

## **8. GEOLOGY, SOILS, AND SEISMICITY**

This section discusses geologic conditions in the Manteca area. Specific issues are addressed including soil erosion, expansive soils, and seismicity.

As discussed in Section 1, Summary, mineral resources are not an issue in this General Plan Study Area, and will not be further analyzed.

### **8.1 EXISTING CONDITIONS**

#### **8.1.1 Geology of the Manteca Area**

Manteca is located in northern San Joaquin Valley. The San Joaquin Valley is the southern section of the Great Central Valley of California; the Sacramento Valley is the northern section.

The Great Central Valley is a sedimentary basin, with the Coast Range to the west and the Sierra Nevada to the east. Almost all of the sediments that fill the Great Central Valley eroded from the Sierra Nevada. The oldest of these sediments are full of fragments of volcanic rocks eroded from its early volcanoes. As erosion stripped the cover of volcanic rocks from the granites of the Sierra Nevada, their detritus of pale quartz and feldspar sand began to wash into the Great Central Valley.

Drainage into the San Joaquin Valley is mainly from the Sierra Nevada. The sediments on the valley floor were deposited within the past one-two million years, some within the past few thousand years. (1)

#### **Slope Instability**

Generally, slopes are nearly level across the Study Area. The elevation ranges from approximately 10-50 feet above sea level, gently rising from the San Joaquin River on the west toward the east and the Sierra Nevada.

Slope instability is not a major constraint to land use in the Study Area because of the relatively flat topography

#### **8.1.2 Study Area Soils**

The Soil Conservation Service (now referred to as the Natural Resources Conservation Service (NRCS)) published a Soil Survey for San Joaquin County in 1992. (2) According to that Soil Survey, there are nineteen (19) soil series within the Study Area. A soil series consists of soils that have similar horizons in their profile. The horizons are similar in color, texture, structure,

reaction, consistence, mineral and chemical composition, and arrangement in the profile. The texture of the surface layer or of the underlying material can differ within a series.

The majority of the soils in the Study Area were formed in alluvium, and are found on low alluvial fans, low terraces, and floodplain along the San Joaquin River. These soils are moderately-deep to very-deep, and drainage ranges from partially-drained to moderately well-drained on the majority of these soils. The water table is relatively high.

The Study Area soils are shown in Table 4-1 of Section 4, Agricultural Resources.

### **Erosion Potential**

Erosion can be defined as a combination of processes in which the materials of the surface of the earth are loosened, dissolved, or worn away, and transported from one place to another by natural agents. The primary concerns regarding soil erosion are soil loss, and water quality loss due to erosion and sedimentation.

There are two (2) types of soil erosion: water erosion and wind erosion.

Water Erosion: The Study Area soils are moderately-deep to very-deep, and drainage ranges from partially-drained to moderately well-drained on the majority of these soils. Given the partial-to-moderate drainage characteristics of the majority of the soils and the nearly level topography of the Study Area, water erosion hazard is considered low.

Wind Erosion: The Carquinez Strait, located approximately 55 miles to the northwest of the Study Area, is a sea-level gap in the coastal range. The prevailing wind through the Strait pushes marine breezes over the relatively flat terrain of the Valley. The wind erosion potential within the Study Area ranges from moderate-to-high during the spring, summer, and fall. These sea breezes diminish during the winter.

### **Subsidence Potential**

Subsidence is the settlement of soils. Settlement can result from either desiccation (dehydration) and shrinkage, or oxidation of organic material, or both, following drainage.

The Soil Conservation Service found that subsidence is not a characteristic of the twenty-two soil series found within the Study Area (Table 4-1 in Section 4, Agricultural Resources).

