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APPENDIX E-5

SEISMIC—FAULT AND EARTHQUAKE—EVALUATION OF THE CALIFORNIA AQUEDUCT, DELTA-MENDOTA CANAL, AND AQUEDUCT CHECK STRUCTURES, ADJACENT TO THE PROPOSED TRACY HILLS DEVELOPMENT, CITY OF TRACY, SAN JOAQUIN COUNTY, CALIFORNIA, DATED APRIL 2015

SEISMIC--FAULT AND EARTHQUAKE--EVALUATION OF THE CALIFORNIA AQUEDUCT, DELTA-MENDOTA CANAL, AND AQUEDUCT CHECK STRUCTURES, ADJACENT TO THE PROPOSED TRACY HILLS DEVELOPMENT, CITY OF TRACY, SAN JOAQUIN COUNTY, CALIFORNIA

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1. INTRODUCTION

1.1 PURPOSE AND SCOPE OF WORK

As proposed (March 26, 2014), along with Geodynamics, Inc. (GDI), Wilson Geosciences Inc. (WGI) has performed a seismic evaluation of the California Aqueduct, Delta-Mendota Canal, and California Aqueduct check structures 2 and 3, adjacent to the proposed Tracy Hills development, Tracy, California. The purpose of the study is to respond to a comment on the Supplemental DEIR for the project. The comment is as follows:

> "Aqueduct
>
> Comments by the CDWR [California Department of Water Resources] on the 1997 DEIR indicated that they believe seismic events from local and regional faults (e.g., the Greenville fault approximately 7 miles west and the Calaveras and Hayward faults approximately 13 and 21 miles west, respectively) could cause a failure of the aqueduct. The DEIR recognizes Impact 4.8-5 which identifies that implementation of the proposed school may be subject to a breach or rupture of the California Aqueduct. The DEIR does not discuss failure of the Aqueduct due to seismic activity."

WGI previously prepared a pipeline risk assessment for the proposed Tracy Hills school site that did not include this scope of work. The evaluation considers the structures mentioned above and provides expected seismic parameters for the project location considering the earthquake faults in the region. We compared these seismic parameters with relevant criteria considered for the earthquake performance of the structures. Analysis was performed using probabilistic and deterministic seismic hazard analyses for several points along the aqueduct, and earthquake size and distance relationships commonly used in the profession for this type of assessment. Specifically we considered:

- Known potential earthquake generating faults in the region,
- Response spectra based on probabilistic and deterministic seismic hazard analyses for several points within the project area,
- A review and discussion of geologic and geotechnical conditions documented by others for the site area,
- Earthquake hazard related maps, including liquefaction, for the region and area,
- General information readily available for the aqueduct, canal, and check structures,
- A discussion of liquefaction and related hazards at the site, and
- Comparison of our findings with a 1983 Coalinga Earthquake case history.

Although future assessments may be required, in our professional opinion the purpose as stated above is satisfied.

1.2 FACILITIES LOCATIONS AND GENERAL CHARACTERISTICS

The proposed development site (Site) is located both northeast and southwest (herein called north and south) of Interstate Highway 580 (I-580), west of Corral Hollow Road, immediately south of the Delta-Mendota Canal, and adjacent to the California Aqueduct (Figure 1) within what is understood to be the city limits of the City of Tracy. The Site generally slopes from south to north within the proposed development area.

The facilities of interest in this analysis are the sections of the California Department of Water Resources (CDWR) California Aqueduct and the Delta-Mendota Canal immediately adjacent to the Site, and two check structures, Check 2 and Check 3 located approximately 1.4 miles north and one mile south of the Site, respectively. These check structures regulate flow along the California Aqueduct.

The California Aqueduct (CDWR, 1964) has a symmetrical trapezoid shape approximately 100-feet across at the top, 60-feet across at the invert, and 38-feet deep. Two check structures are present along the aqueduct one northwest (Check 2) and one southeast (Check 3) of the proposed Site; the pool in between is Pool 3 which can hold 1,939 acre-feet of water. We did not find specific construction details for the Delta-Mendota Canal, but the designs are expected to be similar. Based on the Tracy Hills Specific Plan Draft EIR (1997, page 4.7-7):

> *"According to the Department of Conservation, the California Aqueduct has an average freeboard of 8 to 11 feet. However, freeboard is reduced to three feet during the hottest days of the summer season, to minimize heat expansion of the canal's concrete panels. According to the Bureau of Reclamation, the Delta Mendota Canal maintains a freeboard of one to two feet during maximum flow. Water levels are, however, decreased during episodes of fish migration and at time of poor water quality. Both the California Aqueduct and the Delta Mendota Canal are equipped with check structures which monitor massive dewatering and automatically shut off flows."*

Water flow in the California Aqueduct at this location is carried below adjacent grades on the south, and at or below adjacent grades on the north. We understand the Delta-Mendota grade relationships and flow rates are similar. This at or below grade design is more secure than a levee type system, which stands above surrounding topography and, if a breach were to form, erosion and flooding would occur in adjacent areas.

1.3 SITE AREA TOPOGRAPHY AND DRAINAGE

Figure 2 shows the topography surrounding the entire proposed development area from the 1981 United States Geological Survey (USGS) topographic map contours (20-foot contour interval). Assuming a roughly northeast-southwest topographic profile through the center of the proposed development, in general, topography slopes downhill from I-580 on the southwest (approximate elevation 290-feet) toward the edge of the California Aqueduct (roughly elevation 240-feet), and the edge of the Delta-Mendota Canal (roughly elevation 200-feet). This slope gradient is approximately one to two percent. The slope is not uniformly flat in that a subtle, similarly low gradient broad ridge-feature occupies the southeastern two-thirds of the Phase I area north of I-580. Normal surface drainage across the Phase I area is directed to two artificial drainage features (culverts) that cross the aqueduct above the water level in the aqueduct.

As indicated, surface runoff is primarily by overland and channel flow across the proposed development area toward the aqueduct, and from the aqueduct toward the canal. CDWR commented on the DEIR (1997; January 26, 1996 comment) that while considering the below grade aqueduct design, due to significant earthquake shaking potential:

> *". . . we believe that in light of the above [earthquake] concerns that the ideal solution would be to designate the lands on both sides of the Aqueduct as open space/greenbelt. This would reduce the need to mitigate the above concerns and further protect the public who would live and work in this planned development."*

Because of the conditions described here, the California Aqueduct flood risk study (Wilson Geosciences Inc., 2013) concluded that a proposed school site south of the aqueduct near Corral Hollow Road (and by extension other higher elevations south of the aqueduct outside the 100-feet wide setback) would not be subject to flooding from an aqueduct failure. Flooding concern therefore exists for areas north to northeast of the aqueduct. For the same reasons flooding from the Delta-Mendota Canal would affect areas north of the canal and not the proposed development area between the aqueduct and the canal (Figure 3).

1.4 GENERAL SEISMIC EVALUATION METHODOLOGY

The Central Valley/San Joaquin Valley lies within a seismically active area as does almost all of California. The four facilities evaluated herein were constructed in the 1960s and 1970s using the standard design practices used by the State of California at that time. Seismic design has become a very important aspect of facilities design in California over the past 40 years or so. The California Department of Water Resources (CDWR, 2012) has recently evaluated facility types within the statewide water conveyance system and provided some guidelines describing their levels of risk related to earthquake loading (ground shaking/acceleration). This study determines the potential seismic parameters for several locations along the subject facilities and compares these results to risk levels considered acceptable by the State. Likewise, commonly used analytical processes from the USGS and the California Transportation Department (Caltrans) are used in this study to determine the potential seismic parameters for the proposed development area. Also USGS predictions for the blind thrust fault system beneath the Site area are considered.

Comments by the CDWR quoted above indicated that they believe seismic events could cause a failure of the California Aqueduct (i.e., this cannot be precluded). The CDWR indicates that an aqueduct failure could generate a maximum flow from the California Aqueduct at this location of 10,300 cubic feet per second (cfs) with an initial surge equaling almost 25,000 cfs, posing a risk to persons and property situated down slope (north) of the Aqueduct. It is inferred that this conclusion would also apply to the Delta-Mendota Canal and, depending upon conditions, the Check 2 and 3 structures. It is therefore believed that severe seismic shaking would be the primary natural hazard that would impact the aqueduct, canal, and check structure locations.

