a characteristic future event. The distance listed to the various faults represents the shortest distance to the action area. Two of the regional active faults, the Rodgers Creek and West Napa fault, are located within the action area.

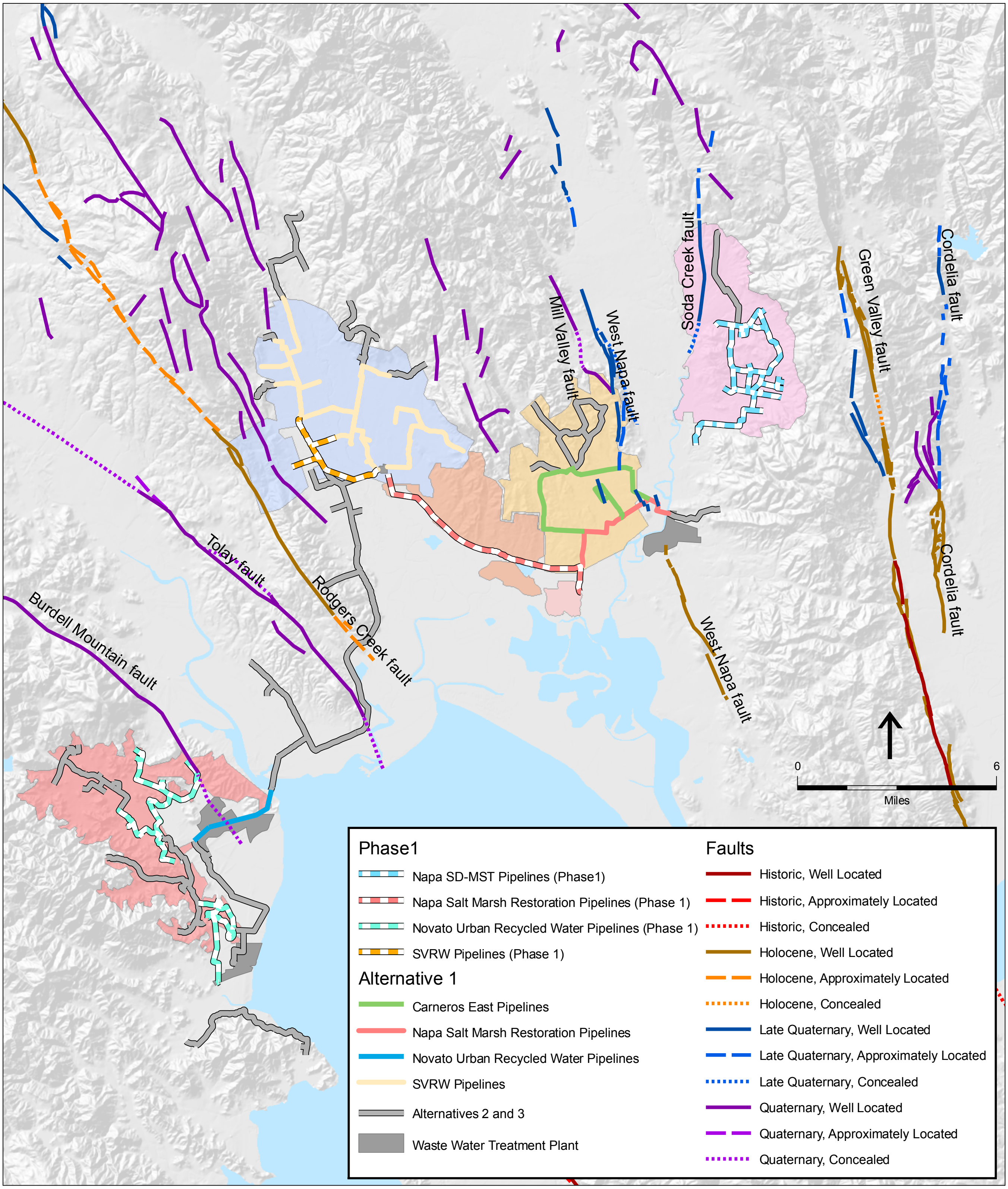
Large historic earthquakes (magnitude 6 and greater) on regional active faults have been responsible for generating significant ground shaking throughout the region including events on the Rodgers Creek fault (1886, 1965), San Andreas (1906, 1989) and the Maacama fault (1906). The Rodgers Creek fault is considered the northern extension of the Hayward fault and is capable of causing significant ground shaking from Vallejo to north of Healdsburg. The most recent significant earthquake on the Rodgers Creek fault occurred in October 1, 1969. On this date, two earthquakes of magnitude 5.6 and 5.7 occurred in an 83-minute period and caused serious damage to buildings in Santa Rosa. The last major earthquake (estimated Richter magnitude 6.7) was generated in 1898 with an epicenter near Mare Island at the north margin of San Pablo Bay. The USGS estimates the probability of a large earthquake (magnitude 6.7 or greater) on the Rodgers Creek fault (when considered together with the Hayward fault) during the period between 2002 and 2032 to be 31 percent (USGS, 2008). The expected ground shaking generated by a seismic event on the Rodgers Creek Fault is anticipated to cause significant damage and interruption of service for transportation (e.g., highways, railroads, and marine facilities) and lifeline (e.g., water supply, communications, and petroleum pipelines) facilities throughout Sonoma County.

---

1 An “active” fault is defined by the State of California as a fault that has had surface displacement within Holocene time (approximately the last 10,000 years). A “potentially active” fault is defined as a fault that has shown evidence of surface displacement during the Quaternary (last 1.6 million years), unless direct geologic evidence demonstrates inactivity for all of the Holocene or longer. This definition does not, of course, mean that faults lacking evidence of surface displacement are necessarily inactive (Hart and Bryant, 1997).

2 Moment magnitude is related to the physical size of a fault rupture and movement across a fault. The Richter magnitude scale reflects the maximum amplitude of a particular type of seismic wave. Moment magnitude provides a physically meaningful measure of the size of a faulting event (California Geological Survey (CGS), 2002).

3 The Rodgers Creek fault is considered to be a northern extension of the Hayward fault which has not been mapped beneath San Pablo Bay.




SOURCE: CDM, 2008; ESRI, 2006; SWRCB, 2006; CGS, 2005; and ESA, 2008

NBWRA North Bay Water Recycling Program. 206088.01

**Figure 3.1-1**
**Regional Faults**

**TABLE 3.1-1**
**ACTIVE AND POTENTIALLY ACTIVE REGIONAL FAULTS IN THE VICINITY OF THE NBWRP ACTION AREA**

| Fault Zone | Location Relative to Action Area | Recency of Faulting[a] | Historical Seismicity[b] | Maximum Moment Magnitude[d] |
|---|---|---|---|---|
| Burdell Mountain | Within Area | Potentially Active | NA | NA |
| Rodgers Creek (includes potentially active Healdsburg and Tolay fault zones) | Within Area | Historic – Active | M 6.7: 1898<br>M 5.6, 5.7: 1969 | 7.0 |
| San Andreas (Peninsula and Golden Gate segments) | 8 miles west | Historic – Active | M 7.1: 1989<br>M 8.25: 1906<br>M 7.0: 1838<br>Many <M 6 | 7.3 |
| Hayward | 4 miles east | Historic – Active | M 6.8: 1868<br>M 7.0: 1838<br>Many <M 4.5 | 6.9 |
| West Napa | Within Area | Holocene –Active | NA | 6.5 |
| Americano Creek | 12 miles northwest | Potentially Active | NA | NA |
| Bloomfield | 11 miles northwest | Potentially Active | NA | NA |
| Carneros | Within Area | Potentially Active | NA | NA |
| Soda Creek | Within Area | Potentially Active | NA | NA |
| Concord-Green Valley (includes Cordelia Fault Zone) | 3 miles east | Holocene – Active | Active creep[c] | 6.9 |
| Maacama | 20 miles north | Holocene – Active | NA | 7.1 |
| Marsh Creek-Greenville | 18 miles southeast | Historic – Active | M 5.6: 1980 | 6.9 |
| Calaveras | 30 miles southeast | Historic – Active | M 6.1: 1984<br>M 5.9: 1979<br>Many <M 6.5 | 6.8 |

[a] Recency of faulting from Jennings (1994). Historic: displacement during historic time (within last 200 years), including areas of known fault creep; Holocene: evidence of displacement during the last 10,000 years; Quaternary: evidence of displacement during the last 1.6 million years; Pre-Quaternary: no recognized displacement during the last 1.6 million years (but not necessarily inactive).
[b] Richter magnitude (M) and year for recent and/or large events.
[c] Slow fault movement that occurs over time without producing an earthquake.
[d] Maximum moment magnitude from Peterson *et al.* (1996). This is the maximum earthquake moment magnitude which could occur within the specified fault zone.

NA = Not applicable and/or not available.

SOURCES: Jennings, 1994, Hart and Bryant, 1997, and Peterson *et al,* 1996.

## *Shaking Intensity*

While the moment and Richter magnitudes are a measure of the energy released in an earthquake, intensity is a measure of the earthquake ground shaking effects at a particular location. Intensity varies depending on the overall magnitude, distance to the fault, focus of earthquake energy, and type of geologic material underlying a particular area. The Modified Mercalli Intensity (MMI) scale (**Table 3.1-2**) is commonly used to express the earthquake intensity and damage severity

**TABLE 3.1-2**
**MODIFIED MERCALLI SCALE (ABRIDGED)**

| Intensity Value | Intensity Description | Average Peak Acceleration[a] |
|---|---|---|
| I | Not felt except by a very few persons under especially favorable circumstances. | < 0.0017 g |
| II | Felt only by a few persons at rest, especially on upper floors on buildings. Delicately suspended objects may swing. | < 0.014 g |
| III | Felt quite noticeably indoors; especially on upper floors of buildings, but many people do not recognize it as an earthquake. | < 0.014 g |
| IV | During the day felt indoors by many, outdoors by few. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. | 0.014–0.039 g |
| V | Felt by nearly everyone, many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned. | 0.039–0.092 g |
| VI | Felt by all, many frightened and run outdoors. Some heavy furniture moved; minor fallen plaster or damaged chimneys. Damage slight. | 0.092–0.18 g |
| 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. | 0.18–0.34 g |
| 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. Fall of chimneys, factory stacks, columns, monuments, walls. | 0.34–0.65 g |
| IX | Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. | 0.65–1.24 g |
| X | Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from riverbanks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks. | > 1.24 g |
| XI | Few, if any, (masonry) structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly. | > 1.24 g |
| 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. Objects are thrown upward into the air. | > 1.24 g |

[a] g is gravity = 980 centimeters per second squared. Acceleration is scaled against acceleration due to gravity or the acceleration with which a ball falls if released at rest in a vacuum (1.0 g). Acceleration of 1.0 g is equivalent to a car traveling 100 meters (328 feet) from rest in 4.5 seconds.

SOURCE: CGS, 2003a.

caused by earthquakes because it expresses ground shaking relative to actual physical effects observed by people and therefore is a useful scale for comparing different seismic events. MMI values range from I (earthquake not felt) to XII (damage nearly total). Earthquakes on the various active and potentially active San Francisco Bay Area fault systems can produce a wide range of ground shaking intensities within the action area.

The closest active faults to the action area are the Rodgers Creek fault and the West Napa fault, both of which transect the action area. The Rodgers Creek fault trends to the northwest from

San Pablo Bay (east of where the Petaluma River enters the Bay) to Healdsburg. The West Napa fault is located east of the Napa River and trends northwest across the Napa County Airport. The most recent significant earthquakes on the Rodgers Creek fault both occurred on October 1, 1969. On this date, two earthquakes of Richter magnitude 5.6 and 5.7 occurred within an 83-minute period. Buildings in Santa Rosa sustained serious damage during these quakes. Prior to these events, the last major earthquake (estimated Richter magnitude 6.7) was generated in 1898 with an epicenter near Mare Island at the north margin of San Pablo Bay (see Table 3.1-2).

Potentially active faults within the action area include the Burdell Mountain, the Americano Creek, the Bloomfield, Carneros and Soda Creek faults. Geologic evidence suggests that there may have been relatively recent movement on the Burdell Mountain fault zone, suggesting that it might be considered active rather than potentially active (County of Marin, 2005). However, no official change has been made. Seismic events along any of these potentially active faults could possibly be triggered by activity within other active faults in the region, such as the Hayward-Rodgers Creek, San Andreas, West Napa, and/or Concord-Green Valley fault zones.

### *Seismic Ground Shaking*

Strong ground shaking from earthquakes generated by active faults in the Bay Area is a hazard to the action area. During project operation, it is likely that at least one moderate to severe earthquake will cause strong ground shaking within the project vicinity. Ground shaking intensity is related to the size (i.e., magnitude) of an earthquake, the distance from the epicenter to the project's location, and the response of the geologic materials that underlie the site. As a rule, the greater the earthquake magnitude and the closer the fault rupture to the site, the greater the intensity of ground shaking. Violent shaking is generally expected at and near the epicenter of a large earthquake, although studies of recent earthquakes, such as those conducted after the 1992 Landers earthquake, indicate that directional ground motion along a fault can cause strong ground shaking farther away from the epicenter. Seismic hazards due to ground shaking can cause the greatest amounts of damage to structures and utilities and unsecured equipment.