### **Expansive Soils**

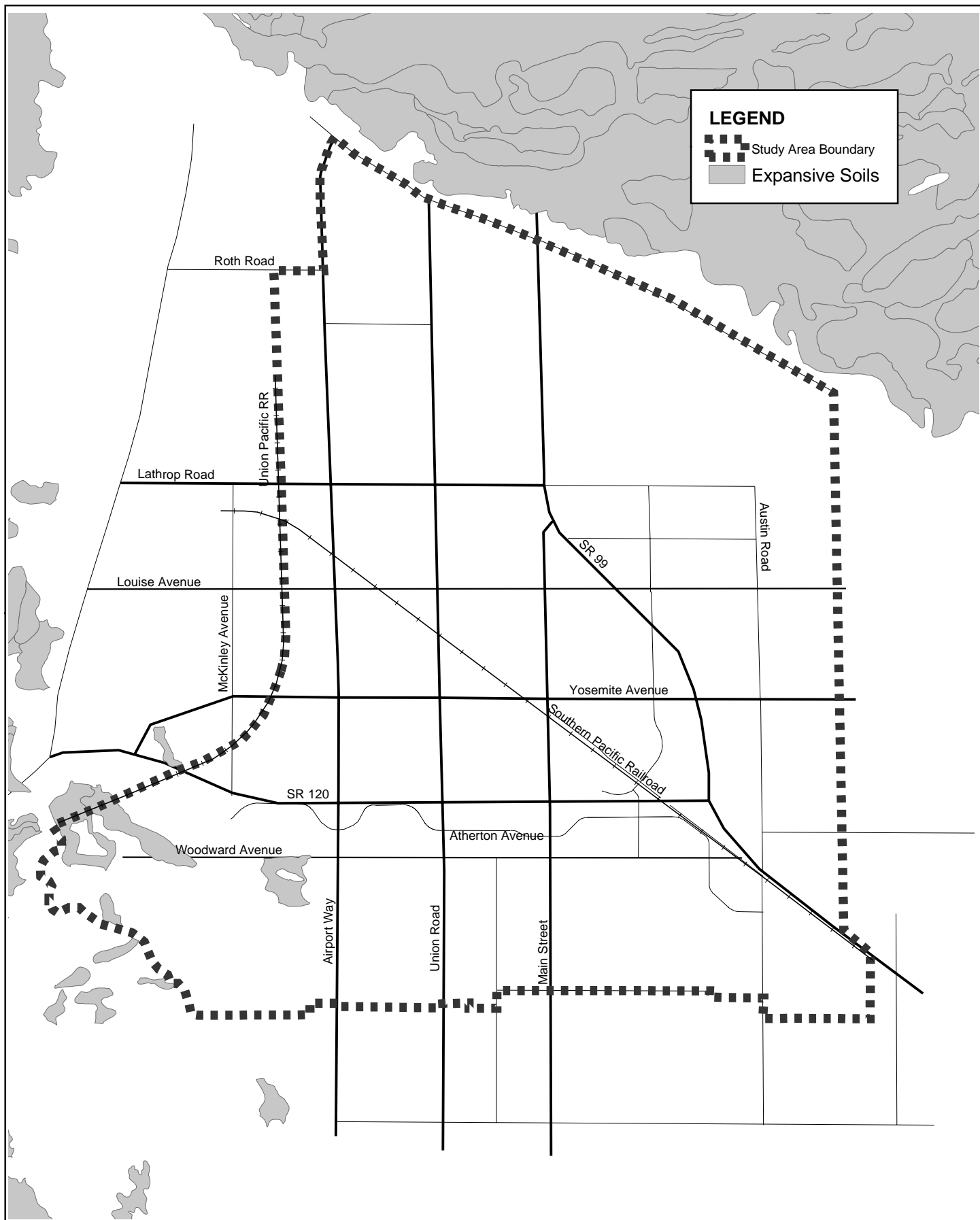
Expansive soils are those that increase in volume when they absorb water and shrink when they dry out, commonly referred to as “shrink-swell” potential. Soil surveys generally rate shrink-swell potential in soils on a low, medium, and high basis. If the shrink-swell potential is rated moderate to high, shrinking and swelling can cause damage to buildings, roads, and other structures. Special design is often needed.

As shown in Table 8-1, four (4) of the twenty-two Study Area soils have been identified as expansive soils: one (1) with a high shrink-swell potential, two (2) with a moderate-high shrink-swell potential, and one (1) with a moderate shrink-swell potential. The location of these expansive soils is shown in Figure 8-1.