Flooding is the primary concern should the aqueduct, canal, or check structures fail adjacent to the Site. Erosion, flowing water, and subterranean saturation are also considerations, but not specifically considered by the State (2012). For an aqueduct, breach size in the levee wall, water flow rate, and breach direction would be considered to approximate the flow direction, flood size, flood height and water velocity. Flooding consequences are not within the scope of this evaluation.

1.5 REPORT CONCLUSIONS

The primary report conclusions are:

1. The California Aqueduct, Delta-Mendota Canal, and aqueduct Check Structures 2 and 3 lie over or adjacent to the Great Valley blind (buried) thrust fault GV-07 similar to the California Aqueduct, check stations, and pump stations in the Coalinga area near where the 1983 Coalinga earthquake occurred on fault GV-13.

2. The 1983 Coalinga earthquake magnitude (M) 6.5 is similar to the most likely large earthquake that could occur

near Tracy Hills on GV-07 and resulted in no damage to the California Aqueduct and minor damage to pumping stations based on immediate post-earthquake surveys by the responsible California agencies.

3. Based on water elevations and adjacent ground elevations, only the proposed area between the California Aqueduct and the Delta-Mendota Canal could be affected by a breach in either structure. Since the California Aqueduct water levels are at or below the ground level north (down slope) of the Aqueduct, flow would be relatively dispersed.

4. California Department of Water Resources (CDWR; 2012)) has established Consequence Rating criteria for potential flood areas north of the California Aqueduct based on population within 5-miles of the aqueduct. The resident population of Tracy within this overall area would increase by approximately 3-percent based on planned development in the potential affected area between the aqueduct and the canal, not a significant increase from the proposed development.

5. Considering the population Consequence Rating criteria from the CDWR (2012), the mandated future aqueduct, canal, and check structure design criteria near Tracy must utilize the 500- and 1000-year return period earthquakes, respectively. Calculated Peak Ground Acceleration (PGA) for 500- and 1000-year return period values for this study suggest that ground accelerations for these structures would likely be lower than those experienced in Coalinga without damage to the aqueduct or significant damage to pump stations that were surveyed.

2 GEOLOGIC AND GEOTECHNICAL CHARACTERISTICS AFFECTING THE SITE

2.1 PROJECT DEVELOPMENT AREA REPORTS

Several geologic reports (TERRASEARCH, INC., 1990; Kleinfelder, 2000; T. Makdissy Consulting, Inc., 2012) have been prepared for some, or all, of the overall development site. The Tracy Hills Draft EIR (1997) Geology and Soils (Section 4.7), and Surface Water Hydrology, Groundwater, and Water Quality (Section 4.9) sections, and the same-titled 2014 SDEIR sections address some relevant seismic, geology and geotechnical issues for the proposed specific plan development area at an EIR level of detail.

The 1997 Draft EIR indicated that geology, soils, and flooding impacts can be mitigated for the Tracy Hills development, but does not address aqueduct flooding specifically. The 2012 Makdissy report was a geologic and geotechnical feasibility evaluation to assess geologic, geotechnical, and seismic hazards; it very generally describes the geologic units, faulting, groundwater occurrence, liquefaction, seismic conditions, and geotechnical considerations. They determined that the overall development is feasible and did not identify geologic or geotechnical conditions that would be detrimental to the performance of the California Aqueduct, the Delta-Mendota Canal or the check structures. The TERRASEARCH (1990) and Kleinfelder (2000) reports provide geotechnical field exploration and analysis information within the proposed development area including 134 borings to a maximum depth of 30 feet. Neither the 1990 or 2000 geotechnical reports appear to contain information that contradicts this conclusion or identifies conditions that would negatively impact the aqueduct, canal, or check structures (these two structures are outside the previous study areas). More geotechnical and geologic details contained in these reports are discussed in a following section.

2.2 REGIONAL AND AREA REPORTS: GENERAL GEOLOGY AND FAULT DATA

2.2.1 Geologic Units

Geologic mapping by Dibblee and Minch (2006; Figure 2) indicates that the aqueduct and canal are located within recent (Holocene) surficial sediments (Qa) that are underlain and adjacent to older (Pleistocene age) surficial sediments (map symbols Qoa and Qoa_2). None of these formations is susceptible to landslides and the Qoa and Qoa_2 are not susceptible to liquefaction due to their high relative density and lack of groundwater within 50-feet of the surface. If groundwater is present, Qa may have a very low liquefaction potential that could affect the aqueduct and canal. No known active or potentially active faults cross the aqueduct, canal or check structures within at least one mile of the proposed development site.

2.2.2 Active and Potentially Active Faults

The following are descriptions of the major fault systems (Figure 3) identified by ENGEO Inc. (2014) that are active or potentially active within the vicinity of the proposed development area. Those discussions are modified somewhat based on the USGS/CGS/SCEC latest Uniform California Earthquake Rupture Forecast Report (UCERF3; Field, and others, 2013).

Calaveras Fault

The Calaveras Fault is considered active over a distance of more than 80 miles from Danville on the north to Hollister on the south. Tectonic creep also occurs episodically along the fault, mainly from Coyote Lake to Hollister. Seismic activity along the Calaveras Fault has been felt in the central San Joaquin Valley as recently as April 1984. The California Division of Mines and Geology (CDMG) database lists two segments near the City of Tracy, with maximum moment magnitudes ranging from 6.2 to 6.8 and slip rates ranging from 6.0 to 15.0 millimeters per year. UCERF3 developed a magnitude (M) 7.0 earthquake scenario.

Hayward Fault

The Hayward Fault is considered active and parallels the San Andreas Fault to the east. The last major earthquake on the Hayward Fault occurred in 1868 with a magnitude of 7.0. The Hayward Fault is capable of producing earthquakes ranging from 6.5 to 7.1. UCERF3 developed a M7.3 earthquake scenario.

Ortigalita Fault

The Ortigalita fault is a 48.8 mile long, north-northwest-striking, right-lateral strike-slip fault located in the southern Diablo Range. The fault extends from Panoche to southeast of Mount Stakes. The fault consists of two distinct geometric segments, separated by a 3.1-mile (5 KM) wide right-step across San Luis Reservoir. The Ortigalita fault is capable of producing a maximum 7.1 magnitude earthquake with an effective recurrence of 1100 years.

San Andreas Fault

The San Andreas Fault is associated with two of the largest earthquakes that have occurred in California during historic time: the 1857 Fort Tejon earthquake (magnitude 8.3) on the south- central portion of the fault and the 1906 San Francisco earthquake (magnitude 8.3) on the northern portion of the fault. Due in part to the length of the fault (approximately 625 miles) various portions of the San Andreas Fault can be characterized by distinctly different seismic behavior related to rupture location, length, and expected repeat time. UCERF3 developed a M7.9 earthquake scenario.

Greenville Fault

The Greenville Fault is northwest trending, strike-slip fault that extends for approximately 30 miles. It’s a parallel secondary system to the San Andreas Fault credited with the 5.8 magnitude Livermore earthquake in 1980. The Greenville Fault is located approximately 10 miles to the southwest of the Project Area. UCERF3 developed a M7.0 earthquake scenario.

Great Valley Fault System

The San Joaquin segment of the Great Valley Fault has a projected surface expression located approximately 4 miles to the west of Tracy. The Great Valley Fault is a blind thrust fault. Portions of the Great Valley Fault are considered seismically active thrust faults; however, since the Great Valley Fault segments are not known to extend to the ground surface, the State of California has not defined Earthquake Fault Hazard Zones around the postulated area of the fault. The Working Group on Northern California Earthquake Potential (WGNCEP, 1996; Figure 3 upper map) shows 14 segments (GV01 through GV14) of the Great Valley blind thrust fault system within the Central Valley. Based on their map it appears the proposed development area is located above the northern portion of Great Valley 07 (GV7; Figure 3). UCERF3 developed a M6.9 earthquake scenario for GV07. At least three >M6 earthquakes have occurred in the along segments GV06, GV07, and GV13. The 1983 Coalinga M6.5 earthquake occurred on segment GV13. Overall the southerly 12 segments including GV07 have a slip rate of approximately 1.5 millimeters per year.