The composition of underlying soils can be a primary determining factor of ground shaking because loose or soft alluvial sediments or fill, even those relatively distant from earthquake epicenters, can intensify ground shaking. Non-engineered artificial fill, if present, could intensify ground shaking effects in the event of an earthquake on one of the aforementioned faults. Areas directly underlain by bedrock would likely experience less-severe ground shaking due to the ability of the bedrock to attenuate seismic waves.

Strong ground shaking or ground motion is described as motion of sufficient strength to affect people and their environment. The common way to describe ground motion during an earthquake is with the motion parameters of acceleration and velocity in addition to the duration of the shaking. A common measure of ground motion is the peak ground acceleration (PGA), which is the largest value of horizontal acceleration obtained from a seismograph. PGA is expressed as the percentage of the acceleration due to gravity (g) which is approximately 980 centimeters per second squared. In terms of automobile accelerations, one "g" of acceleration is a rate of increase in speed equivalent to a car traveling 328 feet from a stopped position in 4.5 seconds. For comparison purposes, the maximum PGA value recorded during the Loma Prieta earthquake of 1989 was in the vicinity of the epicenter, near Santa Cruz, at 0.64 g. The highest value measured in the East Bay was 0.29 g, recorded at the Oakland Wharf near the Naval Supply Center. Soils at the wharf are artificial fill over bay mud. The lowest values recorded were 0.06 g in the bedrock on Yerba Buena Island. Recorded ground motion at the Stafford Dam south abutment in Novato resulting from the Loma Prieta event was 0.04 g.

Geologists and engineers attempt to predict earthquake ground acceleration at sites to improve the structural design of buildings and underground utilities to enable them to withstand earthquake motion. A probabilistic seismic hazard assessment describes seismic hazard from earthquakes that geologists and seismologists agree could occur. It is “probabilistic” in that the analysis takes into consideration the uncertainties in the size and location of earthquakes and the resulting ground motions that can affect a particular site. The results of probabilistic analyses are typically more realistic because it accounts for the full range of possible earthquakes, their location, frequency of occurrence, size, and the propagation of the earthquake motion from the rupture zone to the site of interest; the results take into account certainty in the vulnerability of structures. The fundamental difference between deterministic and probabilistic analyses is that deterministic analyses do not consider the probability associated with the earthquake hazard.

In 1999, the California Geological Survey (CGS) completed the Seismic Shaking Hazard Maps for California to describe the statewide distribution of estimated ground motion throughout the state. These maps provide a conservative estimate, through probabilistic analysis, of the peak ground acceleration for all regions of California. Based on estimates of this seismic hazards assessment, the PGA in the region of the NBWRP could reach or exceed 0.5 to 0.8 g (1 chance in 475 of being exceeded each year) (CGS, 2009; Petersen *et al.*, 1996). Seismic ground shaking is discussed further in the impacts analysis below.

## Potential Geologic / Seismic Hazards

The action area could experience the effects of a major earthquake from one of the active or potentially active faults located within 100 miles of the action area. The four major hazards associated with earthquakes are fault surface rupture (ground displacement), ground motion (or ground shaking, discussed above), ground failure (e.g., liquefaction), and differential settlement. Considering the geologic context of the action area and nature of the project, the typical geologic hazards could include slope instability, soil erosion, settlement, and the potential to encounter expansive and/or corrosive soil materials. These hazards are discussed briefly below and provide the initial context for further evaluation in the impact analysis.

### *Seismic Hazards*

#### Surface Fault Rupture

Surface fault rupture is typically observed and is expected on or within close proximity to the causative fault trace.[4] The Rodgers Creek and West Napa fault zones are the closest active faults

4 Fault rupture is displacement at the earth’s surface resulting from fault movement associated with an earthquake.

to the action area zoned under the Alquist-Priolo Earthquake Fault Zoning Act. As mentioned above, both of these faults transect the action area. However, none of the project elements are located within an Alquist-Priolo Earthquake Fault Zone. Surface fault rupture would not necessarily be limited to the boundaries of the Alquist-Priolo Fault Zones, however the risk of surface rupture outside these zones would be considered very low. Therefore, there is very low risk of surface fault rupture within the action area.

#### Liquefaction

Liquefaction is the sudden temporary loss of shear strength in saturated, loose to medium dense, granular sediments subjected to ground shaking. Liquefaction generally occurs when seismically-induced ground shaking causes pore water pressure to increase to a point equal to the overburden pressure. Liquefaction can cause foundation failure of buildings and other facilities due to the reduction of foundation bearing strength. The potential for liquefaction depends on the duration and intensity of earthquake shaking, particle size distribution of the soil, density of the soil, and elevation of the groundwater. Areas at risk due to the effects of liquefaction are typified by a high groundwater table and underlying loose to medium-dense, granular sediments, particularly younger alluvium and artificial fill. Liquefaction hazard maps produced by USGS for the Bay Area Region indicate that there is a high to very high hazard for liquefaction in several locations within the action area especially in the low lying areas that lie close to the Bay or other major drainages (USGS OFR 00-444, 2000). Specific liquefaction hazards zones with the general action area are illustrated in **Figure 3.1-2**. Based on the relative hazard, this issue is discussed further under the impacts analysis below.

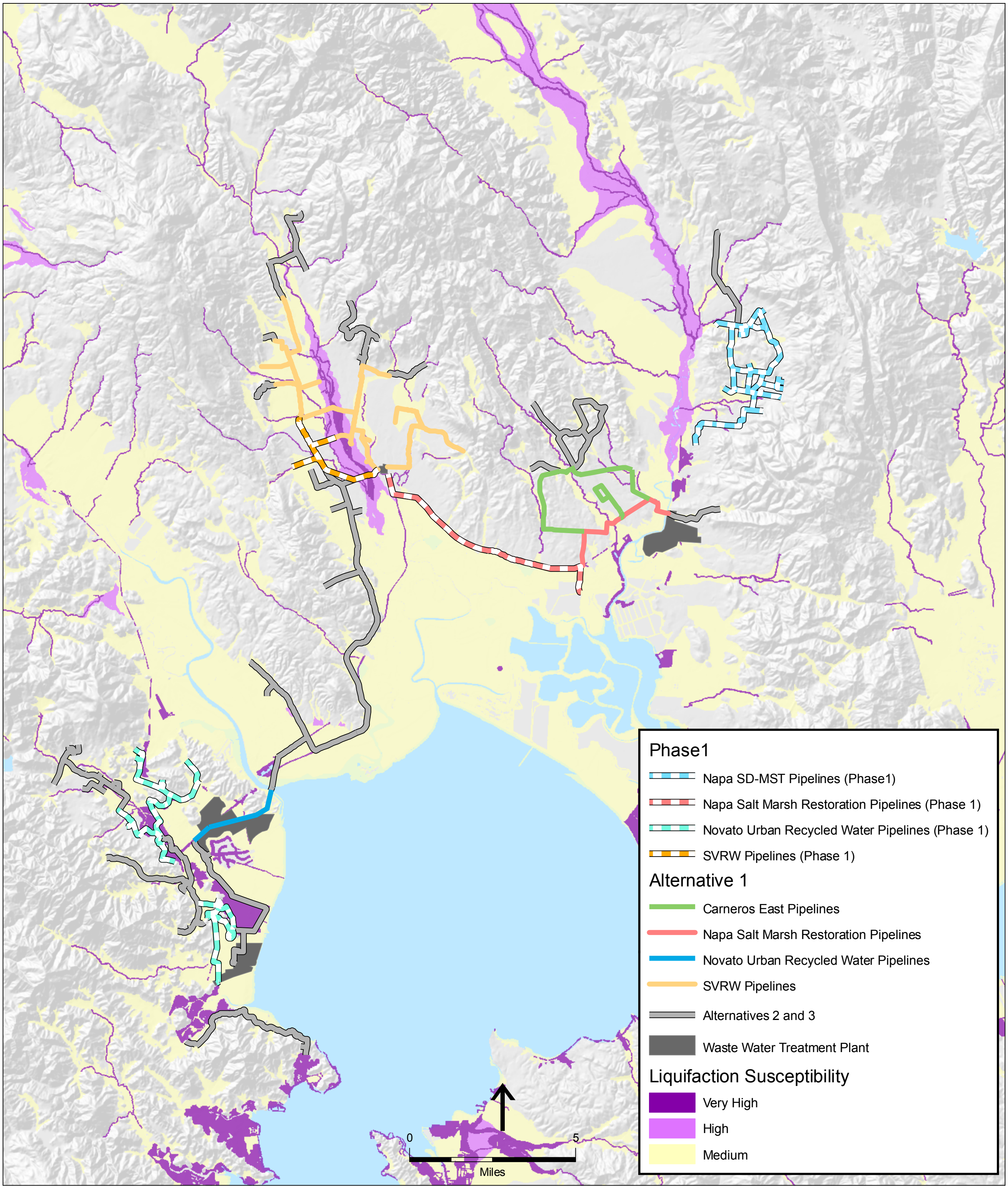
#### Earthquake-Induced Settlement

Settlement of the ground surface can be accelerated and accentuated by earthquakes. During an earthquake, settlement can occur as a result of the relatively rapid compaction and settling of subsurface materials (particularly loose, non-compacted, and variable sandy sediments) due to the rearrangement of soil particles during prolonged ground shaking. Settlement can occur both uniformly and differentially (i.e., where adjoining areas settle at different rates). Typically, areas underlain by artificial fills, unconsolidated alluvial sediments, slope wash, and areas with improperly engineered construction fills are susceptible to this type of settlement. In recognition of the variability of underlying material in the action area, earthquake-induced settlement is discussed further under the impacts analysis below.

### *Other Geologic Hazards*

#### Slope Instability and Landslides

Slope failures, commonly referred to as landslides, include many phenomena that involve the downslope displacement and movement of material, either triggered by static (i.e., gravity) or dynamic (i.e., earthquake) forces. Rock slopes exposed to either air or water can undergo rockfalls, rockslides, or rock avalanches, while soil slopes experience shallow soil slides, rapid debris flows, and/or deep-seated rotational slides. As previously indicated, the action area contains areas that are generally level but also some upland areas with steeper inclines. The issues related to potential landslides are discussed further under the impacts analysis below.




SOURCE: CDM, 2008; ESRI, 2006; USGS 2006; and ESA, 2008

NBWRA North Bay Water Recycling Program. 206088.01

**Figure 3.1-2**
**Liquefaction Susceptibility**

#### Soil Erosion

Soil erosion is the process whereby soil gets dislodged and transported downslope either by wind or water. Rates of erosion can vary depending on the surface soil material and structures, slope angle and length, and human activity. The erosion potential for soils in the action area will vary according to the type of soil and its characteristics as identified by the National Resource Conservation Service in their soil surveys. In general terms, soils containing high amounts of fine sand or silt can be easily eroded while clayey soils are generally less susceptible. Based on the disturbance area anticipated under the project, soil erosion is discussed further under the impacts analysis below.

#### Settlement

Settlement is the depression of the bearing soil when a load, such as that of a building or new fill material, is placed upon it. The process whereby soil materials settle at varying rates depending on the load weight is referred to as differential settlement. Differential settlement can be a greater hazard than total settlement if there are variations in the thickness of previous and new fills or natural variations in the thickness and compressibility of soils across a building footprint. Settlement commonly occurs as a result of building construction or other large projects that involve soil stockpiling. The NBWRP would entail the construction of new structures which could introduce new loads thereby resulting in the potential for settlement. This issue is addressed in the impacts analysis below.

#### Expansive Soils

Expansive soils are characterized by a shrink-swell characteristic.[5] Structural damage may result over a long period of time, usually resulting from inadequate soil and foundation engineering or the placement of structures directly on expansive soils. Expansive soils are largely comprised of clays, which expand in volume when water is absorbed and shrink when dried. Soil materials within the action area are generally comprised of fine sands, silts and in some locations finer clay materials. In recognition that a Geotechnical Investigation will be required for the NBWRP in conjunction with the incorporation of standardized engineering practices for areas identified as containing expansive soil materials, this issue is discussed further in the impacts analysis below.

#### Corrosive Soils

Corrosive soils can damage underground utilities including pipelines and cables, and can weaken roadway structures. Given that some of the action area is comprised of reclaimed marshland protected from tidal influx, the soil resource base is characterized by a higher than normal sodium content. This generally increases the susceptibility of steel and concrete structures to the effects of corrosion. However, current construction materials and practices provide engineering designs to prevent the potential for corrosion therefore, this issue is not discussed further in this section.

5 “Shrink-swell” is the cyclical expansion and contraction that occurs in fine-grained clay sediments from wetting and drying. Structures located on soils with this characteristic may be damaged over a long period of time, usually as the result of inadequate foundation engineering.

## Local Geology

### *LGVSD*

The LGVSD project service area lies within the city of San Rafael and also includes unincorporated areas of Marin County. Regional geologic mapping by the CGS identifies four distinct geologic units in the San Rafael area: bedrock (various units within the Franciscan complex), colluvium, alluvium, and marine/estuary deposits such as Bay mud. In general the marine estuary deposits are likely found in the near shore flat lying areas and bedrock in the upland areas. However, San Pedro Hill which is located close to the Bay contains a massive graywacke deposit from the Franciscan Complex, which is currently being mined for aggregate resources. Colluvium is a general term that refers to loose soil or rock fragments typically found at the base of gentle slopes or hillsides. Alluvium is a general term for loose clays, silt, sand, or gravels that have been deposited by a surface water body during recent geologic time.