**Table 8-1**  
**Expansive Soils in the Study Area**

<b>Soil (Symbol &amp; Series Name)</b>	<b>Shrink-Swell Potential</b>
152 Egbert	Moderate-High
153 Egbert	Moderate-High
169 Guard	Moderate
160 Galt	High

*Source: Extracted from Soil Survey of San Joaquin County, California. October 1992. U.S. Department of Agriculture, Soil Conservation Service.*



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### **8.1.3 Seismicity**

Seismicity can be defined simply as earthquake activity.

A seismic hazard is a risk or danger to our environment due to existence of active or potentially active earthquake faults. The term “earthquake” is used to describe both a sudden slip along a fault and the resulting ground shaking and radiated seismic energy caused by the slip, or by volcanic or magmatic activity, or other sudden stress changes in the earth.

#### **Earthquake Hazards**

Earthquake hazards include surface faulting, ground shaking, landslides, liquefaction, tectonic deformation, tsunamis, and seiches (tsunami-like waves from an inland body of water). The risk associated with earthquake hazards is generally described in terms of the probability of building damage, and the number of people that are expected to be hurt or killed if a likely earthquake on a particular fault occurs.

Earthquakes are measured by their physical effects and by the amount of energy being released. The Modified Mercalli Scale is used to measure the physical effect of earthquakes, as described in Table 8-2. This scale ranges from I to XII, with an earthquake intensity of XII resulting in nearly total damage to manmade structures and displacement of large masses of rock. The Richter Scale is used to assign a number to the calculated energy release of an earthquake, measuring the amplitude of seismic waves recorded by a seismograph. The Richter Scale is logarithmic, and an increase of one number in magnitude is the same as an increase of 32 times in energy release. A comparison of these two earthquake scales is shown in Table 8-3.

**Table 8-2**  
**Modified Mercalli Scale of 1931**

<u>Scale</u>	<u>Effects</u>
I	Earthquake shaking not felt.
II	Shaking felt by those at rest.
III	Felt by most people indoors; some can estimate duration of shaking.
IV	Felt by most people indoors. Having objects swing, windows and doors rattle, wooden walls and frames creak.
V	Felt by everyone indoors; many estimate duration of shaking. Standing autos rock. Crockery clashes, dishes rattle, and glasses clink. Doors close, open, or swing.
VI	Felt by everyone indoors and most people outdoors. Many now estimate not only the duration of the shaking, but also its direction and have no doubt as to its cause. Sleepers awoken. Liquids disturbed, some spilled. Small unstable objects displaced. Weak plaster and weak materials crack.
VII	Many are frightened and run outdoors. People walk unsteadily. Pictures thrown off walls, books off shelves. Dishes or glasses broken. Weak chimneys break at roofline. Plaster, loose bricks, unbraced parapets fall. Concrete irrigation ditches damaged.
VIII	Difficult to stand. Shaking noticed by auto drivers, waves on ponds. Small slides and cave-ins along sand or gravel banks. Stucco and some masonry walls fall. Chimneys, factory stacks, towers, elevated tanks twist or fall.
IX	General fright. People thrown to the ground. Steering of autos affected. Branches broken from trees. General damage to foundations and frame structures. Reservoirs seriously damaged. Underground pipes broken.
X	General panic. Conspicuous cracks in ground. Most masonry and frame structures destroyed along with their foundations. Some well-built wooden structures and bridges are destroyed. Serious damage to dams, dikes, and embankments. Railroads bent slightly.
XI	General panic. Large landslides. Water thrown out of banks of canals, rivers, lakes, etc. Sand and mud shifted horizontally on beaches and flatland. General destruction of buildings. Underground pipelines completely out of service. Railroads bent greatly.
XII	General panic. Damage nearly total, the ultimate catastrophe. Large rock masses displaced. Lines of sight and level distorted. Objects thrown into air.