These primary active and potentially active faults contribute to the potential seismic ground shaking environment of the proposed development area, the California Aqueduct, the Delta-Mendota Canal and Check 2 and 3. The most-likely nearby event to impact the proposed development area may be a Coalinga-like event occurring beneath the GV07 buried thrust fault. Figure 4 shows some of the earthquake parameters associated with the Coalinga M6.5 event. The specific potential ground shaking parameters are discussed in the following sections.

2.3 SITE GEOTECHNICAL AND GEOLOGIC PARAMETERS AFFECTING SEISMIC RESPONSE

The most comprehensive known development-specific geotechnical investigations were performed by TERRASEARCH (1990) as described above, including 131 borings to maximum depths of 30 feet. Kleinfelder (2000) used this work for a different project and added 3 borings, in addition to percolation tests. The depth of the aqueduct invert is approximately 38-feet below adjacent ground.

2.3.1 TERRASEARCH (1990)

TERRASEARCH borings extend across the "Phase 1" area north of I-580 and south of the California Aqueduct are shown on Figure 2 of the Kleinfelder report (2000). Additional TERRASEARCH borings extend to the northwest end of the proposed development area and north of the aqueduct south of the canal. The borings near the aqueduct provide the best information on what geologic materials likely underlie the aqueduct and form its foundation materials. For this discussion we focused on borings 1, 5, 11, 12, 13, 17, 19, 20, 33, 62-67, 72, 74, 76, 77, 124, 125, and 126.

All of the listed borings begin in Qa based on the Dibblee and Minch (2006) geology map. Those listed borings between the aqueduct and canal (e.g., 1 through 20) indicate that the materials are silty clay and clayey silt, with silty sand and sandy/silty/clayey gravel layers. These units are generally stiff and very stiff or dense to very dense suggesting that these are not recent alluvial deposits but some intermediate age between young and old, probably late Pleistocene in age. Mapping by Dibblee and Minch (2006) was modified locally by Kleinfelder (2000) suggesting more area is covered by Qoa than shown on Figure 2. This suggests that the deposits underlying the aqueduct (deeper/older than the listed borings) appears to be Qoa and Qoa_2, which are very good to excellent foundation materials. Canal foundation materials likely range from the older and intermediate materials, to younger alluvium that may have fair (if Qa) to excellent (if Qoa) foundation properties.

TERRASEACH indicates that the alluvial materials are moderately expansive pebbly silty clays nearer the surface and clayey silt layers with gravel interbeds down to the maximum explored depth of 30-feet. These materials are said to have a low potential for liquefaction due to the material properties. In addition, groundwater levels (Geotracker, 2015) in wells to the north and west have groundwater depths that vary between approximately 139-feet and 39-feet. Adjacent to Check 2 groundwater is about 88-feet deep along I-580 to the northwest of the proposed development area. The deeper water depths are nearer the proposed development area and the shallower depths at greater distances toward the central portion of the valley. It is likely that since there are no wells within or very near the proposed development area, this indicates groundwater is similar to the 88-feet depth and may approach the 139 feet depth of the wells farther north into the basin.

2.3.2 Kleinfelder (2000)

Kleinfelder used the TERRASEARCH borings, as well as three borings of their own, for their analysis of the site for an interim wastewater reclamation facility. Their borings were 15-, 10-, and 16-feet deep. Other percolation tests were conducted since the primary purpose of the facility was for water treatment and water storage ponds. The borings were clustered south of the aqueduct in Qa (B-2 and -3) and Qoa (B-1) as mapped by Dibblee and Minch (2006). They encountered silty clay, sandy clay, and sandy silty clay in what would appear to be Qa and deeper deposits of mixed, partially cemented silt/sand/clay/gravel classified as stiff to very stiff, and dense/hard. As with the TERRASEARCH borings this suggests that the deposits underlying the aqueduct in this area are most likely Qoa and Qoa_2 with very good to excellent foundation properties. Percolation and infiltration rate tests indicate that percolation is slow with low rates (0.57 to 3 inches/hour) indicating relative tight, low porosity materials within the depths tested. Kleinfelder terms these deposits as “relatively impermeable silty clay materials.”

While we have no specific data at the Check 2 and 3 sites, their locations in Qa in close proximity to Qoa (Figure 2) suggest the same general geologic and geotechnical conditions as for the aqueduct.

2.4 EXPECTED GROUND SHAKING AND SEISMIC RESPONSE

2.4.1 State Water Project Facilitates Consequence Rating and Seismic Loading Criteria

CDWR Consequence Rating

The CDWR (2012) developed a Consequence Rating system that will allow aqueducts/canals to be designed for different loadings depending on such factors as affected population, economic loss, and degree of dependency of local users on the water supply. Low to medium and medium to high hazard zones were developed based on population within five miles of a canal pool between adjacent check structures. For Check 2 and 3 (Pool 3 with 1,939 acre-feet of water) bracketing the proposed development area, a medium to high rating was given due to the population (currently about 84,691; U. S Census Bureau, 2013)) down slope within five miles of the aqueduct. Using that population figure and considering the development between the aqueduct and canal (population approximately 2,767), total population would reach approximately 87,458. The proposed development in the area between the California Aqueduct and the Delta-Mendota Canal (the only potentially significant flood area) would add a maximum population on a given day of approximately 2,767, considering a night-time maximum condition in the residential area (795 residences x 3.48 persons per residence; John Palmer, personal communication, April 2015). This residential population addition within the area north of the California Aqueduct represents 3.1-percent of the overall City population, not a significant change in the population due to the proposed development even if there were to be any potential failure impact. As populations grow in the greater Tracy area this percentage will continue to decrease over time.

Seismic Loading Criteria

California Department of Water Resources (2012) published a report describing the seismic loading criteria for State Water Project facilities, including the California Aqueduct, canals, and check structures. The report “provides design engineers with a guideline in selecting appropriate seismic loading criteria for a wide variety of SWP facilities.” Design structural engineers should select the appropriate seismic design load and a procedure or process for analyzing the structure. They further state “Seismic Loading Criteria” (SLC) are being developed to provide guidance to design engineers in the California Department of Water Resources (DWR) for determination of the minimum seismic loading requirement for the design or retrofit of State Water Project (SWP) facilities.”

For CDWR, operational and flooding consequences are the risks considered in defining the SLC for each facility type. The operational consequences are not discussed further here. The flooding consequences can be dependent on: (1) size/length of aqueduct/canal pool section; (2) location and alignment of the aqueduct relative to surrounding uses; (3) volume of discharge; and (4) environmental impacts. Populations located downstream from the aqueduct, or canal, are considered in the determination of the SLC. These considerations are discussed below for the facilities being considered here.

For canals and aqueducts, information about design was found for the North San Joaquin Division and Coastal Branch, which had a horizontal seismic loading of 0.1g (g = force of gravity) that was used in both areas for slope stability analyses. With this seismic load, minimum factors of safety, 1.0 and 1.20, were used for both construction and operation conditions, respectively. For check structures, CDWR indicates that check structures in the San Joaquin Field Division (where the proposed development is located) were designed for seismic loading of 0.1 g. A recent check structure design for the South Bay Aqueduct (SBA) utilized the California Building Code (CBC) and the American Society of Civil Engineers (ASCE) 7-05 Minimum Design Loads for Buildings and Other Structures for structural design including seismic loading. Since then new CBC and ACSE design criteria have become available, and are discussed below.

After considering CBC, ASCE, Army Corps of Engineers (USACE), and Bureau of Reclamation (USBR) seismic criteria, the following are the seismic loading criteria for the SWP facilities being considered herein.

- Aqueducts and Canals - A Consequence Rating (CR) for each canal pool was established based on the estimated population of the inundation area. A “Medium to High Hazard” rating was established for Pool 2 (between Check 2 and 3) considering the potential inundation area has a population of over 10,000 people. This rating should be evaluated using a level of seismic loading for a 500-year earthquake return period.
- Check Structures - Based on operational protocol, check structures should remain in operation during an emergency. Thus, the minimum design loading for a given check structure should be greater than the criteria for the adjacent canals/pools. For check structures the recommended seismic loading to be equal to 1.25 percent of the 10% probability of exceedance in 50 year curve or 475 year return period, which equates to roughly a 1000-year return period, which is greater than the adjacent aqueduct/canal (500-year return period).