### *Novato SD*

The Novato SD service area is located along the northwestern shore of San Pablo Bay. Just north of the service area is where the Petaluma River flows into the Bay. Most of the area lies within low lying marine and marsh deposits. The estuarine deposits are overlain by artificial fill beneath the Novato wastewater treatment plant (WWTP) site. Typically these deposits consist of Bay mud and varying amounts of organic material, silty mud, silt, and sand. Further north in the service area, the underlying geology consists primarily of alluvial deposits that include loose sand, gravel, silt, and clay (Blake *et al.*, 2000).

### *SVCSD*

Sonoma Valley is a northwest trending alluvial valley typical of the Coast Ranges Geomorphic Province. The valley is bound on the west by the Sonoma Mountains and on the east by the Arrowhead Mountains. The basement rocks of this area consist primarily of the Franciscan Assemblage, which is overlain with more recent volcanic flows of the Sonoma Volcanics. The Franciscan Assemblage contains primarily greenstone (altered volcanic rocks), basalt, chert (ancient silica-rich ocean deposits), and sandstone that originated as ancient sea floor sediments. The Sonoma Volcanics represent more recent flows and are typically a more weather resistant rock which form most of the ridges and upper regions of the area. The northern section of the action area, in the vicinity of Glen Ellen, is underlain by alluvial deposits that are younger than the Sonoma Volcanics and referred to as the Huichica and Glen Ellen Formations. The formations consist of gravel, silt, sands, and clays and can be quite thick (Ford, 1975).

The youngest geologic units underlying the action area are surficial deposits made up of unconsolidated sediments eroded from the surrounding bedrock units. These units are locally mapped as Older Alluvium and Younger Alluvium (Wagner and Bortugno, 1982). The Older Alluvium consists of alluvial deposits. The Younger Alluvium consists of unconsolidated stream, channel, levee, flood plain, basin, terrace, and fan deposits ranging in size from boulder to clay. Younger Alluvium underlies areas along Sonoma Creek and the Older Alluvium is found throughout the broader Sonoma Valley. The alluvial deposits can be divided into alluvial fan deposits located along the margins of the valley and finer-grained fluvial basin deposits that occur near the center of the valley and underlie the city of Sonoma. The alluvial fan deposits underlying the action area are approximately 200-foot thick and vary from dissected, highly weathered gravels, to deeply weathered, poorly sorted sand and gravel (Ford, 1975).

### *Napa SD*

Napa Valley is another northwest trending valley similar to Sonoma Valley that is typical of the Coast Ranges Geomorphic Province. The alluvial basin that is drained by the Napa River is bounded by mostly marine sedimentary and metamorphic rocks on the west side, and lava flows and other eruptive volcanic materials on the east. The valley floor is filled with thick alluvium which represents a combination of sediments derived from both sides of the valley although the volcanic rocks known as the Sonoma Volcanics constitute the principal rock source of the soils of Napa Valley. These volcanic deposits include many silica-rich materials that represent the product of explosive eruptions and deposition from a hot volcanic cloud (pyroclastic deposits). Short-lived lakes and redistribution of volcanic rocks by stream action locally formed interlayered sandstones, conglomerates, and siltstones. The source region of the Sonoma Volcanic rocks is uncertain; the region was possibly near the northern end of Napa Valley not far from the town of Calistoga.

## Topography

### *LGVSD*

The topography of the Coast Range Geomorphic Province is characterized by northwest–southeast trending mountain ridges and intervening valleys that were formed by extensive faulting activity approximately 7 to 18 million years ago. More recent activity in the region is concentrated along the San Andreas Fault zone, which consists of a complex group of generally parallel faults. As a result of the tectonic activity, the topography of San Rafael varies greatly with relatively flat lowland areas near the bayshore to hilly slopes that reach up to over 1,000 feet above mean sea level (msl).

### *Novato SD*

Much of the action area is level and resides within the floodplain of Novato Creek, which is situated along the inter-tidal margin of San Pablo Bay. In the southern portion of the action area, near the Ignacio WWTP, surface elevations range near or just below mean sea level (msl). Several levee embankments in the vicinity of the Ignacio WWTP rise to approximately ten feet above msl. Surface elevations along the proposed force main alignment also range from just below or at sea level. Near the Novato WWTP, surface elevations begin to rise gradually towards a low-gradient hill feature, which rises to approximately 270 feet msl north of the WWTP.

### *SVCSD*

The majority of the action area is located within the Sonoma Valley which is drained by Sonoma Creek. Sonoma Valley is a relatively flat-lying sediment-filled valley flanked on either side by the more resistant ridges. The Sonoma Creek flows south from the uplands near Glen Ellen and enters the Sonoma Valley at an elevation of approximately 200 feet above amsl. Continuing south, Sonoma Creek enters the broad Sonoma Valley that extends from the city of Sonoma at 80 feet above msl, to the tidal lands of the San Pablo Bay at sea level.

### *Napa SD*

Napa County is part of the California Coast Range. The county is characterized by a number of northwesterly parallel mountain ridges and intervening valleys of varying widths (Lambert, 1978). The county is bisected by the Napa Valley from Calistoga to San Pablo Bay. The soils in Napa Valley generally are very deep and have high potential productivity and are used for vineyards, orchards, and pastures. The soils in the southern part of the valley have lower production potential because they are limited by strongly developed subsoil. The soils are used mainly for dry land pasture and for oats and hay (Lambert, 1978).

Maacama Mountain is located on the west side of Napa Valley. The soils in this area are moderately deep to very shallow over sandstone and shale, and they are used mainly for range, wildlife habitat, and watersheds (Lambert, 1978).

The mountain ridges on the west side of the valley extend as far south as Napa, where the landscape consists of rolling hills and dissected terraces. The soils in this area are moderately deep over sandstone and shale or are shallow to a claypan and are used for range, pasture, and vineyards (Lambert, 1978).

Howell Mountain borders Napa Valley on the east and rises abruptly from the valley floor. The soils in this area are moderately deep to shallow over rhyolitic tuff and basic igneous rock and are used for timber, range, wildlife habitat, and watersheds. Where the ridge broadens to a plateau near Angwin, some areas of soils are used for vineyards and orchards (Lambert, 1978).

The plateau drops off to the northeast into Pope Valley, and Vaca Mountain rises abruptly to the east. The soils in the northern and eastern part of the county are moderately deep to shallow over sandstone, shale, and serpentine. They are used for range, wildlife habitat, and watersheds (Lambert, 1978).

## Soils

### *LGVSD*

The Soil Survey prepared by the Natural Resources Conservation Service identifies a variety of soil units within the city of San Rafael. The more prominent units include the Tocaloma-McMullin series in the upland areas where slopes range up to 75 percent and the Novato and Reyes Clays in the low lying flat areas (USDA, 2008). Developed areas are mapped as an urban complex which usually refers to the reworking of topsoils associated with development including roads and structures. In the LGVSD WWTP area, the Reyes Clays are the predominant soils in addition to some Saurin series soils and urban complex soils. The Reyes Clays typically occur on relatively flat bayshore areas that range from 0 to 10 feet above msl. In general, the soil resource base has varying hazards of erosion from water and varying potential for shrink-swell behavior.

**Reyes Clay.** These clays are somewhat poorly drained, have a high shrink-swell potential, and very slow runoff rates, are very acidic at depth, and represent little to no hazard of water erosion. These clays are commonly found along the flat areas of the Bay margin on slopes that range from 0 to 2 percent.

**Tocaloma-McMullin.** This series of loams and clays are somewhat excessively drained, have a very low available water capacity, low shrink-swell potential, associated with rapid runoff, and have a high hazard of water erosion. These soils are commonly found on slopes that range from 15 to 30 percent.

**Saurin-Bonnydoon Complex.** This soil complex is comprised of soils that are generally excessively drained to well drained, with very low to moderate available water capacity, have a moderate shrink-swell potential, show medium runoff rates, and have a moderate hazard of water erosion. These soils are generally found on gentle slopes ranging from 2 to 15 percent.

**Xerorthents and Xerorthents-Urban Land Complex.** This soil unit is comprised of fills and reworked soils associated with developed areas. Urban land soils have been altered to the extent that their original characteristics are no longer present. The soils are well drained, have varying water capacities, prone to very rapid runoff, and have a high hazard of water erosion. These soils are generally found on graded areas that are relatively flat or gently sloping ranging from 0 to 10 percent.

### *Novato SD*

The Soil Survey for Marin County identifies five soil map units across the action area, which include: the Bonnydoon gravelly loam (15 to 30-percent slopes), Reyes clay (0 to 2-percent slopes), Saurin-Bonnydoon complex (2 to 15-percent slopes), Xerorthents (fill), and Xerorthents-Urban land complex (0 to 9-percent slopes). These soil units occur on slopes ranging between 0 and 30-percent. The Reyes clay (0 to 2-percent slopes) and Xerorthents (fill) occupy most of the forcemain alignment and the Ignacio WWTP site towards the south. The Xerorthents-Urban land complex (0 to 9-percent slopes) is limited to areas in the vicinity of the Novato WWTP. In general, the soil resource base has varying hazards of erosion from water and varying potential for shrink-swell behavior.

### *SVCSD*

Soils in the area have been mapped as “soil associations,” which are a broad grouping of soils with common characteristics such as similar management uses or slope steepness. Three soil associations occupy the terrain crossed by the action area and are described below. Surficial soils exhibit various characteristics dependent on location, slope, parent rock, climate, and drainage. Certain soils may have characteristics that if not appropriately engineered can be problematic to buildings and infrastructure. These characteristics can include low permeability or susceptibility to expansion or soil erosion. The United States Department of Agriculture (USDA) defines the following major soil associations underlying the action area (USDA, 1972):

*Huichica-Wright-Zamora Association*. This association underlies the majority of the action area. These soils are generally located on low bench terraces and alluvial fans and are comprised of nearly-level to moderately-sloping soils that are well drained to excessively-drained[6] loams to silty clay loams. Slopes range from 0 to 15 percent.

*Yolo-Cortina-Pleasanton Association*. This association lies in the northern portion of the action area just south of Kenwood on flood plains, alluvial fans, and low terraces. Slopes range from 0 to 9 percent. Soils in this association are well drained to excessively drained, nearly level to moderately sloping, and very gravelly sandy loams to clay loams.

*Goulding-Toomes-Guenoc Association*. This association lies further to the east and west of the action area, mainly on ranges of hills that extend nearly the length of the central-eastern third of the county. Slopes range from 2 to 75 percent. This soil formation is located on uplands and comprises of generally well drained with gently sloping to very steep loams and clay loams to loams.

Soils associated with the Napa Salt Marsh Restoration Action area are assigned to the Clear Lake-Reyes, Haire-Diablo, and Huichica-Wright-Zamora associations.

*Huichica-Wright-Zamora Association*. This association underlies the majority of the action area in the 3 pipeline alternative routes. See the above for a detailed description.

*Haire-Diablo Association.* This association underlies the area surrounding the SVCSD WWTP. The Haire-Diablo association soils are characterized as moderately well drained and well drained, gently sloping to steep fine sandy loams to clays on terraces and uplands.

*Clear Lake-Reyes Association.* The soil transitions to this association after the pipeline crosses SR 12/121. Clear Lake-Reyes Association is characterized as poorly drained, nearly level to gently sloping clays to clay loams in basins and on tidal flats. (JSA, 2003)

### Napa SD

The soils within the Napa SD service area also include a wide range of soil types as mapped by the Natural Resources Conservation Service. The soil series that are most prominent in the action area are described below. Surficial soils exhibit various characteristics dependent on location, slope, parent rock, climate, and drainage. Certain soils may have characteristics that if not appropriately engineered can be problematic to buildings and infrastructure. These characteristics can include low permeability or susceptibility to expansion or soil erosion. The USDA defines the following major soil associations underlying the action area (USDA, 1978):

*Coombs Gravelly Loam*. This gravelly loam underlies the majority of the action area. These soils are generally located on alluvial fans and terraces found on nearly-level slopes. The loams are well drained and derived from sedimentary or igneous parent rock materials. Slopes range from 0 to 2 percent.

*Egbert Silty Clay Loam*. This silty clay loam is typically found at the rim of basin floors and on nearly-level slopes. Slopes range from 0 to 2 percent. These soils are poorly drained and are derived from alluvium.

[6] Well drained soils are generally soils that allow water to easily pass through.

*Haire Loam*. Haire loam is found on terraces and alluvial fans, this soil series lies on gentle slopes ranging from 2 to 9 percent. This soil formation is derived from sedimentary rocks and is generally moderately well drained and includes loams, sandy clays, and clays.

*Hambright Rock-Outcrop*. Typically found on more moderate slopes of upland areas, this weathered volcanic rock material is found on hills and some plateaus. The loamy upper layer is underlain by weathered bedrock that is well drained. Slopes range from 2 to 30 percent.

## Mineral Resources

The CGS classifies the regional significance of mineral resources in accordance with the California SMARA of 1975. Mineral Resource Zones (MRZ) have been designated to indicate the significance of mineral deposits. The MRZ categories are as follows and are discussed for each Member Agency below:

*MRZ-1*: Areas where adequate information indicates that no significant mineral deposits are present or where it is judged that little likelihood exists for their presence.

*MRZ-2*: Areas where adequate information indicates significant mineral deposits are present, or where it is judged that a high likelihood exists for their presence.