*Source: California Geologic Survey, 2002*

**Table 8-3**  
**Comparison of Richter Magnitude and Modified Mercalli Intensity**

<b>Richter Magnitude</b>	<b>Expected Modified Mercalli Maximum Intensity</b> <b>(at epicenter)</b>
2	I-II Usually detected only by instruments
3	III Felt indoors
4	IV-V Felt by most people; slight damage
5	VI-VII Felt by all; many frightened and run outdoors; damage minor to moderate
6	VII-VIII Everybody runs outdoors' damage moderate to major
7	IX-X Major damage
8+	X-XI Total and major damage

*Source: California Geologic Survey, 2002 after Charles F. Richter, 1958, Elementary Seismology.*

### **Uniform Building Code (UBC) Seismic Zones**

The Uniform Building Code (UBC) includes a Seismic Zone Map to determine applicable construction standards for proposed structures. Seismic zones range from 0 – 4, with Zone 0 being the least active and Zone 4 being the most active. Manteca is located in Seismic Zone 3. (3) All structures built in Manteca must comply with UBC requirements for this zone.

### **Seismic Hazard Zones**

Seismic Hazard Zones are regulatory zones that encompass areas prone to liquefaction (reduction in strength and stiffness of water-saturated soil) and earthquake-induced landslides. California requires the State Geologist to establish regulatory zones (Zones of Required Investigation) and to issue appropriate maps (Seismic Hazard Zone maps). These maps are distributed to all affected cities, counties, and state agencies for their use in planning and monitoring construction. As of this writing, lands in San Joaquin County have not yet been mapped. (4)

### Alquist-Priolo Act

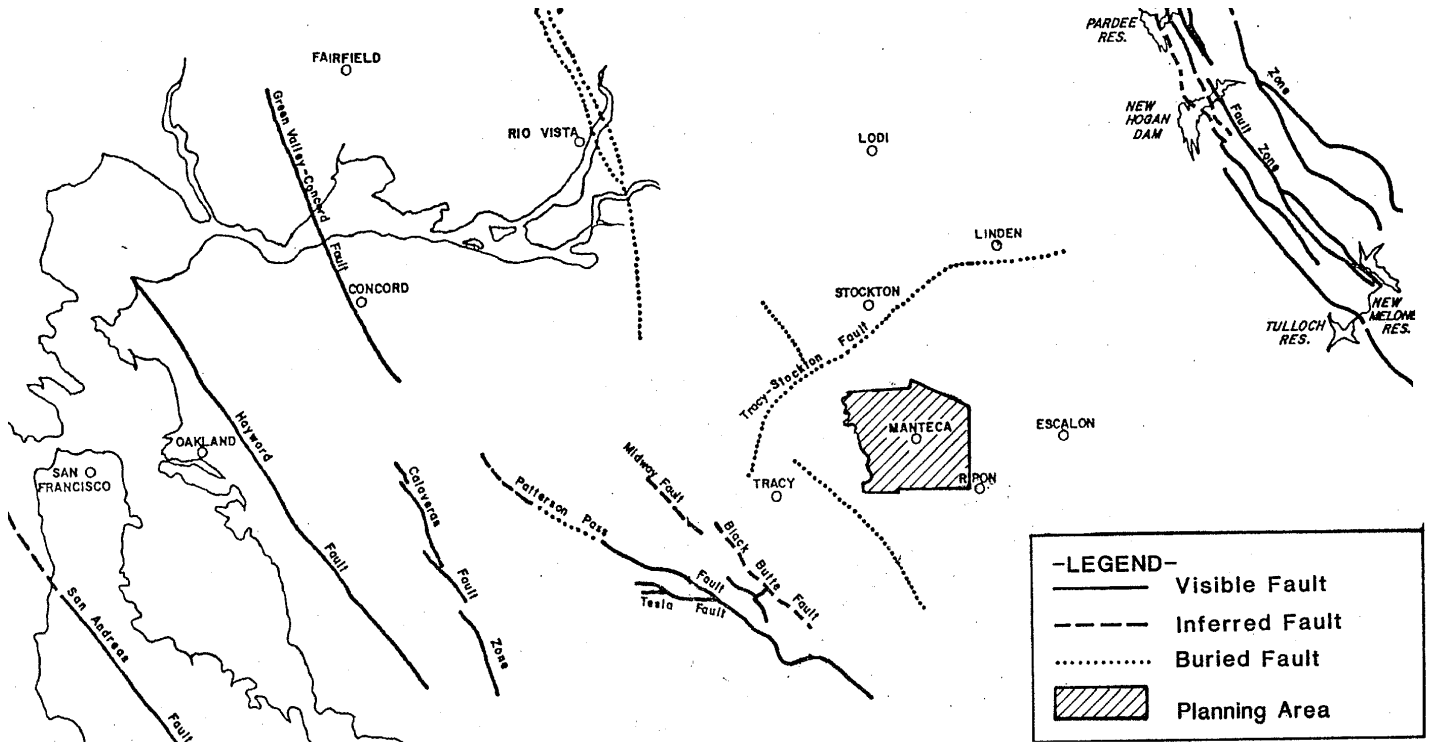
The Alquist-Priolo Special Studies Zone Act of 1972 is directed at areas identified by the California State Geologist as having active surface fault ruptures. It is a regulatory prohibition to build across a surface fault rupture of active faults. It addresses earthquake safety in building permits and subdivision procedures by requiring project applicants to submit a registered geologist's report describing the potential for on-site surface rupture.