2.4.2 Lessons from the May 2, 1983 M6.5 Coalinga Earthquake

Earthquake Parameters

The 1983 Coalinga earthquake occurred on May 2, 1983 in Coalinga, California. The earthquake measured 6.5 (M_L) by the USGS and University of Berkeley (CDMG 1983; USGS 1983) and had a maximum Mercalli Intensity of VIII (Severe). The epicenter was located north of the City of Coalinga on the Great Valley fault segment 13 (GV13) approximately 2.9-miles west of the California Aqueduct (Figure 3). The CDMG installed several accelerographs at various stations within 25 to 140 Km from the epicenter of the earthquake. A strong motion instrument operated by the U.S. Bureau of Reclamation was also installed at the Pleasant Valley Pumping Station, which is part of the California Aqueduct system. The location of the California Aqueduct in relationship to the underlying GV13 fault is analogous to the California Aqueduct location overlying GV07 at Tracy Hills. Earthquake ground shaking records from the switchyard of the Pleasant Valley Pump Station (PVPS) located along the aqueduct near Coalinga indicate the California Aqueduct likely experienced approximately 0.54g (54% the force of gravity) recorded at the PVPS (USGS, 1990; page 387) approximately 5.8 miles northeast of the epicenter. The PVPS switchyard location also experienced 0.22g in a May 9 aftershock (USGS, 1983; Table 3, page 60). The California Aqueduct near the PVPS is approximately 6.8 miles from the epicenter and should have experienced somewhat similar to slightly less ground acceleration. The geologic units at the PVPS and the nearby aqueduct appear to be similar to the proposed development area mainly consisting of Qa-type materials (alluvial fan [Qf] and Qb [basin deposits]), possibly underlain by Qoa-type materials (Jenkins, 1958).

Earthquake Affects on the California Aqueduct and Pump Stations

An extensive assessment was made of damage from the earthquake and no damage to the California Aqueduct was observed or reported by the USGS (1990; pages 381- 408), indicating the design of the aqueduct was sufficient to withstand these reasonably large ground accelerations. A PVPS discharge canal gate (similar to a check structure gate) about 6 miles from the epicenter was not damaged and was disabled due to a broken power supply conduit. A survey of the concrete-lined canal near the discharge gate also revealed no damage. Twenty other pump stations near the epicenter had minor damage of stretched or broken anchor bolts caused by rocking of the stations surge tanks. Cracking of the concrete canal liner and local settlement of the levee enclosing the California Aqueduct was observed near these pumping stations, but with no reported evidence of failure or flooding. Near the El Dorado Bridge south of Route 145 (Klein, 1983) it was reported that there was no damage to the channel lining visible above the waterline.

2.4.3 Seismic Loading Analysis Results

Overall Methodology

Seismic analyses include an evaluation of the Maximum Credible Earthquake (MCE) and the Operating Basis Earthquake (OBE). The MCE is defined as the greatest earthquake that can reasonably be expected to be generated by a specific fault. The OBE is an earthquake that can reasonably be expected to occur with a 50 percent probability of exceedence during the service life. Multiple MCE’s may be defined for a site, each with characteristic ground motion parameters and spectral shape. The MCE is determined by a Deterministic Seismic Hazard Analysis (DSHA). The OBE is determined by a Probabilistic Seismic Hazard Analysis (PSHA). In the deterministic analyses, the 50th and/or 84th percentile deterministic design ground motions are usually considered. The probabilistic analyses require a return period.

As previously discussed, the Central and San Joaquin Valleys lie within a seismically active area as does most of California. California Department of Water Resources (2012) published a report describing the seismic loading criteria for State Water Project facilities, including the California Aqueduct, canals, and check structures. The report "provides design engineers with a guideline in selecting appropriate seismic loading criteria for a wide variety of SWP facilities." Design structural engineers should select the appropriate seismic design load and a procedure or process for analyzing the structure. They further state "Seismic Loading Criteria" (SLC) are being developed to provide guidance to design engineers in the California Department of Water Resources (DWR) for determination of the minimum seismic loading requirement for the design or retrofit of State Water Project (SWP) facilities." The DWR published response spectra for 18 stations along the aqueduct system. Each plot includes spectra based on probabilistic analyses (200, 500, 1000, 3000 return periods), deterministic (median and 84th percentile), ASCE 7-05 and ASCE 07-10.

A response spectrum is used to provide the most descriptive representation of the influence of a given earthquake on a structure or machine. It includes a plot of spectral (peak or steady state) acceleration within structures with various oscillating periods. The spectral acceleration corresponding to zero period is the PGA.

Results of Comparison to the Affects of the Coalinga Earthquake

The Coalinga earthquake magnitude of 6.5 and a peak ground acceleration of 0.54g measured at the Pleasant Valley Pump Station 4.5 miles from the epicenter are comparable with the modal (the most likely values) magnitude (M) of about 6.58 and distance (R) of about 7.2 kilometers (km) obtained from the probabilistic seismic analyses performed on selected stations along the relevant aqueduct. However, the peak ground acceleration of 0.54g measured at the Pleasant Valley is significantly greater than peak ground accelerations of approximately 0.35g and 0.48g associated with a return period 0f 475 and 975 years, respectively. In other words, the Pleasant Valley station and the adjacent aqueduct portion performed adequately when subjected to an earthquake comparable in magnitude and distance from the epicenter of the earthquake, and yet with much higher ground acceleration than the reported design acceleration of 0.1g or even the anticipated ground acceleration from seismic analyses. This case history, if viewed as an indicator of the anticipated performance of the aqueduct under consideration when subjected to the design earthquake, the aqueduct should be expected to perform adequately.

Results of Calculating Ground Shaking at Multiple Locations Using the Caltrans and USGS Methods

We performed seismic analyses on four locations (CA-1, CA-2, CS-2 and CS-3) along the canal and aqueduct (Figure 5; Table 1). The analyses include probabilistic and deterministic analyses. Seismic probabilistic hazard analyses were performed using the USGS 2008 Interactive Deaggregation web site (Figure 6A). Return periods of 224, 475, 975, and 2475 were considered in the analyses. We also utilized the Caltrans ARS Online (v2.3.06) to supplement the analyses with deterministic ASCE 7-10 based response spectra (Figure 6B).

Table 1 – Aqueduct and Canal Facilities Evaluated in the Seismic Analyses

FACILITY	LOCATION NUMBER	LATITUDE NORTH	LONGITUDE WEST
California Aqueduct	CA-1	37.70517	121.49806
	CA-2	37.69192	121.47588
Check Structures	CS-2	37.71675	121.52881
	CS-3	37.66642	121.43977

One of the stations included in the CDWR report is the Banks Pumping Station, which is the closest to the aqueduct segment under consideration. Based on a review of Figures 4 and 6, results of seismic analyses performed on selected stations along the canals and aqueduct are very similar to the corresponding values from the Banks Pumping Station and the Pleasant Valley Pump Station from the 1983 Coalinga earthquake. As such, the seismic demand at the aqueduct is comparable and consistent with published SLC by the CDWR.

Table 2 – Comparison of Design PGA with PGA Recorded at Pleasant Valley Pump Station in the 1983 Coalinga Earthquake

FACILITY	LOCATION NUMBER	PGA (g)
California Aqueduct (475-Year RP)	CA-1	0.35g[a]
	CA-2	0.33g[a]
Check Structures (975-Year RP)	CS-2	0.48g[a]
	CS-3	0.48g[a]
Coalinga Aqueduct (475/975 Year RP)	2.9 miles East of the Coalinga EQ epicenter	0.33/0.46[a]
Pleasant Valley Pump Station (Coalinga Earthquake Area)	Pump Station Switch Yard	0.54g (measured) [b]

a. Design PGA Value
b. Measured during 1983 Coalinga earthquake.