*MRZ-3*: Areas containing mineral deposits the significance of which cannot be evaluated from available data.

*MRZ-4*: Areas where available information is inadequate for assignment to any other MRZ..

### *LGVSD*

The primary mineral resources just outside the city of San Rafael limits, in unincorporated Marin County, are sand and gravel. The CGS (formerly the Division of Mines and Geology) has designated one site as a Resource Sector in the LGVSD area (MRZ-2 zone) at San Pedro Hill (Marin County, 2007). Franciscan Complex Sandstone, consisting of aggregate (suitable for Portland cement and concrete), rip rap, and shale resources, is utilized at San Pedro Hill.

### *Novato SD*

Within the city of Novato, the primary mineral resources are sand and gravel. The CGS has designated three sites as Resource Sectors in the Novato area (MRZ-2 zones): Black Point, Burdell Mountain, and Bowman Canyon (City of Novato, 1996. Crushed rock and decorative fieldstone quarries are located on the southeast slopes of Mt. Burdell; however, extractive operations in this area have not been active for some time. Sand and gravel quarries are located in the Black Point area; however operations have not been active since the 1950s.

### *SVCSD*

The action area has areas classified as MRZ-1, MRZ-2, and MRZ-3a. The MRZ-2b area is roughly linear and related to Sonoma Creek deposits (Sonoma County, 1998). Aggregate resources associated with river deposits are the dominant mineral mined in this area (Sonoma County, 1998). In this area, aggregate material can be found at or below ground level.

#### *Napa SD*

The CGS has only mapped aggregate resource zones for southern Napa County and has designated one MRZ-2 zone associated with the active Napa Quarry located southeast of the city of Napa (Napa County, 2005). However, there has been a history of mining in the county for a variety of commodities including asbestos, mercury, clay, copper, manganese, magnesite, gold, silver, and quarry rock. The market for most of these resources no longer exists. Aggregate and building stone resources remain as the most significant resource in the county, although as mentioned above the potential resources are not clearly known from the lack of detailed mapping by the CGS.

## 3.1.2 Regulatory Framework

### State

#### *Alquist-Priolo Earthquake Fault Zoning Act*

The purpose of the Alquist-Priolo Earthquake Fault Zoning Act (Alquist-Priolo Act) is to regulate development on or near active fault traces to reduce the hazard of fault rupture and to prohibit the location of most structures for human occupancy across these traces. The Alquist-Priolo Act requires the delineation of fault rupture zones along all active faults in California. Cities and counties must regulate certain development projects within the zones, which include withholding permits until geologic investigations demonstrate that development sites are not threatened by future surface displacement (Hart, 1997). Surface fault rupture is not necessarily restricted to the area within an area covered by the Alquist-Priolo Act.

#### *California Building Code*

The California Building Code (CBC) has been codified in the California Code of Regulations (CCR) as Title 24, Part 2. Title 24 is administered by the California Building Standards Commission, which, by law, is responsible for coordinating all building standards. Under state law, all building standards must be centralized in Title 24 or they are not enforceable. The purpose of the CBC is to establish minimum standards to safeguard the public health, safety and general welfare through structural strength, means of egress facilities, and general stability by regulating and controlling the design, construction, quality of materials, use and occupancy, location, and maintenance of all building and structures within its jurisdiction. The CBC is based on the International Building Code. The 2007 CBC is based on the 2006 International Building Code (IBC) published by the International Code Conference. In addition, the CBC contains necessary California amendments which are based on the American Society of Civil Engineers (ASCE) Minimum Design Standards 7-05. ASCE 7-05 provides requirements for general structural design and includes means for determining earthquake loads as well as other loads (flood, snow, wind, etc.) for inclusion into building codes. The provisions of the CBC apply to the construction, alteration, movement, replacement, and demolition of every building or structure or any appurtenances connected or attached to such buildings or structures throughout California.

The earthquake design requirements take into account the occupancy category of the structure, site class, soil classifications, and various seismic coefficients which are used to determine a Seismic Design Category (SDC) for a project. The Seismic Design Category is a classification system that combines the occupancy categories with the level of expected ground motions at the site and ranges from Seismic Design Category A (very small seismic vulnerability) to Seismic Design Category E/F (very high seismic vulnerability and near a major fault). Design specifications are then determined according to the Seismic Design Category.

### *California Department of Water Resources, Division of Safety of Dams*

Since 1929, the State of California has supervised the construction and operation of dams to prevent failure, safeguard life and protect property. The California Department of Water Resources, Division of Safety of Dams (DSOD) oversees the construction of dams that are over 25 feet high and impound over 15 acre-feet of water, or over 6 feet high and impound over 50 acre-feet of water (DSOD, 2008; California Water Code §6002).

The DSOD reviews permit applications to evaluate the safety of dams and reservoirs. DSOD staff provides independent review of facilities design and safety calculations. The DSOD requires the collection of data concerning subsoils, foundation conditions, availability of construction materials, and geologic hazards to assess the potential for seepage, earth movement, and other conditions that may occur in the vicinity of a dam or reservoir. Investigations usually include exploratory pits, trenches, drilling, coring, geophysical survey, tests to determine leakage rates, and physical tests to measure properties of foundation materials. During construction or repair of a dam or reservoir, the DSOD makes continuous or periodic inspections to verify that construction is proceeding in accordance with approved plans.

### *Seismic Hazards Mapping Act*

The Seismic Hazards Mapping Act was developed to protect the public from the effects of strong ground shaking, liquefaction, landslides, or other ground failure, and from other hazards caused by earthquakes. This act requires the State Geologist to delineate various seismic hazard zones and requires cities, counties, and other local permitting agencies to regulate certain development projects within these zones. Before a development permit is granted for a site within a seismic hazard zone, a geotechnical investigation must be conducted and appropriate mitigation measures incorporated into the project's design. The California Geological Survey has not at this time completed seismic hazard mapping within any of the North San Pablo Bay topographic quadrangles.

## Local

The local general plans, policies, and regulations associated with impacts to geology and soils within the affected jurisdictions are presented in **Appendix 3.1** of this EIR/EIS.

# 3.1.3 Environmental Consequences/ Impacts

## Significance Criteria under CEQA

### *Geology, Soils, and Seismicity*

Based on the Appendix G of the CEQA Guidelines, project implementation would have significant impacts and environmental consequences related to geology, soils, and seismicity if it would:

- Expose people or structures to potential substantial adverse effects, including risk of loss, injury, or death involving earthquake rupture, strong seismic ground shaking, seismic related ground failure including liquefaction, and landslides;
- Result in substantial soil erosion or the loss of topsoil;
- Be located on a geologic unit or soil that is unstable that could potentially result in landslide, lateral spreading, subsidence, liquefaction or collapse; or
- Be located on expansive soil creating substantial risks to life or property.

### *Mineral Resources*

For this EIR, a project is considered to have a significant impact related to mineral resources if it would:

- 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.

Based on the NBWRP characteristics and existing conditions of the action area, there is no potential for the project to result in the loss of mineral resources. The NBWRP would largely consist of the construction of various pipelines which would mostly occur within existing roadways. The improvements to the WWTPs and construction of pump stations and storage facilities would occur either within or immediately adjacent to existing facilities and would not interfere with the availability of any known mineral resources. Therefore, no impact is expected and this issue is not discussed further.

## Environmental Consequences/Impact Analysis

**Impact 3.1.1: Seismicity. In the event of a major earthquake in the Bay Area Region, the proposed facilities could be subject to fault rupture, severe ground shaking, liquefaction, or earthquake induced landslides capable of causing injury, structural damage, pipeline rupture and service interruption. (Less than Significant with Mitigation)**

The NBWRP would include new construction, modification, and expansion of existing facilities. The proposed facilities would extend over a range of geologic materials and environments from saturated, unconsolidated Bay mud deposits of the Bay shore to bedrock deposits as described above in the setting section. According to the California Working Group on Earthquake Probabilities, a major earthquake, defined as being a magnitude 6.7 M or greater, has a 63 percent probability of occurring some time over the next 30 years. Seismic effects such as landslides, ground shaking, and liquefaction could vary depending on underlying geologic materials and conditions and distance to the epicenter of the seismic event.

### *No Project Alternative*

The NBWRP would not be implemented under the No Project Alternative, therefore no impact would occur. For a discussion of the No Project under future conditions, see No Action Alternative below.

### *No Action Alternative*

Under the No Action Alternative, which includes consideration of future conditions, it is likely that a subset of water recycling projects would be implemented by the Member Agencies on an individual basis, without the benefit of regional coordination or federal funding.

For comparison to the Action Alternatives, it is estimated that approximately 17.5 miles of new pipeline, 912 horsepower (HP) of pumping capacity, treatment facilities providing 0.5 million gallons per day (mgd) of tertiary capacity, and approximately 65 AF of storage would be constructed by Member Agencies on an individual basis (see **Chart 3.1-1, No Action**).

Under future baseline (2020) conditions, geologic conditions within the region would be unchanged from existing conditions. Proposed facilities would be subject to the seismic hazards. However implementation of **Mitigation Measure 3.1.1**, which includes designing the proposed facilities by a California licensed geotechnical engineer or engineering geologist and constructing according to California Building Code (CBC) and industry standard geotechnical practices, would reduce the impact to less-than-significant-level. A discussion of individual Member Agencies is provided below.

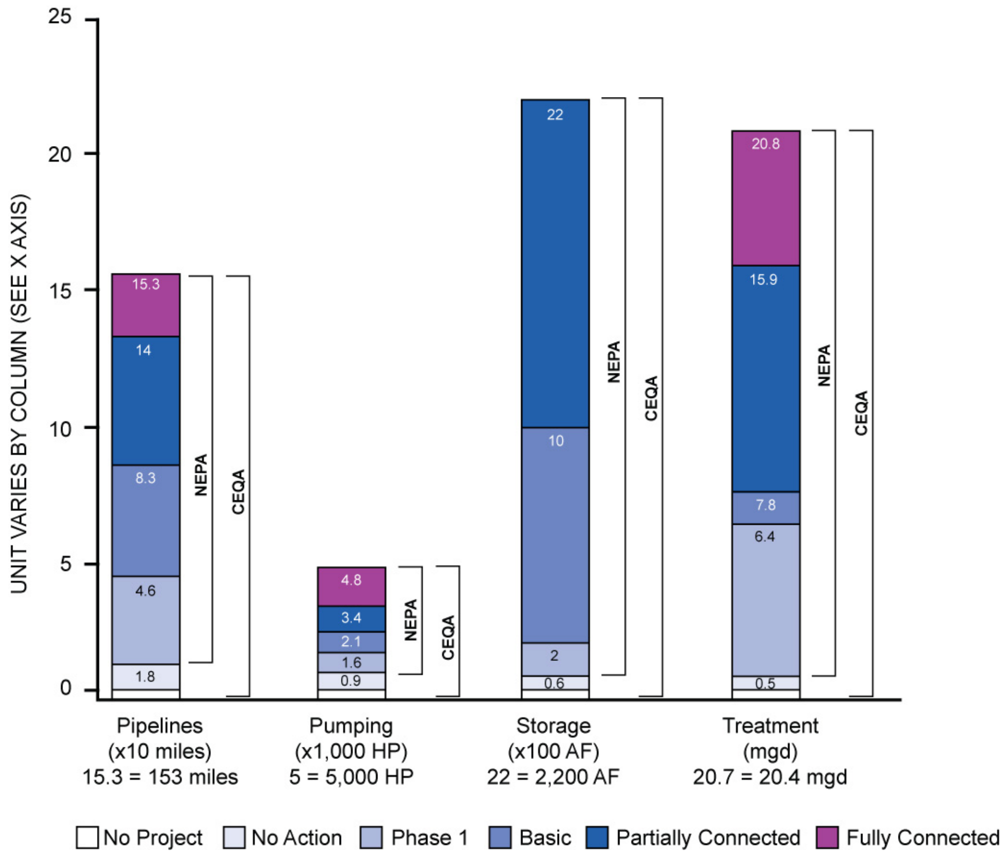
#### LGVSD/ NMWD

There would be no project facilities constructed under the No Action Alternative, therefore no impact would occur.

#### Novato SD/ NMWD

Under the No Action Alternative, recycled water facilities would be implemented in the Novato North Service Area. The majority of the proposed facilities (treatment upgrades, pipeline, storage, and pump station) would not be located within or near any active faults that would be susceptible to fault rupture; however the Novato SD/ NMWD pipeline near Atherton Avenue and Olive Avenue would potentially be located within 100 feet of the Burdell Mountain fault zone. Pipelines crossing active fault zones would have the potential for pipeline rupture and release of recycled water. Structural design measures at fault crossings, as required in **Mitigation Measure 3.1.1**, would reduce potential impacts to a less-than-significant level. In addition, the relatively flat topography

**CHART 3.1-1**
**COMPARISON OF NEPA AND CEQA BASELINES FOR PROPOSED FACILITIES, BY ALTERNATIVE**




SOURCE: CDM, 2009

would make the earthquake-induced landslide potential very low. According to Association of Bay Area Governments (ABAG), the ground shaking potential is moderate to high (ABAG, 2003). In general the higher potential for ground shaking is found east of U.S. 101 and the moderate potential is west of U.S. 101.

The liquefaction potential varies from very low to high within the Novato SD project service area (ABAG, 2004). As a result, some of the proposed pipelines would be located in areas considered to have a high potential for liquefaction, as shown in Figure 3.1-2. However, as discussed above, implementation of **Mitigation Measure 3.1.1** would reduce the impact to less-than-significant level.