Manteca is not located within an Alquist-Priolo Fault-Rupture Hazard Zone.(4) There are faults located in the region, but there are no known faults located within or adjacent to the Study Area.

The known earthquakes affecting San Joaquin County are shown below in Table 8-4.

Figure 8-2 illustrates faults located in the vicinity of the Study Area, as mapped by the California Department of Conservation, Division of Mines and Geology.

**Figure 8-2**  
**Faults in the Vicinity of the Study Area**



**Table 8.1-4**  
**Earthquakes Affecting San Joaquin County**

<i>Date</i>	<i>MM Intensity in San Joaquin Co</i>	<i>MM Intensity Near Epicenter</i>	<i>Epicenter</i>	<i>Richter Magnitude</i>
1836	V-VI	IX-X	Hayward	7.0
1838	VI	X	S.F. Peninsula	7.0
1857	VI	X-XI	Mountains between Santa Barbara and Bakersfield	8.8
1868	V-VI	IX-X	Hayward	7.0
1872	VI	X	Owens Valley	8.0
1881	V-VI	VII	Linden	5.0
1892	IV-V	VIII	Vacaville	7.0
1906	VI-VII	XI	San Francisco	8.3
1940	?	?	Southeast of Linden	4.0
1946	?	?	Patterson Pass	4.5
1952	V	VIII	Bakersfield	7.7
1966	IV-V	VII	North of Tahoe	6.5
1980	?	?	Mammoth Lakes	6.5
1980	?	?	Mammoth Lakes	6.7
1989	?	?	Loma Prieta	7.1

*Source: California Department of Conservation, California Geological Survey, 2002, as compiled from T. Topozada, 2000.*

As shown in Table 8-4 above, seismic activity in other parts of the state can also affect the area. The fault systems detailed below are the most prominent area faults, but do not represent every fault system that could potentially affect the Study Area. *San Andreas Fault Zone.* The San Andreas Fault is one of the longest, most thoroughly studied, and most active faults in the world. Some sections in the Central Coast Ranges south of San Joaquin County are creeping at rates as great as 3.5 centimeters per year. Other segments north and south of the creep areas exhibit essentially no movement. The fault in those areas appears to be temporarily “locked”. It is generally agreed that a “locked” condition allows stresses to accumulate more rapidly, thus shortening the time between major earthquakes.

It is possible to demonstrate an accumulated offset along the San Andreas Fault measured in hundreds of miles, occurring over a period of tens of millions of years. Since there is presently movement along some of its length, and numerous smaller earthquakes are recorded as emanating from the fault zone, it is considered probable that moderate-to-great earthquakes will occur on the San Andreas Fault in the near future.

*Hayward Fault.* The Hayward Fault is located east of San Francisco Bay and extends southeast to where it probably merges with the Calaveras Fault north of Hollister. A review of the recent history of this fault shows two major earthquakes (1836 and 1868) each with an estimated Richter Scale Magnitude 7.0 (Table 8-4). Numerous small earthquakes continue to occur along this fault, indicating continued activity.