As shown in Table 2, the design PGA for the California Aqueduct and the Check Structures are less than the PGA experienced by the Pleasant Valley Pump Station due to the similar magnitude Coalinga Earthquake

3.0 SUMMARY AND CONCLUSIONS

3.1 Aqueduct/Canal Topography and Slope Direction

Both the California Aqueduct and Delta-Mendota Canal were evaluated for seismic ground shaking at the proposed development area. Development is proposed down slope (north) from the California Aqueduct, but not the Delta-Mendota Canal, therefore there should be no significant impact on the proposed development area as the result of a failure of the Delta-Mendota Canal. It is understood that water levels are similar to the California Aqueduct, at or below surrounding topography. Flooding, rapid water flow and erosion concerns are not believed to be potential risks at locations adjacent to and higher in elevation than the aqueduct or canal (Figure 7). Any minor up slope affects (e.g., headward erosion, ground saturation) of a breach in the aqueduct or canal should be contained within the 100-feet wide “buffer” area bordering the aqueduct and the canal. Therefore, the area of concern due to a potential aqueduct or canal failure is between the California Aqueduct and the Delta-Mendota Canal.

With regard to flooding down slope (north) from the aqueduct, the aqueduct’s trapezoidal design carries water below grades adjacent to the proposed development area as opposed to a levee type system, which stands above surrounding topography. As shown in Figure 7, a characteristic cross-section near Corral Hollow Road shows the aqueduct level is roughly elevation 241- to 242-feet. On the down slope (north) side, flooding could occur as the ground adjacent to the aqueduct becomes saturated, the ground settles, and water seeks the lower elevations to the north farther from the aqueduct. There is no reasonable scenario where a breach in the aqueduct or canal can raise flood waters to the south side of either the aqueduct or the canal.

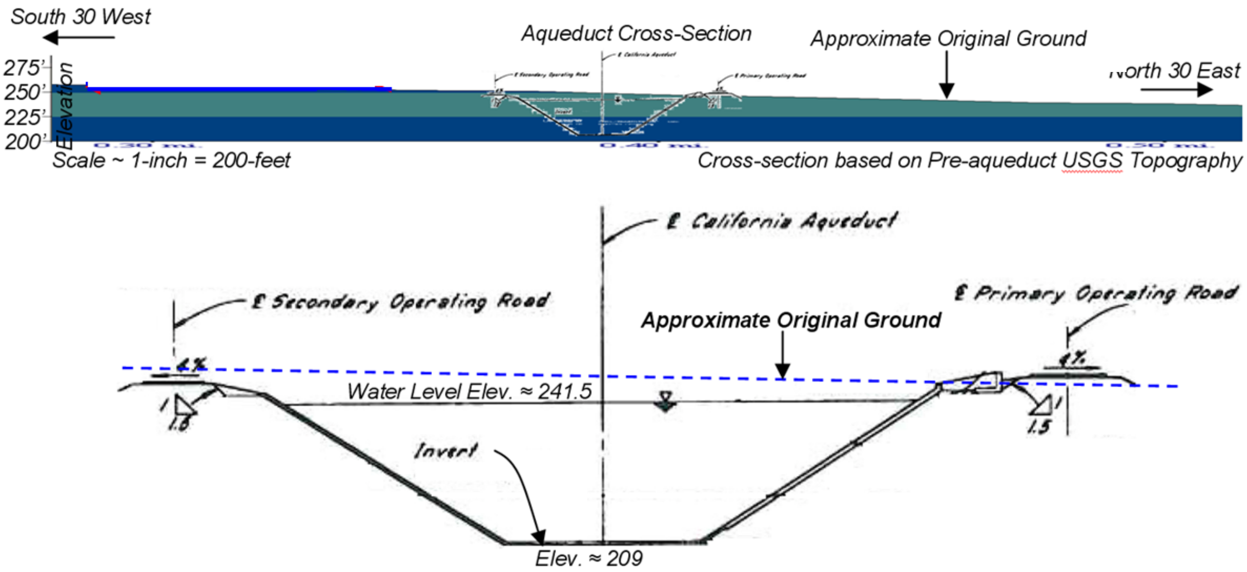

FIGURE 7 - Representative Aqueduct Cross-Section Adjacent to Proposed School Site (CDWR, 1964)

3.2 Geotechnical and Geologic Considerations

Geotechnical and geologic conditions within the proposed development area adjacent to, and down slope from, the California Aqueduct are characterized by both older and younger alluvial formations. Based on borings, laboratory testing, and analysis from two previous geotechnical reports (TERRSEARCH, 1990; Kleinfelder, 2000), we believe that the California Aqueduct and Check 2 and 3 foundations are predominantly within older alluvium which provides very good foundation support for the aqueduct.

3.3 Seismic Loading Considerations

The seismic evaluation was conducted using state-of-the-practice analysis tools from the USGS and Caltrans. Results of the seismic loading analysis compared to the CDWR seismic loading criteria for the aqueduct, canal, and check structures suggest that the level of seismicity expected at these locations is consistent with the current design criteria considered by the CDWR. The seismic loading associated with the current design criteria is higher than the seismic loading considered in the design of the aqueducts, canals, and check stations. However, when similar aqueducts and structures were subject to ground shaking comparable in magnitude to the design earthquake and higher peak ground acceleration, they seemed to perform adequately as noted by published observations after the Coalinga earthquake.

Based on published maps, no known active or potentially active is traversing the site; hence the potential for ground rupture to affect the existing aqueduct, canal, or check structures is considered to be remote. Furthermore, the potential for liquefaction and related hazards is also considered low due to the depth of historical groundwater and the density of underlying materials.

4. TECHNICAL CONSIDERATIONS AND LIMITATIONS

The purpose of this report is to provide a professional opinion regarding the likelihood that earthquake shaking-induced failures of the California Aqueduct, the Delta-Mendota Canal, or Check Structures 2 and 3 would create risks affecting construction within the boundaries of the proposed development area as defined (see Figures 1, 2, and 3). This report does not present a structural analysis that satisfies the 2013 California Building Code (CBC) or other regulations governing construction of the facilities discussed. This report presents a review and analysis of the seismic parameters of the 2013 CBC and the CDWR Division of Engineering that defines the risk and concludes that aqueduct, canal, and check structures fall within an acceptable range of risk for the down stream populations present near the proposed development area.

Our interpretations and conclusions presented in this report are based on experience conducting similar risk assessments for other projects in California, and reviewing a 2012 report by the CDWR for analogous conditions. The CDWR states “This report is intended for DWR use for SWP facilities. It reflects the current state of practice at DWR. This report contains references specific and unique to DWR and may not be applicable to other public or private parties and agencies.” In addition, USGS topographic maps, aerial photographs and the scales determined from the documents provided by Ruggeri~Jensen~Azar (for Integral Communities, 2013), and Google Earth (2013) were used to determine some lengths and distances used in this analysis. Final development plans and designs, and decisions to adopt recommendations in this report are the responsibilities of others. The aqueduct, canal, and check structure risk assessment process cannot predict future events or their likelihood and, therefore, this report provides an estimate of the likelihood and magnitude of certain events that may occur. Events can occur that are not foreseen at this time. Wilson Geosciences Inc. and GeoDynamics, Inc. make no warranties either expressed or implied regarding the content of this report.