### SVCSD

The No Action Alternative would include installation of Alignment 1A (5.2 miles of pipeline) in Sonoma Valley and one booster pump station at the SVCSD WWTP. Installation of the Alignment 1A pipeline would predominantly occur along existing roadways and additional storage and pumping capacities would occur within or adjacent to the existing WWTPs.

According to the Sonoma Valley Recycled Water Project (SVRWP) EIR (ESA, 2006), the proposed facilities would not be located within close proximity of an active fault where surface fault rupture would be considered a hazard and the relatively flat topography makes the potential for earthquake induced landslides also very low. In addition, the EIR similarly identified the regional seismic hazard, which could be a significant impact. However implementation of **Mitigation Measure 3.1.1** would reduce the impact to less-than-significant-level.

Under the No Action Alternative, the Napa Salt Marsh Restoration Project would include construction of pipeline parallel to an existing pipeline that extends between SVCSD WWTP and the SVCSD storage ponds located near the intersection of Northwestern Pacific Railroad and Ramal Road. From the ponds, additional new pipeline would be constructed to convey water to the salt pond mixing chamber in one of three alternative pipeline routes (see **Chapter 2, Project Description**).

Installation of the Napa Salt Marsh pipeline (under Options A, B, or C) would occur mostly in existing roadways and access roads. The proposed facilities would not be proximate to an active fault where surface fault rupture would be considered a hazard and the relatively flat topography makes the potential for earthquake induced landslides also very low. The facility could be exposed to regional seismic hazard, which could be a significant impact. However implementation of **Mitigation Measure 3.1.1** would reduce the impact to less-than-significant-level.

#### Napa SD

There would be no project facilities constructed under the No Action Alternative, therefore no impact would occur.

### *Phase 1 (Project level)*

Compared to the CEQA Baseline Phase 1 projects would provide 46 miles of new pipeline, 1,655 HP of pumping capacity, treatment facilities providing 6.4 mgd of tertiary capacity, and 65 AF of storage. Compared to the No Action Alternative (NEPA Baseline), Phase 1 projects would provide 28 miles of new pipeline, 743 HP of pumping capacity, treatment facilities providing 5.9 mgd of tertiary capacity, and no additional storage.

The geologic impacts to proposed facilities under Phase 1 would be equivalent to and greater than the impacts discussed for the No Action Alternative, in proportion to the facilities constructed under this alternative. A discussion of impacts by Member Agency is provided below. **Table 3.1-3** summarizes the amount of Phase 1 pipelines that would potentially be affected by seismic events, liquefaction, or landslides.

#### LGVSD/ NMWD

Implementation of Phase 1 would require construction of one of the three pipeline options, described in **Chapter 2, Project Description**, which would connect the Recycled Water Treatment Facility (RWTF) at LGVSD WWTP to the Hamilton Field area and the existing 0.5-million gallon (MG) Reservoir Hill Tank.

**TABLE 3.1-3**
**SUMMARY OF PHASE 1 PIPELINES POTENTIALLY AFFECTED BY LANDSLIDES LIQUEFACTION, OR SEISMIC EVENTS**

| Service Area | Amount of Pipeline (miles) within 100 ft of landslide areas | Amount of Pipeline (miles) within 100 ft of very high or moderate liquefaction areas | Amount of Pipeline (miles) within 100 ft of faults/ Fault Name |
|---|---|---|---|
| LGVSD | -- | -- | -- |
| Novato SD | 0.484 | 23 | 0.015/ Burdell Mountain Fault |
| SVCSD | -- | -- | -- |
| Napa SD | -- | -- | -- |

SOURCE: ESA, 2009

Installation of the pipelines for the Coast Guard Housing Distribution Loop would occur predominantly along existing roadways. Pipeline Options A, B, and C are proposed primarily along open, undeveloped areas. None of these proposed pipeline routes are located within or in the immediate vicinity of any active fault, therefore the potential for surface fault rupture to affect these pipelines is considered very low. These pipelines are also located in the flatlands that are not typically susceptible to earthquake induced landslides (ABAG, 1997). However, according to shaking potential maps compiled by the ABAG, which is derived from a probabilistic seismic hazard map produced by the California Geological Survey (CGS), the proposed pipelines are located in an area that is mapped as “near major, active faults that will on average experience stronger earthquake shaking more frequently” (ABAG, 2003). In general, the completion of pipelines within compacted engineered fill makes them less susceptible to damage from ground shaking alone. However, the secondary seismic effects such as ground displacement from liquefaction can be more damaging to pipelines.

As illustrated in **Figure 3.1-2**, the proposed pipelines in this area would be located in areas mapped as having high to very high susceptibility to liquefaction, according to ABAG (ABAG, 2004). The project facilities have a potential for damage related to ground shaking and ground failure such as liquefaction, which would be a significant impact. Implementation of **Mitigation Measure 3.1.1** would minimize the impact. Therefore, the potential impact from strong seismic ground shaking or seismic-related ground failure, including liquefaction and landslides, would be less than significant. As compared to the No Action Alternative, the impact would be greater under Phase 1 and would be proportional to the new proposed facilities.

### Novato SD/NMWD

The Phase 1 improvements for the Novato Central service area would include additional recycled pipelines. Please refer to the impacts discussed for the No Action Alternative above. Incorporation of **Mitigation Measure 3.1.1** would reduce the potential rupture impact to a less-than-significant. As compared to the No Action Alternative, the impact would be equivalent to and greater under Phase 1 and would be proportional to the additional facilities.

#### SVCSD

The Phase 1 plan for SVCSD includes elements of the SVRWP, such as 5.2 miles of proposed new pipelines, additional storage at the WWTP, and construction of additional pumping capacity for distribution. The Napa Salt Marsh Restoration Project would also be implemented including installation of one of the three options of proposed pipelines (approximately 8 miles), and installation of a new pump station at the reservoirs. The impacts would be similar to those discussed above under Novato SD and would be less than significant. As compared to the No Action Alternative, the impact would be equivalent to and greater under Phase 1 and would be proportional to the additional facilities.

#### Napa SD

A total of 17.5 miles of new pipeline and four booster pump stations would be constructed under Phase 1 for Napa SD although a smaller local project may become the preferred option. The local project would include a more direct pipeline system extending north from Imola Avenue and ending at the Napa Valley Country Club, with a second option following North Avenue and North 3rd Avenue. All of these options have similar ranges of seismic related hazards. No active faults are located within the immediate vicinity of any of the NBWRP elements for Phase 1. The Phase 1 facilities are located in relatively flat areas that would not be subject to the effects of earthquake-induced landslides. In addition, the Phase 1 facilities are located within areas that have relatively moderate potential for groundshaking (ABAG, 2003). The liquefaction potential would generally be low, however there are areas, typically those adjacent to surface waters, where the liquefaction potential is high (ABAG, 2004). However, as discussed above implementation of **Mitigation Measure 3.1.1** would reduce the impact to less-than-significant level. As compared to the No Action Alternative, the impact would be equivalent to and greater under Phase 1 and would be proportional to the additional facilities.

### *Alternative 1: Basic System (Program level)*

Compared to the CEQA Baseline, the Basic System projects would provide 83 miles of new pipeline, 2,158 HP of pumping capacity, treatment facilities providing 7.8 mgd of tertiary capacity, and 1,020 AF of storage. Compared to the No Action Alternative (NEPA Baseline), Basic System would provide 65 miles of new pipeline, 1,246 HP of pumping capacity, treatment facilities providing 7.3 mgd of tertiary capacity, and 955 AF of storage.

The geologic impacts to proposed facilities under the Basic System would be equivalent to and greater than the impacts discussed for Phase 1, in proportion to the facilities constructed under this alternative. A discussion of impacts by Member Agency is provided below.

#### LGVSD/ NMWD, Novato SD/ NMWD, SVCSD

The impacts associated with the Basic System would, in general, be equivalent to the impacts discussed for Phase 1 above. The Basic System would include the construction of additional facilities and that would result in an overall increased potential for impacts related to seismic activity. The additional pipelines and facilities required to provide the increased delivery of recycled water, interconnectivity between the SVSCD and Napa SD, and increased treatment capacities at LGVSD, Novato SD, and Napa SD would be constructed to the same standards as discussed under Phase 1. The additional facilities are similarly not located within areas susceptible to fault rupture or earthquake-induced landslides. The impacts would be similar to those discussed under the Basic System and would apply to the additional components. Despite the potential for seismic hazards such as severe ground shaking and liquefaction, the incorporation of **Mitigation Measure 3.1.1** for the additional facilities would have a less-than-significant impact for all the service areas under the Basic System. As compared to the No Action Alternative, the impact would be greater in the case of LGVSD than other Member Agencies and proportional to the additional facilities under the Basic System.

### Napa SD

The majority of the proposed facilities (treatment upgrades, pipeline, storage, and pump station) would not be located within or near any active faults that would be susceptible to fault rupture; however the Carneros East pipeline and portions of the Napa Salt Marsh pipeline would potentially be located within 100 feet of the West Napa fault zone. Pipelines crossing active fault zones would have the potential for pipeline rupture and release of recycled water. Structural design measures at fault crossings, as required in **Mitigation Measure 3.1.1**, would reduce potential impacts to a less-than-significant level.

## *Alternative 2: Partially Connected System (Program level)*

Compared to the CEQA Baseline, the Partially Connected System would provide 139 miles of new pipeline, 3,454 HP of pumping capacity, treatment facilities providing 15.9 mgd of tertiary capacity, and 2,220 AF of storage. Compared to the No Action Alternative (NEPA Baseline), the Partially Connected System would provide 122 miles of new pipeline, 2, 542 HP of pumping capacity, treatment facilities providing 15.4 mgd of tertiary capacity, and 2,155 AF of storage.

The geologic impacts to proposed facilities under the Partially Connected System would be equivalent to and greater than the impacts discussed for the Basic System, in proportion to the facilities constructed under this alternative. A discussion of impacts by Member Agency is provided below.

#### LGVSD/ NMWD, Novato SD/ NMWD, Napa SD

The Partially Connected System would include all of the facilities described under the Basic System in addition to delivery of recycled water to the Peacock Gap Golf Course, interconnectivity between Novato SD and LGVSD to serve the Sears Point Area, additional pipelines and facilities within Novato SD, and additional facilities within Napa SD. The Partially Connected System would require the construction of additional facilities over a range of geologic materials which would be susceptible to seismic hazards such as ground shaking and, in some areas, liquefaction. The proposed additional facilities would not be located within areas that are susceptible to fault rupture or earthquake-induced landslides (Jennings, 1994 and ABAG, 1997). The impacts would be similar to those discussed under the Basic System and would apply to the additional components. Incorporation of **Mitigation Measure 3.1.1** for the additional facilities would reduce impacts to less than significant. As compared to the No Action Alternative, the impact would be greater for all the

Member Agencies and proportional to the additional facilities under the Partially Connected System.

#### SVCSD

The majority of the proposed facilities (treatment upgrades, pipeline, storage, and pump station) would not be located within or near any active faults that would be susceptible to fault rupture; however portions of the Sears Point pipeline would potentially be located within 100 feet of the Rodgers Creek fault zone and the Tolay fault zone. Pipelines crossing active fault zones would have the potential for pipeline rupture and release of recycled water. Structural design measures at fault crossings, as required in **Mitigation Measure 3.1.1**, would reduce potential impacts to a less-than-significant level.

### *Alternative 3: Fully Connected System (Program level)*

Compared to the CEQA Baseline, the Fully Connected System would provide 153 miles of new pipeline, 5,021 HP of pumping capacity, treatment facilities providing 20.8 mgd of tertiary capacity, and 2,220 AF of storage. Compared to the No Action Alternative (NEPA Baseline), the Fully Connected System would provide 135 miles of new pipeline, 3, 907 HP of pumping capacity, treatment facilities providing 20.3 mgd of tertiary capacity, and 2,155 AF of storage.

The geologic impacts under the Fully Connected System would be equivalent to and greater than the impacts discussed for the Partially Connected System, in proportion to the facilities constructed under this alternative. A discussion of impacts by Member Agency is provided below.

#### LGVSD/ NMWD, Novato SD/ NMWD, SVCSD, Napa SD

The Fully Connected System would result in the impacts equivalent to those discussed under the Partially Connected System in addition to the impacts associated with the additional components proposed under the Fully Connected System. The impacts would be similar to those discussed under the Partially Connected System and would apply to the additional components. Incorporation of **Mitigation Measure 3.1.1** for the additional facilities would have a less-than-significant impact for all the service areas. As compared to the No Action Alternative, the impact would be greater for all the Member Agencies and proportional to the additional facilities under the Fully Connected System.

### *Mitigation Measures*

**Mitigation Measure 3.1.1:** The Member Agencies will implement the following measures:

- All proposed improvements will be designed and constructed in accordance with current geotechnical industry standard criteria, including the California Building Code (CBC) and American Waterworks Association (AWWA) criteria.
- The project construction materials and backfill materials will be designed according to a geotechnical investigation by a California-licensed geotechnical engineer or

engineering geologist to address landslide, subsidence, liquefaction, and expansive soils and seismic hazards such as ground shaking and liquefaction.