*San Joaquin Fault Zone.* A new fault system has recently been identified by the U.S. Geologic Survey (USGS), extending from Tracy to Los Banos, paralleling Interstate 5. Geologic studies show that the zone has sustained activity during the Quaternary period. This could be an important fault system for San Joaquin County.

Other nearby fault systems include: Rescue Lineament-Bear Mountains fault zone, Clayton-Marsh Creek-Greenville fault, O'Neil fault system, and Ortigalita fault. The known faults nearest to the Study Area are the Tracy-Stockton Fault crossing southwest near Tracy to the northeast near Linden, and a small buried fault running southeast from the Tracy area (Figure 8-2).

## **8.2 REGULATORY SETTING**

### **8.2.1 Applicable Federal Regulations**

#### **U.S. Uniform Building Code (UBC)**

The U.S. Uniform Building Code (UBC) provides site development and construction standards. The UBC is widely used throughout the United States, and is generally adopted on a district-by-district or state-by-state basis. The UBC has been modified for California conditions with more detailed and more stringent regulations.

### **8.2.2 Applicable State Regulations**

#### **California Uniform Building Code (CUBC)**

The California Uniform Building Code (CUBC) is based upon the 1997 U.S. Uniform Building Code (UBC). Where no other building codes apply, Chapter 29 regulates excavation, foundations, and retaining walls; Chapter 70 regulates grading activities, including drainage and erosion control.

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### **California Code of Regulations (CCR), Title 24 (Building Standards)**

The State of California provides minimum standards for building design through the California Building Standards Code.

### **California Health and Safety Code 19100 et seq. (Earthquake Protection Law)**

The State of California earthquake protection law requires that buildings be designed to resist stresses produced by lateral forces caused by wind and earthquakes.

### **California Department of Conservation, Division of Land and Resource Protection (DLRP)**

The California Division of Land and Resource Protection (DLRP) provides information to guide land use planning decisions, and well as programs that allow agricultural and open space landowners to voluntarily protect their land.

### **California Department of Conservation, Division of Mines and Geology**

The California Division of Mines and Geology has historically focused on gathering geologic information and mapping information. However, programs have expanded often due to the passage of legislation. DMG's authority now includes obtaining statewide records of the response of rock, soil, and structures to ground motion caused by earthquakes; mandating the delineation of zones along traces of hazardous faults; ensuring that significant mineral deposits are identified and protected; providing geologic hazard review and investigation; identifying and mapping seismic hazard zones; developing public policy; and providing emergency response services.

#### **8.2.3 City of Manteca**

The Health and Safety Element (Section VII) of the existing 1988 General Plan includes the following goals and policies to protect Manteca residents and structures from geologic and seismic hazards:

Goal A: To prevent loss of lives, injury, and property damage due to geological hazards.

Policy A-1 The City shall require preparation of geological reports and/or geological engineering reports for proposed new development located in areas of suspected significant geological hazards.

Goal B: To prevent loss of lives, injury, and property damage due to the collapse of building and critical facilities and to prevent disruption of essential services in the event of an earthquake.

Policy B-1      The City shall maintain an inventory of pre-1940 unreinforced masonry buildings within the City. No change in use to a higher occupancy or more intensive use shall be approved in such structures until an engineering evaluation of the structure has been conducted and any structural deficiencies corrected. The Redevelopment Agency shall be encouraged to assist property owners in reinforcing buildings.

Policy B-2.      The City should ensure that all public facilities, such as buildings, water tanks, and reservoirs, are structurally sound and able to withstand seismic shaking and the effect of seismically induced ground failure.

### **8.3 IMPACT EVALUATION CRITERIA**

In accordance with CEQA Guidelines, Appendix G, the proposed project would have a significant adverse impact the project would:

- 1) Expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving:
  - Rupture of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map issued by the State Geologist for the area or based on other substantial evidence of a known fault.
  - Strong seismic ground shaking.
  - Seismic-related ground failure, including liquefaction.
  - Inundation by seiche, tsunami, or mudflow.
  - Landslides.
- 2) Result in substantial soil erosion or the loss of topsoil.
- 3) Be located on a geologic unit or soil that is unstable, or that would become unstable as a result of the project, and potentially result in on- or off-site landslide, lateral spreading, subsidence, liquefaction or collapse.
- 4) Be located on expansive soil creating substantial risks to life or property.
- 5) Have soils incapable of adequately supporting the use of septic tanks or alternative waste water disposal systems where sewers are not available for the disposal of waster water.