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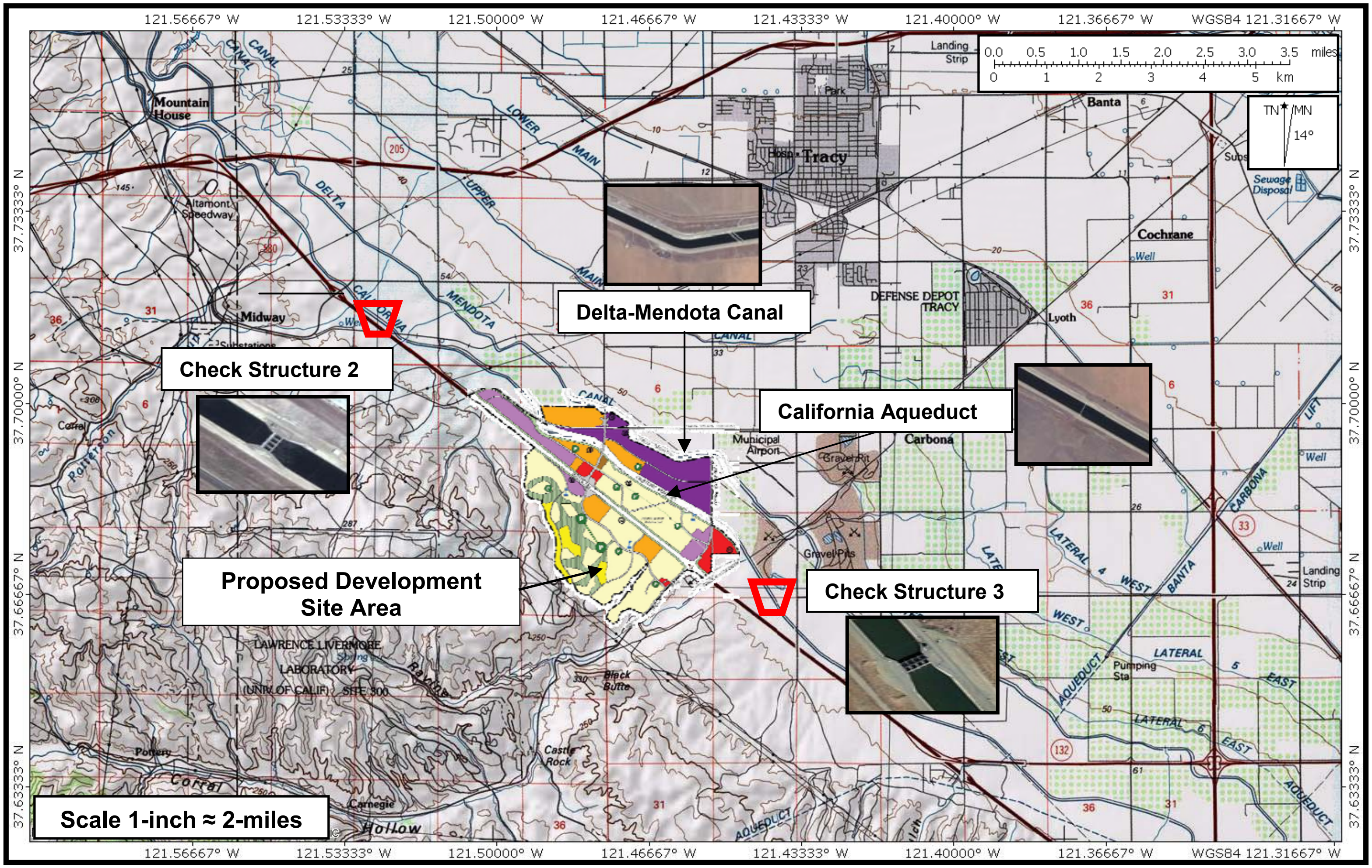
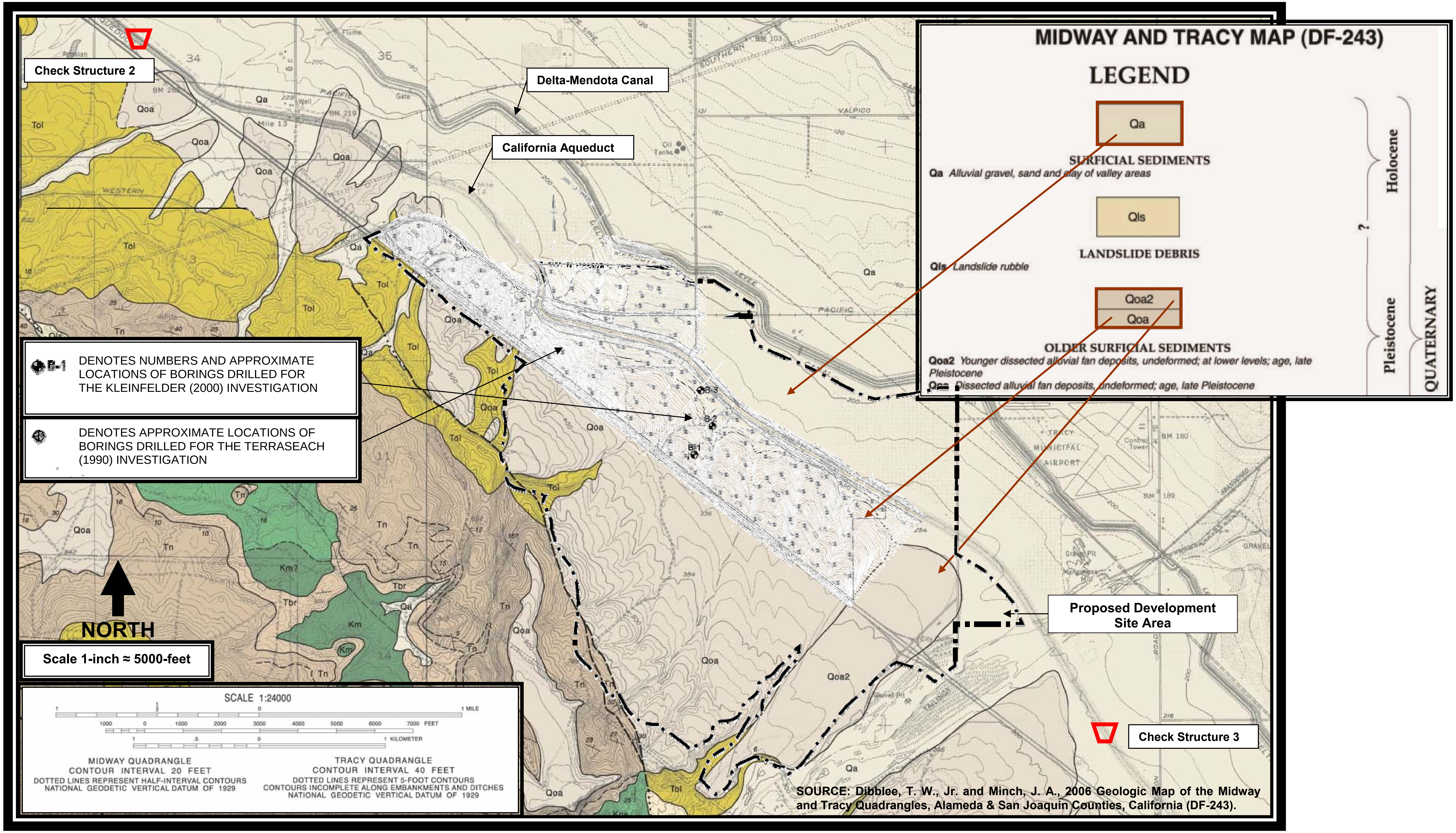
APPENDIX—FIGURES



SOURCE: United States Geological Survey Topographic Maps, Scales 1:100,000 and 1:24,000 (Tracy, 1981).

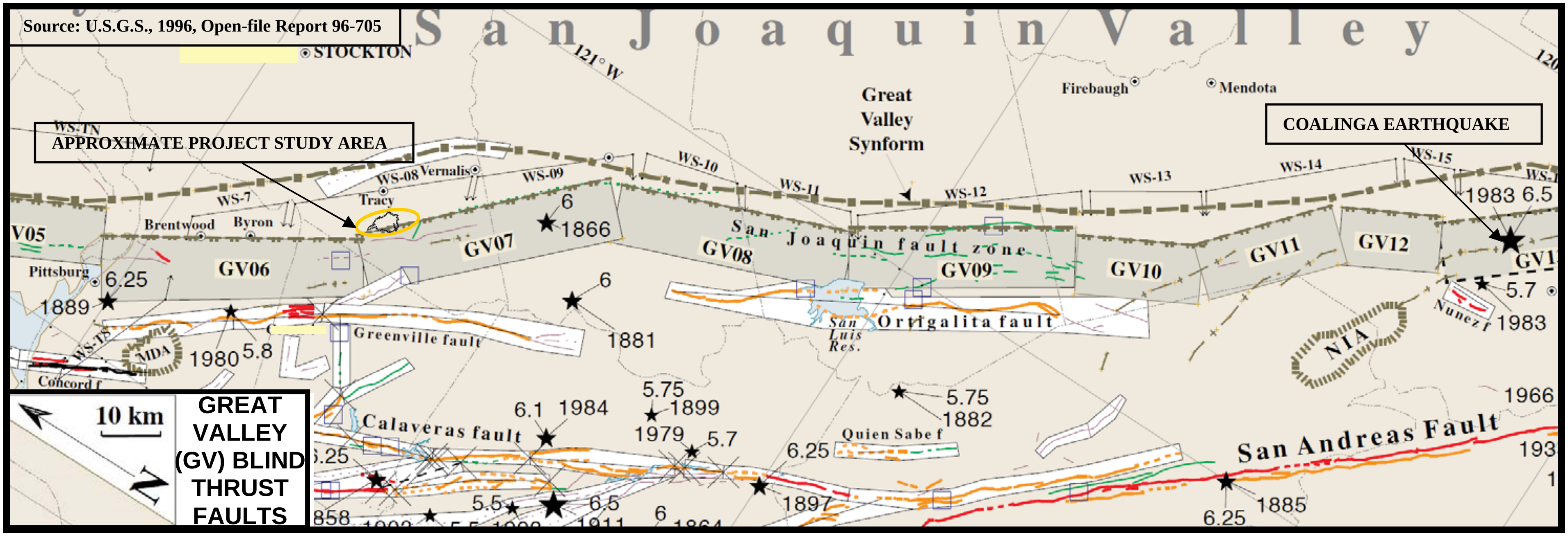
FIGURE 1 - LOCATION MAP FOR THE PROPOSED TRACY HILLS DEVELOPMENT SITE, CITY OF TRACY, CALIFORNIA