- Implementation of industry standard geotechnical measures such as replacing excavated soils with engineered fill materials are effective means to overcome the potential for subsidence. If excavated soils are to be reused for backfill, they would still be appropriately compacted to mitigate the potential for subsidence or settlement and evaluated for expansion and amended, if necessary, to reduce the potential for expansion in accordance with accepted geotechnical practices.

- Proposed facilities will be designed to include flexible connections, where deemed necessary, along with backfill requirements that minimize the potential for significant damage. All other associated improvements will employ standard design and construction using the most recent geotechnical practices and California Building Code (CBC) seismic criteria, which would provide conservative design criteria.

**Impact Significance after Mitigation:** Less than Significant.

---

**Impact 3.1.2: Erosion. Project construction activities could result in short-term erosion and loss of topsoils. (Less than Significant with Mitigation)**

Construction for the NBWRP would require significant ground disturbing activities that include excavation, stockpiling removed soils, and placement of imported fill materials or reuse of excavated soils. Construction of the pipelines would primarily use the open-trench and/or trenchless techniques, which would involve excavation of existing soils and stockpiling them in dedicated areas. If not managed correctly, the soils disturbed by project earthwork and construction activities as well as stockpiled materials for use in the construction would be susceptible to the effects of wind or water induced erosion and loss of topsoil. However, the NBWRP would be required to prepare a Storm Water Pollution Prevention Plan (SWPPP) that would include best management practices (BMPs) that are designed to minimize the potential for erosion and sedimentation of stormwater runoff. The SWPPP will be consistent with Regional Water Board requirements. Treatment upgrades within the existing WWTPs could include groundbreaking activities and therefore could be susceptible to erosion or loss of topsoil; however BMPs defined in **Mitigation Measure 3.1.2** would minimize impacts from erosion on topsoil.

### *No Project Alternative*

The NBWRP would not be implemented under the No Project Alternative, therefore no impact associated with erosion and loss of topsoils would occur. For a discussion of the No Project under future conditions, see No Action Alternative below.

### *No Action Alternative*

Under the No Action Alternative, which includes consideration of future conditions, it is likely that a subset of water recycling projects would be implemented by the Member Agencies on an individual basis, without the benefit of regional coordination or federal funding. Future baseline conditions (2020) for erosion and sedimentation are assumed to be equivalent to current conditions.

For comparison to the Action Alternatives, it is estimated that approximately 17.5 miles of new pipeline, 912 HP of pumping capacity, treatment facilities providing 0.5 mgd of tertiary capacity, and approximately 65 AF of storage would be constructed by Member Agencies on an individual basis.

#### LGVSD/ NMWD

There would be no project facilities constructed under the No Action Alternative, therefore no impact associated with erosion and loss of topsoils would occur.

#### Novato SD/ NMWD

Under the No Action Alternative, recycled water facilities would be implemented in the Novato North Service Area to provide service to Stone Tree Golf Course, large commercial/ industrial campuses, and Valley Memorial Park Cemetery. Installation of the proposed pipelines would predominantly occur along existing roadways and additional storage and pumping capacities would occur within or adjacent to the existing WWTP facilities. Soils along these roadways may or may not contain native topsoils and may be comprised of engineered fill associated with the construction of the roadway. Refer to the discussion under No Action Alternative. BMPs would be installed including erosion control measures such as covering stockpiles, use of straw bales, silt fences, etc. that would minimize the potential for erosion and loss of topsoils. As required by **Mitigation Measure 3.1.2** below, the NBWRP would be required to prepare a SWPPP that would include BMPs that are designed to minimize the potential for erosion and sedimentation of stormwater runoff. Implementation of these BMPs, as required by **Mitigation Measure 3.1.2**, would reduce the potential for erosion and loss of topsoil to less-than-significant levels.

#### SVCSD

Under the No Action Alternative, Alignment 1A (5.2 miles of pipeline) of the Sonoma Valley Recycled Water Project (SVRWP) would be implemented, as well as one of three alternative pipeline routes for the Napa Salt Marsh Restoration Project (see **Chapter 2, Project Description**).

The impacts would be similar to construction effects described above for facilities within Novato SD service area, and would apply to the additional components. The impact would be less than significant with implementation of **Mitigation Measure 3.1.2**.

#### Napa SD

There would be no project facilities constructed under the No Action Alternative, therefore no impact associated with erosion and loss of topsoils would occur.

### *Phase 1 (Project level)*

Compared to the CEQA Baseline, Phase 1 projects would provide 46 miles of new pipeline, 1,655 HP of pumping capacity, treatment facilities providing 6.4 mgd of tertiary capacity, and 65 AF of storage. Compared to the No Action Alternative (NEPA Baseline), Phase 1 projects would provide 28 miles of new pipeline, 743 HP of pumping capacity, treatment facilities providing 5.9 mgd of tertiary capacity, and no additional storage.

The erosion impact to under Phase 1 would be equivalent to and greater than the impacts discussed for the No Action Alternative, in proportion to the facilities under this alternative. A discussion of impacts by Member Agency is provided below.

#### LGVSD/ NMWD

Implementation of Phase 1 would require construction of one of three pipeline options, described in **Chapter 2, Project Description**, from the RWTF at LGVSD WWTP to the Hamilton Field area and Reservoir Hill Tank, as well as an additional booster pump station.

Installation of these pipelines for the Coast Guard Housing Distribution Loop System would occur predominantly along existing roadways, while pipelines for Options A, B, and C would occur primarily along open undeveloped areas. Soils along these roadways may or may not contain native topsoils and may be comprised of engineered fill associated with the construction of the roadway. However, under Option C, a total of 5.9 miles of pipeline would be installed using open trench methods of construction. In general, the construction of pipelines using open trench methods includes BMPs that include erosion control measures such as covering stockpiles, use of straw bales, silt fences, etc. that minimize the potential for erosion and loss of topsoils. As required by **Mitigation Measure 3.1.2** below, the NBWRP would be required to prepare a SWPPP that would include BMPs that are designed to minimize the potential for erosion and sedimentation of stormwater runoff. Implementation of these BMPs, as required by **Mitigation Measure 3.1.2,** would reduce the potential for erosion and loss of topsoil to less-than-significant levels for the additional facilities. As compared to the No Action Alternative, the impact would be greater under Phase 1 and would be proportional to the new proposed facilities.

#### Novato SD/NMWD

The impacts would be similar to those discussed under No Action Alternative in addition to the impacts in the Novato Central Service Area. The impacts under Phase 1 would be similar to those discussed above and would apply to the additional components. The impact would be less than significant with implementation of **Mitigation Measure 3.1.2** for the additional facilities. As compared to the No Action Alternative, the impact would be greater under Phase 1 and would be proportional to the additional facilities.

#### SVCSD

Please refer to the discussion under the No Action Alternative. The impacts would be similar to those discussed above and would apply to the additional components and occur in the larger SVRWP area in addition to the Alignment 1A route. Impacts under Phase 1 for the Napa Salt

Marsh Restoration Project would be equivalent to those under the No Action Alternative. The impact would be less than significant with implementation of **Mitigation Measure 3.1.2**. As compared to the No Action Alternative, the impact would be greater under Phase 1 and would be proportional to the additional facilities.

#### Napa SD

Phase 1 requires 17.5 miles of pipeline, which would occur predominantly along existing roadways, Soils along these roadways may or may not contain native topsoils and may be comprised of engineered fill associated with the construction of the roadway. In general, the construction of pipelines using open trench methods includes BMPs that include erosion control measures such as covering stockpiles, use of straw bales, silt fences, etc. that minimize the potential for erosion and loss of topsoils. As required by **Mitigation Measure 3.1.2** below, the NBWRP would be required to prepare a SWPPP that would include BMPs that are designed to minimize the potential for erosion and sedimentation of stormwater runoff. Implementation of these BMPs, as required by **Mitigation Measure 3.1.2,** would reduce the potential for erosion and loss of topsoil to less-than-significant levels for the additional facilities. As compared to the No Action Alternative, the impact would be greater under Phase 1 and would be proportional to the additional facilities.

### *Alternative 1: Basic System (Program level)*

Compared to the CEQA Baseline, the Basic System projects would provide 83 miles of new pipeline, 2,158 HP of pumping capacity, treatment facilities providing 7.8 mgd of tertiary capacity, and 1,020 AF of storage. Compared to the No Action Alternative (NEPA Baseline), Basic System would provide 65 miles of new pipeline, 1,246 HP of pumping capacity, treatment facilities providing 7.3 mgd of tertiary capacity, and 955 AF of storage.

The geologic impacts under the Basic System would be equivalent to and greater than the impacts discussed for the No Action Alternative, in proportion to the facilities constructed under this alternative. A discussion of impacts by Member Agency is provided below.

#### LGVSD/NMWD, Novato SD/NMWD, SVCSD, Napa SD

The impacts associated with the Basic System would, in general, be equivalent to the impacts discussed for Phase 1 above and would apply to the additional components. The Basic System would include the construction of additional facilities and that would result in an overall increased potential for erosion and loss of topsoil. However, **Mitigation Measure 3.1.2** would apply to the additional components under the Basic System, therefore the impact would be less than significant impact. As compared to the No Action Alternative, the impact would be greater under the Basic System and would be proportional to the additional facilities.

### *Alternative 2: Partially Connected System (Program level)*

Compared to the CEQA Baseline, the Partially Connected System would provide 139 miles of new pipeline, 3,454 HP of pumping capacity, treatment facilities providing 15.9 mgd of tertiary capacity, and 2,220 AF of storage. Compared to the No Action Alternative (NEPA Baseline), the

Partially Connected System would provide 122 miles of new pipeline, 2, 542 HP of pumping capacity, treatment facilities providing 15.4 mgd of tertiary capacity, and 2,155 AF of storage.

The geologic impacts under the Partially Connected System would be equivalent to and greater than the impacts discussed for the No Action Alternative, in proportion to the facilities constructed under this alternative. A discussion of impacts by Member Agency is provided below.

#### LGVSD/NMWD, Novato SD/NMWD, SVCSD, Napa SD

The Partially Connected System would include all of the facilities described under the Basic System in addition to facilities for delivery of recycled water to the Peacock Gap Golf Course, interconnectivity between Novato SD and LGVSD to serve the Sears Point Area, additional pipelines and facilities within Novato SD, and additional facilities within Napa SD. The impacts would be similar to those discussed under the Basic System and would apply to the additional components. Implementation of **Mitigation Measure 3.1.2** for the additional facilities would have a less than significant impact. As compared to the No Action Alternative, the impact would be greater under the Partially Connected System and would be proportional to the additional facilities.

### *Alternative 3: Fully Connected System (Program level)*

Compared to the CEQA Baseline, the Fully Connected System would provide 153 miles of new pipeline, 5,021 HP of pumping capacity, treatment facilities providing 20.8 mgd of tertiary capacity, and 2,220 AF of storage. Compared to the No Action Alternative (NEPA Baseline), the Fully Connected System would provide 135 miles of new pipeline, 3, 907 HP of pumping capacity, treatment facilities providing 20.3 mgd of tertiary capacity, and 2,155 AF of storage.

The geologic impacts to proposed facilities under Phase 1 would be equivalent to and greater than the impacts discussed for the No Action Alternative, in proportion to the facilities constructed under this alternative. A discussion of impacts by Member Agency is provided below.

#### LGVSD/NMWD, Novato SD/NMWD, SVCSD, Napa SD

The Fully Connected System would require the most construction as compared to the other alternatives. Considering the additional facilities under this alternative, there is an increased potential for erosion and loss of topsoil, if not managed appropriately. The impacts would be similar to those discussed above and would apply to the additional components. The impact would be less than significant with implementation of **Mitigation Measure 3.1.2** for the additional facilities. As compared to the No Action Alternative, the impact would be greater under the Fully Connected System and would be proportional to the additional facilities.

### *Mitigation Measures*

**Mitigation Measure 3.1.2:** The Member Agencies will implement the following measures:

- Consistent with SWPPP requirements, the construction contractor shall be required to implement BMPs for erosion control onsite. The use of construction BMPs will minimize the potential for erosion and loss of topsoil, and shall include, without limitation, the following:

- Avoid scheduling construction activities during a rain event, but be prepared for sudden changes in conditions;
- Construct berms, silt fences, straw bales, fiber rolls, and/or sand bags around stockpiled soils;
- Cover stockpiled soils during a rain event and monitor perimeter barriers, repair as necessary;
- Stabilize entrances to work area to prevent tracking of dirt or mud onto roadways; and
- Implement dust control practices as appropriate on all stockpiled material.

**Impact Significance after Mitigation:** Less than Significant.

---

**Impact 3.1.3: Unstable Soils. Project improvements could be located on a geologic unit or soil that is unstable that could potentially result in landslide, lateral spreading, subsidence, liquefaction or collapse causing damage to structures and service disruptions. (Less than Significant)**

The proposed facilities for all service areas would cover a range of geologic materials that have varying geotechnical engineering properties. In general, the proposed facilities are not located in areas that are susceptible to landslides. As discussed above, the majority of improvements would be located along existing roadways or within or near existing WWTPs that have been previously graded or are in relatively flat locations. In addition, the potential for earthquake-induced landslides is discussed above in Impact 3.1.1, and found to be less than significant. Therefore, the potential impact of landslides is not discussed further in this impact analysis.