## 8.4 IMPACTS AND MITIGATION

**POTENTIAL IMPACT GSS-1:**            **Implementation of the General Plan 2023 may expose people and structures to rupture of a known earthquake, as delineated on the Alquist-Priolo Earthquake Fault Zoning Map.**

**Level of Significance:**            **Less Than Significant Impact**

Manteca is not located within an Alquist-Priolo Fault-Rupture Hazard Zone. There are no known active surface fault ruptures located within or adjacent to the Study Area.

**POTENTIAL IMPACT GSS-2:**            **Implementation of the General Plan 2023 may expose people and structures to ground shaking, ground failure (including liquefaction) or landslides.**

**Level of Significance:**            **Potentially Significant**

Lands within San Joaquin County have not yet been mapped in the California Department of Mines and Geology Seismic Hazard Zone Mapping System, which maps areas of possible liquefaction and landslides. However, given the nearly level terrain of the Study Area, the possibility of landslides is considered a less than significant impact. The Soil Survey for the area found that subsidence is not a characteristic of the soils within the Study Area. As shown in Table 8-4 above, significant earthquakes from regional fault systems have affected San Joaquin County in the past; therefore, the possibility of some level of regional ground shaking in the future is likely. Given that there is a relatively high water table, liquefaction could be a significant impact within the Study Area.

### **Mitigation Measures:**

**GSS-2.1:**            The General Plan 2023 Safety Element (Section 7) provides the following goals, policies (P), and implementation measures (I) to lessen the possible exposure of people and structures to ground shaking or ground failure, including liquefaction:

Goal S-1:            Prevent loss of lives, injury, and property damage due to seismic activity and geological hazards.

Goal S-2:            Prevent loss of lives, injury, and property damage due to the collapse of buildings and critical facilities and to prevent disruption of essential services in the event of an earthquake.

S-P-1                The City shall require preparation of geological reports and/or geological engineering reports for proposed new development

- located in areas of suspected significant geological hazards, including potential subsidence (collapsible surface soils) due to groundwater extraction.
- S-P-2 The City shall require new development to mitigate the potential impacts of geologic hazards through Building Plan review.
- S-P-3 The City shall ~~avoid potential~~ require new development to mitigate the potential impacts of seismic induced settlement of uncompacted fill and liquefaction (water-saturated soil) due to the presence of a high water table.
- S-P-4 The City shall maintain an inventory of pre-1940 unreinforced masonry buildings within the city. No change in use to a higher occupancy or more intensive use shall be approved in such structures until an engineering evaluation of the structure has been conducted and any structural deficiencies corrected. The Redevelopment Agency shall be encouraged to assist property owners in reinforcing buildings.
- S-P-5 The City shall ~~should~~ shall ensure that all public facilities, such as buildings, water tanks, and reservoirs, are structurally sound and able to withstand seismic shaking and the effects of seismically induced ground failure.
- S-P-6 The City shall comply with the California State seismic and building standards in the design and siting of critical facilities, including police and fire stations, school facilities, hospitals, hazardous materials manufacturing and storage facilities, and large public assembly halls.
- SG-I-1 All new development shall comply ~~Comply~~ with the current Uniform Building Code (UBC) requirements for Seismic Zone 3, which stipulates building structural material and reinforcement.
- SG-I-2 All new development shall comply ~~Comply~~ with California Health and Safety Code Section 19100 et seq. (Earthquake Protection Law), which requires that buildings be designed to resist stresses produced by natural forces caused earthquakes and wind.

SG-I-3            The City shall inventory potentially hazardous buildings within the City and adopt a mitigation program, including requirements for strengthening buildings, changing the use of the buildings to an acceptable occupancy level, or demolishing the buildings.

**Residual Level of Significance:            Less Than Significant With Mitigation**

The level of significance will be mitigated to less than significant if the above goals, policies, and implementation measures are implemented.