NORTH



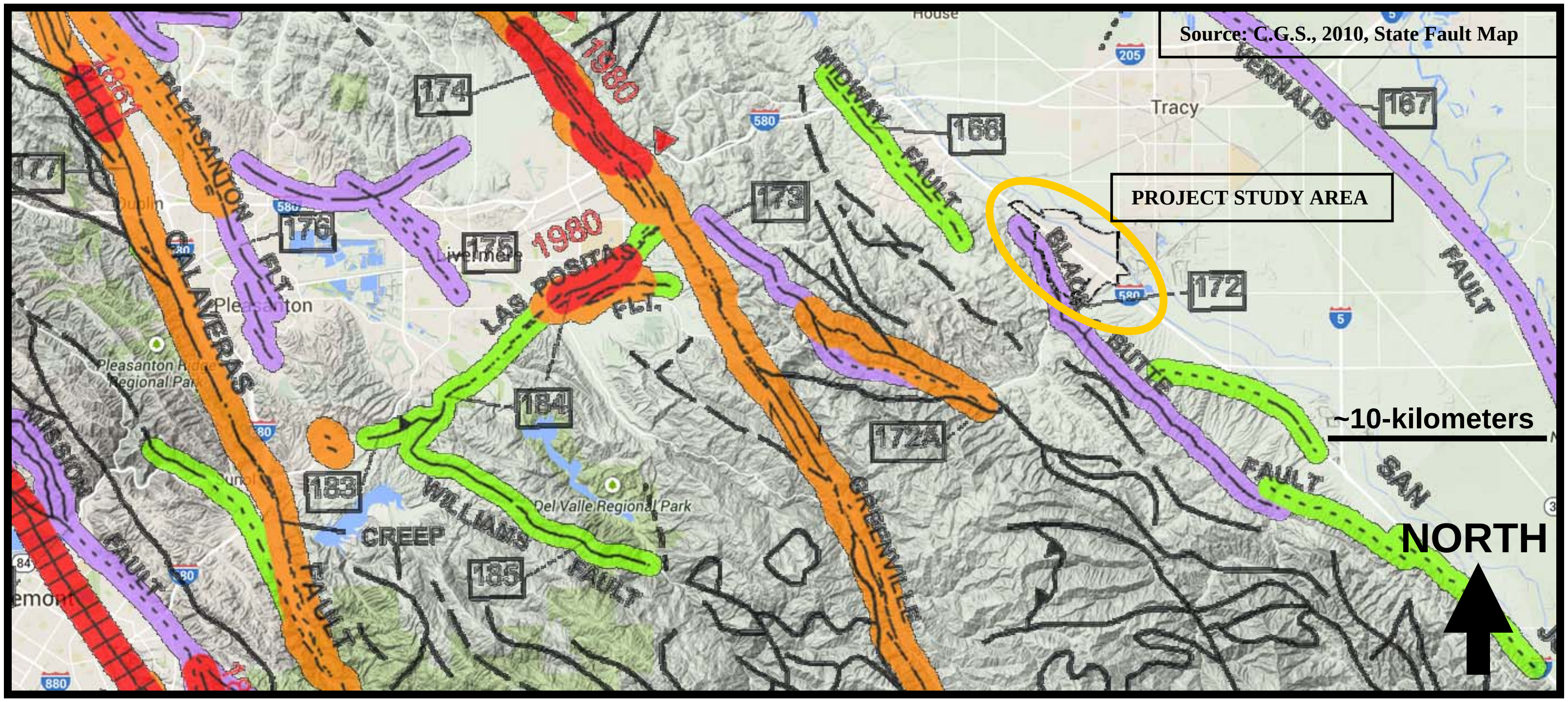
SOURCE: Dibblee, T. W., Jr. and Minch, J. A., 2006 Geologic Map of the Midway and Tracy Quadrangles, Alameda & San Joaquin Counties, California (DF-243).

FIGURE 2 - GEOLOGIC MAP FOR THE PROPOSED TRACY HILLS DEVELOPMENT SITE, CITY OF TRACY, CALIFORNIA



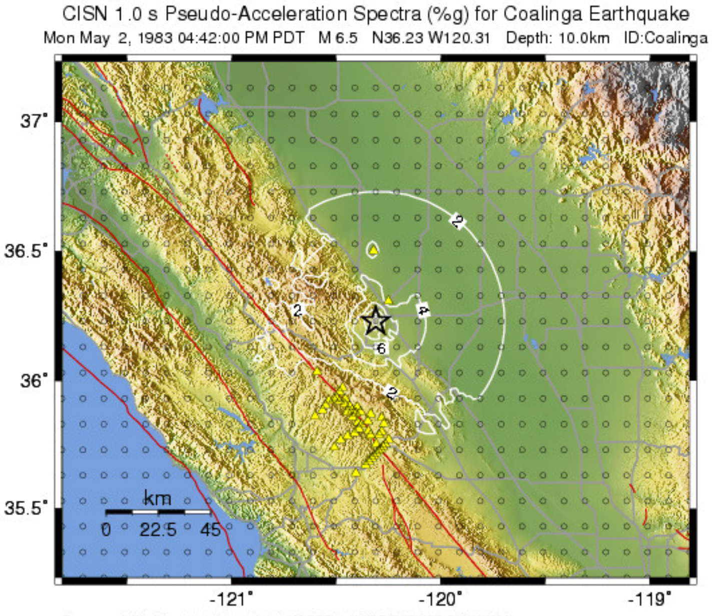
Source: U.S.G.S., 1996, Open-file Report 96-705

FIGURE 3 – REGIONAL FAULTS AND EARTHQUAKES POTENTIALLY AFFECTING THE PROPOSED TRACY HILLS DEVELOPMENT SITE, CITY OF TRACY, CALIFORNIA