Lateral spreading is a secondary effect related to seismicity and liquefaction. As such, the discussion of liquefaction is found in Impact 3.1.1, above, and would apply to the potential for lateral spreading. The use of geotechnical engineering practices and findings through **Mitigation Measure 3.1.1** to mitigate the potential for liquefaction would reduce the potential for lateral spreading to less-than-significant levels. Collapse of subsurface soils or geologic units is not typically associated with materials in this region. Collapsible soils are most often encountered in arid climates, where wind and intermittent streams deposit loose low-density materials. When placed under new loading or the addition of water that reaches deeper than under normal conditions, these soils can collapse causing structural damage. However, these conditions or soils are not found in the action area and therefore there is no potential for collapsible soils and it is not discussed further in this section.

Some of the proposed pipeline routes are located relatively close to the Bay shore areas that contain marsh and intertidal deposits that are generally soft and compressible. Placement of additional loads to these soils, if not engineered appropriately, could result in subsidence or settlement that can damage structures and appurtenances. Therefore, the following discussion focuses on the potential for subsidence and settlement to impact from the NBWRP and alternatives.

### *No Project Alternative*

No project components would be implemented under the No Project Alternative. No impact associated with unstable soils and specifically with subsidence would occur. For a discussion of the No Project under future conditions, see No Action Alternative below.

### *No Action Alternative*

Under the No Action Alternative, which includes consideration of future conditions, it is likely that a subset of water recycling projects would be implemented by the Member Agencies on an individual basis, without the benefit of regional coordination or federal funding.

For comparison to the Action Alternatives, it is estimated that approximately 17.5 miles of new pipeline, 912 HP of pumping capacity, treatment facilities providing 0.5 mgd of tertiary capacity, and approximately 65 AF of storage would be constructed by Member Agencies on an individual basis (see Chart 3.1-1, No Action Alternative).

Under future baseline (2020) conditions, geologic conditions within the region would be unchanged from existing conditions. Proposed facilities would be subject to unstable soils. However implementation of **Mitigation Measure 3.1.1**, which includes designing the proposed facilities by a California licensed geotechnical engineer or engineering geologist and constructing according to CBC and industry standard geotechnical practices, would reduce the impact to less-than-significant-level. A discussion of individual Member Agencies is provided below.

#### LGVSD/NMWD

There would be no project facilities constructed under the No Action Alternative, therefore no impact associated with unstable soils and specifically with subsidence would occur.

#### Novato SD/NMWD

Under the No Action Alternative, recycled water facilities would be implemented in the Novato North Service Area to provide service to Stone Tree Golf Course, Fireman's Fund Campus, and Valley Memorial Park Cemetery. The proposed pipelines routes include a variety of different soil types including Reyes clays, Tocaloma-McMullin series, Los Osos soils, and urban land complex soils. Please refer to the discussion above. The potential impact for subsidence would be less than significant with incorporation of **Mitigation Measure 3.1.1**.

#### SVCSD

Under the No Action Alternative, Alignment 1A of the SVRWP and the Napa Salt Marsh Restoration Project would be implemented. Soils in the SVCSD area primarily include the Huichica-Wright-Zamora Association**.** These soils are generally comprised of nearly-level to moderately-sloping soils that are well drained to excessively-drained loams to silty clay loams. The susceptibility to subsidence cannot be determined on information from the soil survey, however the inland location may be an indication that they may be less susceptible to subsidence than Bay shore deposits. Regardless, the roadways where the pipelines are proposed have likely been sufficiently compacted to prevent subsidence. The potential impact for subsidence would be less than significant with incorporation of **Mitigation Measure 3.1.1**.

#### Napa SD

There would be no project facilities constructed under the No Action Alternative, therefore no impact associated with unstable soils and specifically with subsidence would occur.

### *Phase 1 (Project level)*

Compared to the CEQA Baseline Phase 1 projects would provide 46 miles of new pipeline, 1,655 HP of pumping capacity, treatment facilities providing 6.4 mgd of tertiary capacity, and 65 AF of storage. Compared to the No Action Alternative (NEPA Baseline), Phase 1 projects would provide 28 miles of new pipeline, 743 HP of pumping capacity, treatment facilities providing 5.9 mgd of tertiary capacity, and no additional storage.

The geologic impacts to proposed facilities under Phase 1 would be equivalent to and greater than the impacts discussed for the No Action Alternative, in proportion to the facilities constructed under this alternative. A discussion of impacts by Member Agency is provided below.

#### LGVSD/NMWD

Implementation of Phase 1 would require construction of one of three pipeline options, described in **Chapter 2, Project Description**, from the RWTF at LGVSD WWTP to the Hamilton Field area and Reservoir Hill Tank, as well as an additional booster pump station.

The underlying geologic materials in the area of the proposed pipeline options for Phase 1 include a Reyes clays and urban land complex soils (USDA, 2004). The Reyes clays, based on their close proximity to the Bay, likely consist of soft saturated sediments that are susceptible to subsidence if not engineered appropriately. The urban land complex soils could consist of artificial fill materials that have either been appropriately compacted or not. The roadways have likely been sufficiently compacted to prevent subsidence. Implementation of **Mitigation Measure 3.1.1** would minimize any potentially significant impact to the additional components. The impact would be less than significant.

#### Novato SD/NMWD

The impact would be similar to that discussed under No Action Alternative and would occur in the Novato Central Service Area. The potential impact for subsidence would be less than significant with incorporation of **Mitigation Measure 3.1.1**.

#### SVCSD

Refer to the impacts discussed above and under No Action Alternative. As discussed above, industry standard geotechnical measures and **Mitigation Measure 3.1.1** would overcome the potential for subsidence for the additional components. The impact would be less than significant.

#### Napa SD

Implementation of Phase 1 would require construction of 17.5 miles of pipeline and four booster pump stations. Soils in the area of the proposed pipeline route options for Phase 1 include a number of soil units which likely vary in their engineering characteristics. The potential impact for subsidence is then less than significant with incorporation of **Mitigation Measure 3.1.1**.

### *Alternative 1: Basic System (Program level)*

Compared to the CEQA Baseline, the Basic System projects would provide 83 miles of new pipeline, 2,158 HP of pumping capacity, treatment facilities providing 7.8 mgd of tertiary capacity, and 1,020 AF of storage. Compared to the No Action Alternative (NEPA Baseline), Basic System would provide 65 miles of new pipeline, 1,246 HP of pumping capacity, treatment facilities providing 7.3 mgd of tertiary capacity, and 955 AF of storage.

The geologic impacts to proposed facilities under Phase 1 would be equivalent to and greater than the impacts discussed for the No Action Alternative, in proportion to the facilities constructed under this alternative. A discussion of impacts by Member Agency is provided below.

#### LGVSD/NMWD, Novato SD/NMWD, SVCSD, Napa SD

The impacts associated with the Basic System would, in general, be equivalent to the impacts discussed for Phase 1 above. The Basic System would include the construction of additional facilities which could potentially result in an overall increased potential for subsidence. However, the additional pipelines and facilities required to provide the increased delivery of recycled water, interconnectivity between the SVSCD and Napa SD, and increased treatment capacities at LGVSD, Novato SD, and Napa SD would be constructed to the same standards as discussed under Phase 1. The impacts would be similar to that discussed above for the Member Agencies. The Basic System would have a less than significant impact with incorporation of **Mitigation Measure 3.1.1**.

### *Alternative 2: Partially Connected System (Program level)*

Compared to the CEQA Baseline, the Partially Connected System would provide 139 miles of new pipeline, 3,454 HP of pumping capacity, treatment facilities providing 15.9 mgd of tertiary capacity, and 2,220 AF of storage. Compared to the No Action Alternative (NEPA Baseline), the Partially Connected System would provide 122 miles of new pipeline, 2, 542 HP of pumping capacity, treatment facilities providing 15.4 mgd of tertiary capacity, and 2,155 AF of storage..

The geologic impacts to proposed facilities under Phase 1 would be equivalent to and greater than the impacts discussed for the No Action Alternative, in proportion to the facilities constructed under this alternative. A discussion of impacts by Member Agency is provided below.

#### LGVSD/NMWD, Novato SD/NMWD, SVCSD, Napa SD

The Partially Connected System would include all of the facilities described under the Basic System in addition to delivery of recycled water to the Peacock Gap Golf Course, interconnectivity between Novato SD and LGVSD to serve the Sears Point Area, additional pipelines and facilities within Novato SD, and additional facilities within Napa SD. The Partially Connected System would require the construction of additional facilities compared to Phase 1 above, and would therefore have an increased potential for subsidence. However, the additional pipelines and facilities would be constructed to the same standards as discussed under Phase 1 and the Basic System. The impact would be less than significant with incorporation of **Mitigation Measure 3.1.1**.

### *Alternative 3: Fully Connected System (Program level)*

Compared to the CEQA Baseline, the Fully Connected System would provide 153 miles of new pipeline, 5,021 HP of pumping capacity, treatment facilities providing 20.8 mgd of tertiary capacity, and 2,220 AF of storage. Compared to the No Action Alternative (NEPA Baseline), the Fully Connected System would provide 135 miles of new pipeline, 3, 907 HP of pumping capacity, treatment facilities providing 20.3 mgd of tertiary capacity, and 2,155 AF of storage.

The geologic impacts to proposed facilities under Phase 1 would be equivalent to and greater than the impacts discussed for the No Action Alternative, in proportion to the facilities constructed under this alternative. A discussion of impacts by Member Agency is provided below.

#### LGVSD/NMWD, Novato SD/NMWD, SVCSD, Napa SD

The Fully Connected System would require the most construction of new pipelines, additional tertiary treatment capacity, and storage facilities compared to the Partially Connected System. Considering the additional facilities under this alternative, there is an increased potential for subsidence, if not designed and engineered appropriately. However, the additional pipelines and facilities would be constructed to the same standards as discussed above. The impact would be less than significant with incorporation of **Mitigation Measure 3.1.1**.

---

**Impact 3.1.4: Expansive Soils. Project improvements could be located on expansive soils that over time could cause damage to foundations and pipelines resulting in service disruptions. (Less than Significant)**

The proposed facilities cover a range of soil types that have varying shrink-swell properties. In general, the proposed facilities would not be located in areas that are susceptible to landslides. As discussed above, the majority of improvements are located along existing roadways or within or near existing WWTPs that have been previously graded or are in relatively flat locations. The potential effects of expansive soils is often mitigated through the use of standard geotechnical engineering practices which routinely evaluate backfill soils and foundation soils for their expansion potential. If not engineered appropriately, any expansive soils left beneath proposed improvements could, over time, result in damage to structures or pipelines through cyclical changes in soil volumes from the shrink-swell characteristics of expansive soils. Typical geotechnical mitigation efforts include replacement of soils with engineered fills that have low expansion properties or the addition of soil treatments to existing soils that reduces the expansion potential.

### *No Project Alternative*

No project components would be implemented under the No Project Alternative. No impact associated with expansive soils would occur. For a discussion of the No Project under future conditions, see No Action Alternative below.

### *No Action Alternative*

Under the No Action Alternative, which includes consideration of future conditions, it is likely that a subset of water recycling projects would be implemented by the Member Agencies on an individual basis, without the benefit of regional coordination or federal funding.

For comparison to the Action Alternatives, it is estimated that approximately 17.5 miles of new pipeline, 912 HP of pumping capacity, treatment facilities providing 0.5 mgd of tertiary capacity, and approximately 65 AF of storage would be constructed by Member Agencies on an individual basis (see Chart 3.1-1).

Under future baseline (2020) conditions, geologic conditions within the region would be unchanged from existing conditions. Proposed facilities would be subject to the seismic hazards. However implementation of **Mitigation Measure 3.1.1**, which includes designing the proposed facilities by a California licensed geotechnical engineer or engineering geologist and constructing according to CBC and industry standard geotechnical practices, would reduce the impact to less-than-significant-level. A discussion of individual Member Agencies is provided below.

#### LGVSD/NMWD

There would be no project facilities constructed under the No Action Alternative, therefore no impact associated with expansive soils would occur.

#### Novato SD/NMWD

Under the No Action Alternative, recycled water facilities would be implemented in the Novato North Service Area to provide service to Stone Tree Golf Course, Fireman's Fund Campus, and Valley Memorial Park Cemetery. The proposed pipelines routes include a variety of different soil types including Reyes clays, Tocaloma-McMullin series, Los Osos soils, and urban land complex soils. These soils vary in their shrink-swell behaviors. The roadways where the pipelines are proposed have likely been backfilled with fills that have a low potential for expansion. However, the impact could be significant and implementation of **Mitigation Measure 3.1.1** would reduce the impact to less-than-significant.

#### SVCSD

The impacts under the No Action Alternative, would be associated with the Alignment 1A (5.2 miles of pipeline) of the SVRWP, as well as one of three alternatives for the Napa Salt Marsh Restoration Project. Soils in the SVCSD area of the proposed pipelines primarily include the Huichica-Wright-Zamora Association**.** These soils are generally comprised of nearly-level to moderately-sloping soils that are well drained to excessively-drained loams to silty clay loams. Their susceptibility to expansion cannot be determined on information from the soil survey, however they are primarily comprised of alluvial deposits that may or may not have the potential for expansion. The impact associated with expansive soils would be similar to that discussed under LGVSD above, and could be a significant impact. Incorporation of **Mitigation Measure 3.1.1** for the additional components would ensure a less than significant impact.

#### Napa SD

There would be no project facilities constructed under the No Action Alternative, therefore no impact associated with expansive soils would occur.