**POTENTIAL IMPACT GSS-3:            Implementation of the General Plan 2023 may result in substantial soil erosion or loss of topsoil.**

Given the partial-to-moderate drainage characteristics of the majority of the soils and the nearly level topography of the Study Area, water erosion hazard is considered low.

The wind erosion potential within the Study Area ranges from moderate-to-high during the Spring, Summer, and Fall. These sea breezes diminish during the Winter.

**Level of Significance:            Potentially Significant**

**Mitigation Measures:**

**GSS-3.1:**            The Resource Conservation Element (Section 8) of the City of Manteca General Plan 2023 provides the following goal, policy (P), and implementation measures (I) to mitigate the potential of substantial soil erosion or loss of topsoil.

Goal RC-6            Preserve and maintain Manteca's soils to avoid pollution of surface waters, decreased air quality, and loss of soil.

RC-P-9            The City shall adopt and enforce land management standards that minimize ~~Minimize~~ soil erosion and loss of topsoil from land development activities, wind, and water flow.

RC-I-16            All new development shall comply ~~Comply~~ with the Uniform Building Code (UBC) requirements for specific site development and construction standards for specific soils types.

RC-I-17            All new development shall comply ~~Comply~~ with the Uniform Building Code (UBC), Chapter 70, regulating grading activities including drainage and erosion control.

RC-I-18            Require site-specific land management and development practices ~~survey and research~~ for proposed development

projects, including appropriate mitigation measures for avoiding or reducing erosion, if needed. ~~This requirement may be waived if the City determines that the proposed project area is already sufficiently surveyed.~~

**Residual Level of Significance:            Less Than Significant With Mitigation**

The level of significance will be mitigated to less than significant if the above goal, policies, and implementation measures are implemented.

**POTENTIAL IMPACT GSS-4:            Implementation of the General Plan 2023 may expose people and structures to the hazards of expansive soils.**

**Level of Significance:            Potentially Significant**

Five (5) of the nineteen Study Area soils have been identified as expansive soils: two (2) with a high shrink-swell potential, and three (3) with a moderate shrink-swell potential.

**Mitigation Measures:**

GSS-4.1:            The General Plan 2023 Safety Element (Section 7) provides the following policies (P) to lessen the possible exposure of people and structures to the shrink-swell hazards of expansive soils:

S-P-1            The City shall require preparation of geological reports and/or geological engineering reports for proposed new development located in areas of suspected significant geological hazards, including potential subsidence (collapsible surface soils) due to groundwater extraction.

S-P-2            The City shall require new development to mitigate the potential impacts of geologic hazards through Building Plan review.

The General Plan 2023 Resource Conservation Element (Section 8) provides the following policies implementation measure (I) to lessen the possible exposure of people and structures to the shrink-swell hazards of expansive soils:

RC-I-16            Comply with the Uniform Building Code (UBC) requirements for specific site development and construction standards for specific soil types.

**Residual Level of Significance:            Less Than Significant With Mitigation**

The level of significance will be mitigated to less than significant if the above policies and implementation measure are implemented. Compliance with UBC construction requirements will implement state-of-the-art mitigation relating to site-specific soil types.

**POTENTIAL IMPACT GSS-5:           Septic tanks or alternative waste water systems could be placed in soils incapable of supporting their use.**

**Level of Significance:               No Impact**

All proposed development within the Study Area will be served by the City's municipal sewer system. No septic tanks or alternative waste water systems will be used.

### ***References***

- (1) Alt, David and Donald W. Hyndman. Roadside Geology of Northern and Central California. Mountain Press Publishing Company. Missoula, Montana. August 2001, Second Printing. Extracted from Pg. 243-254.
- (2) U.S. Department of Agriculture, Soil Conservation Service. Soil Survey of San Joaquin County, California. October 1992. Extracted from Pg. 185-238.
- (3) Telephone Conversation with Dennis Rock, San Joaquin County Community Development Department, Building Inspection and Permitting. June 2003.
- (4) Telephone Conversation with Dale Stickney, Information Geologist, California Department of Conservation, Division of Mines and Geology. February 21, 2002; Update June 2003.

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