### *Phase 1 (Project level)*

Compared to the CEQA Baseline, Phase 1 projects would provide 46 miles of new pipeline, 1,655 HP of pumping capacity, treatment facilities providing 6.4 mgd of tertiary capacity, and 65 AF of storage. Compared to the No Action Alternative (NEPA Baseline), Phase 1 projects would provide 28 miles of new pipeline, 743 HP of pumping capacity, treatment facilities providing 5.9 mgd of tertiary capacity, and no additional storage.

The geologic impacts to proposed facilities under Phase 1 would be equivalent to and greater than the impacts discussed for the No Action Alternative, in proportion to the facilities constructed under this alternative. A discussion of impacts by Member Agency is provided below.

#### LGVSD/NMWD

Implementation of Phase 1 would require construction of one of three pipeline options, described in **Chapter 2, Project Description**, from the Recycled Water Treatment Facility at LGVSD WWTP to the Hamilton Field area and Reservoir Hill Tank, as well as an additional booster pump station.

Soils in the area of the proposed pipeline options for Phase 1 include a number of soil units vary in their shrink-swell potential. The Reyes clays have a high shrink-swell potential whereas the Tocaloma-McMullin series have low potential. The roadways where the Coast Guard Housing Distribution Loop pipelines are proposed have likely been backfilled with fills that have a low potential for expansion. However, there is a potential for a significant impact, which would be reduced by implementation of **Mitigation Measure 3.1.1** for the additional components. The impact would be less than significant.

#### Novato SD/NMWD

The impact would be similar to those discussed under LGVSD and would be less than significant with incorporation of **Mitigation Measure 3.1.1** for the additional components.

#### SVCSD

Please see the impacts discussed above. The impact would be less than significant with incorporation of **Mitigation Measure 3.1.1** for the additional components.

#### Napa SD

Implementation of Phase 1 would require construction of 17.5 miles of pipeline and four booster pump stations. Soils in the area of the proposed pipeline options for Phase 1 include a number of soil units, which likely vary in their shrink-swell potential. The impact would be less than significant with incorporation of **Mitigation Measure 3.1.1 for the additional components**.

### *Alternative 1: Basic System (Program level)*

Compared to the CEQA Baseline, the Basic System projects would provide 83 miles of new pipeline, 2,158 HP of pumping capacity, treatment facilities providing 7.8 mgd of tertiary capacity, and 1,020 AF of storage. Compared to the No Action Alternative (NEPA Baseline), Basic System would provide 65 miles of new pipeline, 1,246 HP of pumping capacity, treatment facilities providing 7.3 mgd of tertiary capacity, and 955 AF of storage.

The geologic impacts to proposed facilities under Phase 1 would be equivalent to and greater than the impacts discussed for the No Action Alternative, in proportion to the facilities constructed under this alternative. A discussion of impacts by Member Agency is provided below.

#### LGVSD/NMWD, Novato SD/NMWD, SVCSD, Napa SD

The impacts associated with the Basic System would, in general, be equivalent to the impacts discussed for Phase 1 above. The Basic System would include the construction of additional facilities which could potentially result in an overall increased potential for subsidence. However, the additional pipelines and facilities required to provide the increased delivery of recycled water, interconnectivity between the SVSCD and Napa SD, and increased treatment capacities at LGVSD, Novato SD, and Napa SD would be constructed to the same standards as discussed under Phase 1. Implementation of **Mitigation Measure 3.1.1** would ensure a less-than-significant impact for the additional components under the Basic System.

### *Alternative 2: Partially Connected System (Program level)*

Compared to the CEQA Baseline, the Partially Connected System would provide 139 miles of new pipeline, 3,454 HP of pumping capacity, treatment facilities providing 15.9 mgd of tertiary capacity, and 2,220 AF of storage. Compared to the No Action Alternative (NEPA Baseline), the Partially Connected System would provide 122 miles of new pipeline, 2, 542 HP of pumping capacity, treatment facilities providing 15.4 mgd of tertiary capacity, and 2,155 AF of storage.

The geologic impacts to proposed facilities under Phase 1 would be equivalent to and greater than the impacts discussed for the No Action Alternative, in proportion to the facilities constructed under this alternative. A discussion of impacts by Member Agency is provided below.

#### LGVSD/NMWD, Novato SD/NMWD, SVCSD, Napa SD

The Partially Connected System would include all of the facilities described under the Basic System in addition to delivery of recycled water to the Peacock Gap Golf Course, interconnectivity between Novato SD and LGVSD to serve the Sears Point Area, additional pipelines and facilities within Novato SD, and additional facilities within Napa SD. The Partially

Connected System would require the construction of additional facilities compared to Phase 1 above, and would therefore have an increased potential for subsidence. However, the additional pipelines and facilities would be constructed to the same standards as discussed under Phase 1. Implementation of **Mitigation Measure 3.1.1** would ensure a less-than-significant impact for the additional components under the Partially Connected System.

#### *Alternative 3: Fully Connected System (Program level)*

Compared to the CEQA Baseline, the Fully Connected System would provide 153 miles of new pipeline, 5,021 HP of pumping capacity, treatment facilities providing 20.8 mgd of tertiary capacity, and 2,220 AF of storage. Compared to the No Action Alternative (NEPA Baseline), the Fully Connected System would provide 135 miles of new pipeline, 3, 907 HP of pumping capacity, treatment facilities providing 20.3 mgd of tertiary capacity, and 2,155 AF of storage.

The geologic impacts to proposed facilities under Phase 1 would be equivalent to and greater than the impacts discussed for the No Action Alternative, in proportion to the facilities constructed under this alternative. A discussion of impacts by Member Agency is provided below.

##### LGVSD/NMWD, Novato SD/NMWD, SVCSD, Napa SD

The Fully Connected System would require the most construction of new pipelines, additional tertiary treatment capacity, and storage facilities compared to the other alternatives. Considering the additional facilities under this alternative, there is an increased potential for subsidence, if not designed and engineered appropriately. Implementation of **Mitigation Measure 3.1.1** for the additional components under the Fully Connected System would have a less than significant impact.

---

## 3.1.4 Impact Summary by Service Area

**Table 3.1-4** provides a summary of potential project impacts related to geology and soils.

**TABLE 3.1-4**
**POTENTIAL IMPACTS AND SIGNIFICANCE – GEOLOGY AND SOILS**

| Proposed Action | Impact by Member Agency Service Areas | | | |
|---|---|---|---|---|
| | **LGVSD/ NMWD** | **Novato SD/ NMWD** | **SVCSD** | **Napa SD/ Napa County** |
| Impact 3.1.1: Seismicity. | | | | |
| No Project Alternative | NI | NI | NI | NI |
| No Action Alternative | NI | LSM | LSM | NI |
| Phase 1 | LSM | LSM | LSM | LSM |
| Alternative 1: Basic System | LSM | LSM | LSM | LSM |
| Alternative 2: Partially Connected System | LSM | LSM | LSM | LSM |
| Alternative 3: Fully Connected System | LSM | LSM | LSM | LSM |
| Impact 3.1.2: Erosion. | | | | |
| No Project Alternative | NI | NI | NI | NI |
| No Action Alternative | NI | LSM | LSM | NI |
| Phase 1 | LSM | LSM | LSM | LSM |
| Alternative 1: Basic System | LSM | LSM | LSM | LSM |
| Alternative 2: Partially Connected System | LSM | LSM | LSM | LSM |
| Alternative 3: Fully Connected System | LSM | LSM | LSM | LSM |
| Impact 3.1.3: Unstable Soils. | | | | |
| No Project Alternative | NI | NI | NI | NI |
| No Action Alternative | NI | LSM | LSM | NI |
| Phase 1 | LSM | LSM | LSM | LSM |
| Alternative 1: Basic System | LSM | LSM | LSM | LSM |
| Alternative 2: Partially Connected System | LSM | LSM | LSM | LSM |
| Alternative 3: Fully Connected System | LSM | LSM | LSM | LSM |
| Impact 3.1.4: Expansive Soils. | | | | |
| No Project Alternative | NI | NI | NI | NI |
| No Action Alternative | NI | LSM | LSM | NI |
| Phase 1 | LSM | LSM | LSM | LSM |
| Alternative 1: Basic System | LSM | LSM | LSM | LSM |
| Alternative 2: Partially Connected System | LSM | LSM | LSM | LSM |
| Alternative 3: Fully Connected System | LSM | LSM | LSM | LSM |

NI = No Impact
LSM = Less than Significant with Mitigation

## 3.1.5 References

Association of Bay Area Governments (ABAG), *Earthquake Shaking Potential for the San Francisco Bay Region, http://www.abag.ca.gov/bayarea/eqmaps/mapsba.html*, sourced from California Seismic Safety Commission, California Geological Survey, 2003.

Association of Bay Area Governments (ABAG), *Liquefaction Susceptibility* http://www.abag.ca.gov/bayarea/eqmaps/liquefac/liquefac.html, prepared by ABAG Earthquake Program April, 2004.

Association of Bay Area Governments (ABAG), *Summary Distribution of Slides and Earth Flows in the San Francisco Bay Region,* http://www.abag.ca.gov/bayarea/eqmaps/landslide/index.html, sourced from USGS Open File Report 97-745 E, 1997.

Blake, M. C., Graymer, R. W., and Jones, D. L., *Geologic map and map database of parts of Marin, San Francisco, Alameda, Contra Costa, and Sonoma counties, California, USGS Miscellaneous Field Studies MF 2337*, Online Version 1.0, online at: http://pubs.usgs.gov/mf/2000/2337/, last modified May 25, 2005.

California Geological Survey (CGS), *How Earthquakes Are Measured*, CGS Note 32, 2002.

California Geological Survey (CGS), Background Information on the Shake Maps. Available online at http://quake.usgs.gov/research/strongmotion/effects/shake/about.html, 2003.

California Geological Survey, *Probablistic Seismic Hazards Ground Motion Page* , http://redirect.conservation.ca.gov/cgs/rghm/pshamap/psha12338.html, accessed, March 23, 2009.

California Water Code, Division 3, Dams and Reservoirs, Part 1, Supervision of Dams and Reservoirs, Chapter 1, Definitions, 6000-6008.

City of Novato, Community Development Department, *City of Novato General Plan, Community Identity Element*, adopted 8 March 1996, revised 25 March 2003 by Resolution No. 33-03.

City of Sonoma, City of Sonoma, Crawford Multari & Clark Associates, Strategic Economics, Crane Transportation, and Illingworth & Rodkin, *City of Sonoma General Plan: 2020*, October 2006.

County of Marin, Marin County Community Development Agency, *Geology, Mineral Resources, and Hazardous Materials Technical Background Report*, updated November 2005.

Department of Water Resources, Division of Dam Safety, DSOD, Jurisdictional Size Chart, http://www.water.ca.gov/damsafety/jurischart/index.cfm, last updated June 18, 2008, accessed March 31, 2009.

Environmental Science Associates (ESA*), Sonoma Valley Recycled Water Project Final Environmental Impact Report*, Certified by Sonoma Valley County Sanitation District, December, 2006, (SCH # 2005092083).

Ford, R., Evaluation of Ground Water Resources: Sonoma County, California Department of Water Resources, 1975.

Hart, E.W., *Fault Rupture Hazard Zones in California: Alquist-Priolo Special Studies Zones Act of 1972 with Index to Special Studies Zone Maps*. California Division of Mines and Geology, Special Publication 42, 1990. revised and updated 1997.

Jennings, C. W., *Fault Activity Map of California and Adjacent Areas*, California Division of Mines and Geology Data Map No. 6, 1:750,000, 1994.

Jones and Stokes Associates (JSA), *Napa River Salt Marsh Restoration Project Draft Environmental Impact Report/Environmental Impact Statement*, Certified by California State Coastal Conservancy, April 2003, (SCH#1998072074).

Lambert, G. and J. Kashiwagi, USDA Natural Resources Soil Conservation Service, Soil Survey of Napa County California, Aug 1978, available online: http://www.ca.nrcs.usda.gov/mlra02/napa/, accessed on 17 Oct 2008.

Napa County, *Napa County Baseline Data Report, Mineral and Rock Resources*, November 30, 2005.

Marin County, Marin County Community Development Agency Marin Countywide Plan 2020, November 6, 2007

Peterson, M.D., Bryant, W.A., Cramer, C.H., *Probabilistic Seismic Hazard Assessment for the State of California*, California Division of Mines and Geology Open-File Report issued jointly with United States. Geological Survey, CDMG 96-08 and USGS 96-706, 1996.

U.S. Department of Agriculture (USDA), Soil Conservation Service (SCS), Soil Survey, Sonoma County, California, 1972.

United States Department of Agriculture (USDA), *Soil Survey of Napa County*, 1978.

United States Department of Agriculture (USDA), *Web Soil Survey*, http://websoilsurvey.nrcs.usda.gov/app/, accessed October 17, 2008.

United States Geological Survey (USGS) Working Group on California Earthquake Probabilities (WG07), Fact Sheet 2008-3027, *Forecasting California's Earthquakes – What Can We Expect in the Next 30 Years?*, http://pubs.usgs.gov/fs/2008/3027/fs2008-3027.pdf, 2008.

Wagner D.L, and Bortugno, E.J., California Division of Mines and Geology, *Geologic Map of Santa Rosa, Regional Geologic Map Series*, 1982.