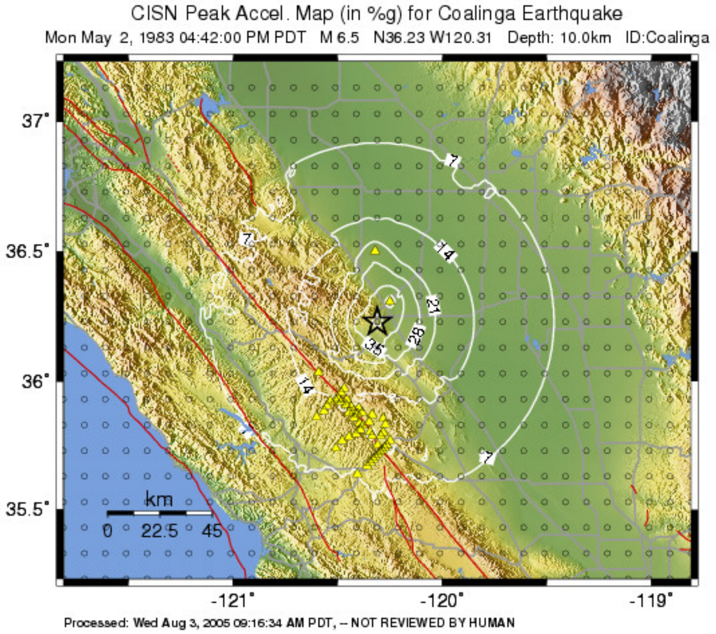
Source: C.G.S., 2010, State Fault Map

FIGURE 4 – 1983 COALINGA GREAT VALLEY FAULT EARTHQUAKE PARAMETERS, SAN JOAQUIN VALLEY, CALIFORNIA

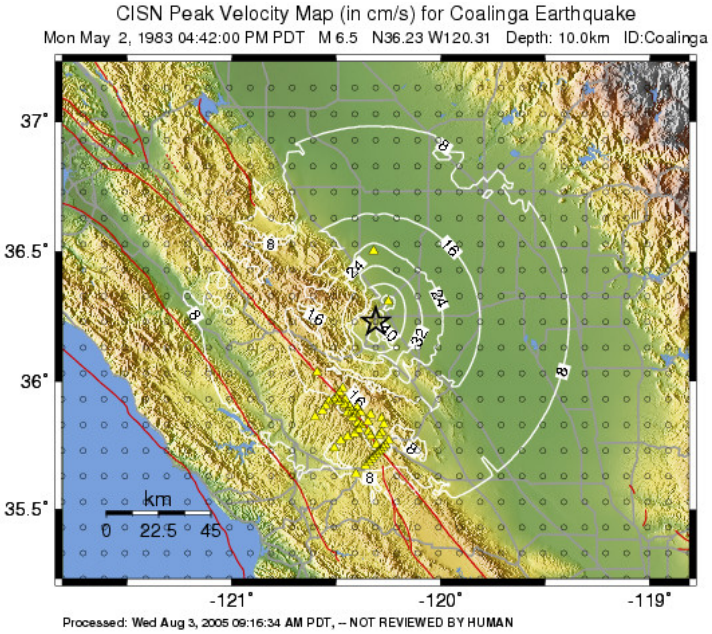


PSEUDO-ACCELERATION SPECTRA FOR 1.0 SECOND PERIOD

PEAK ACCELERATION



PEAK VELOCITY



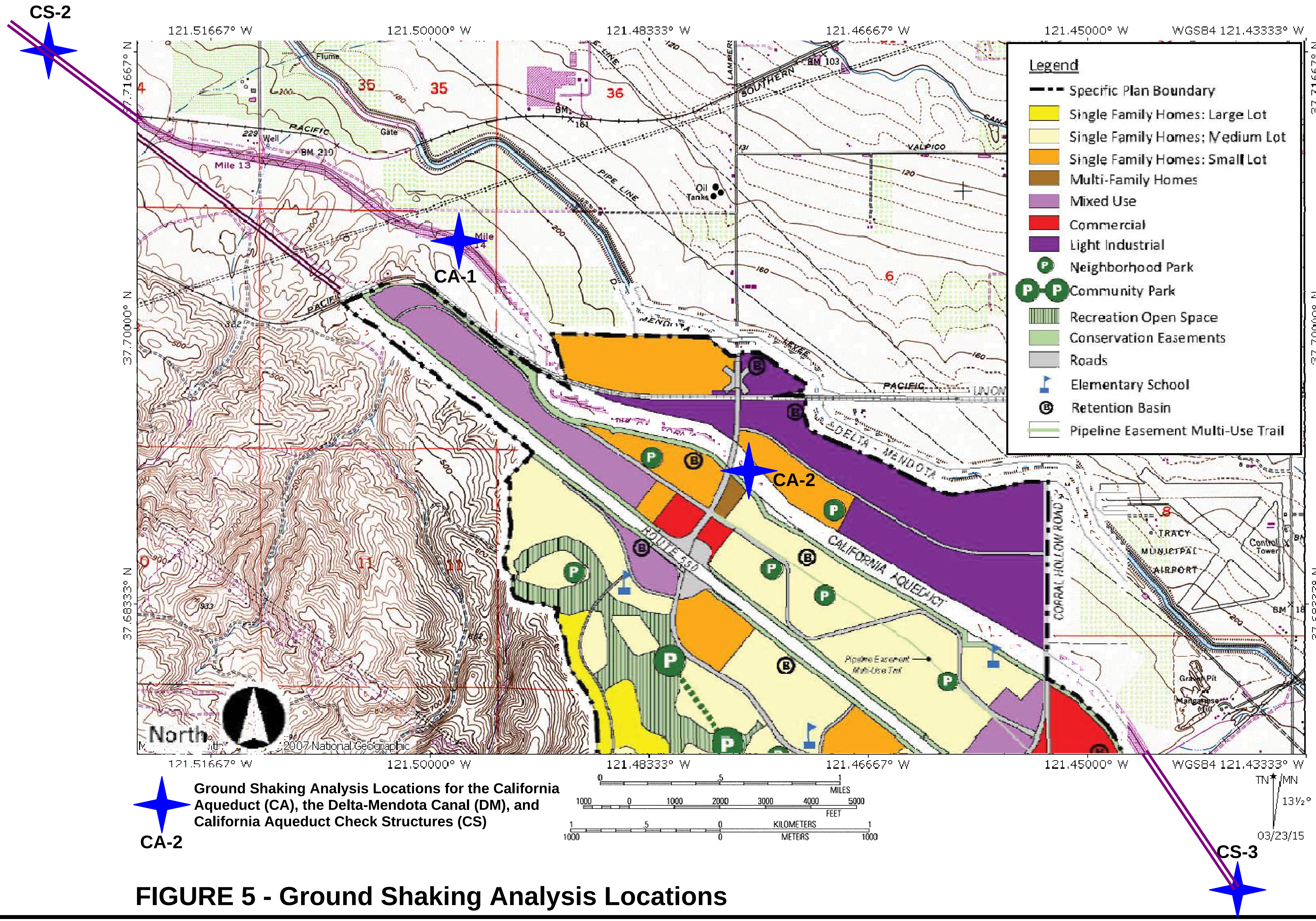


FIGURE 5 - Ground Shaking Analysis Locations

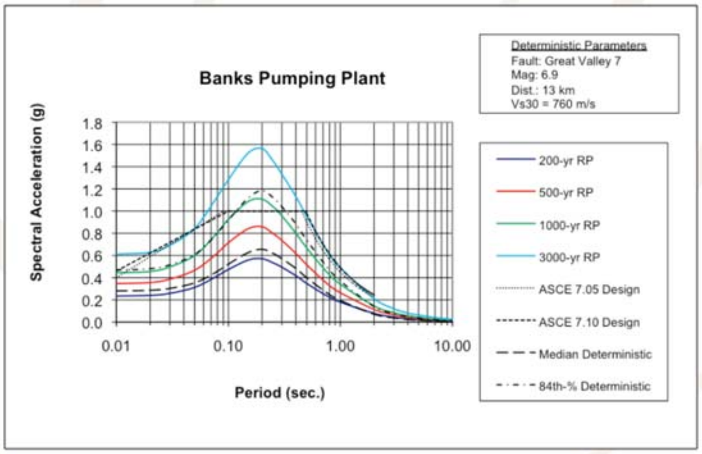
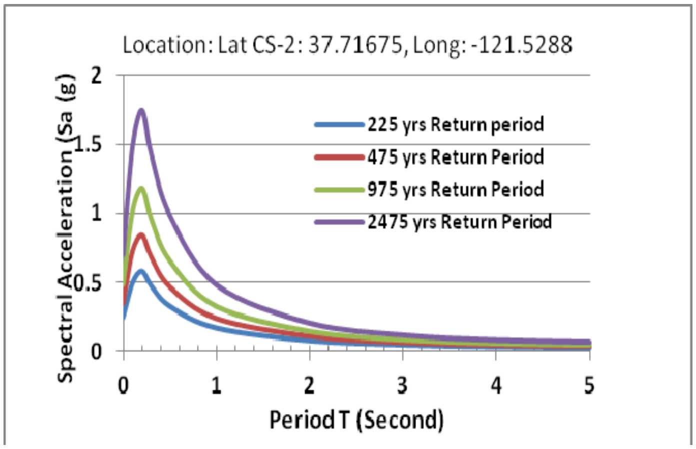
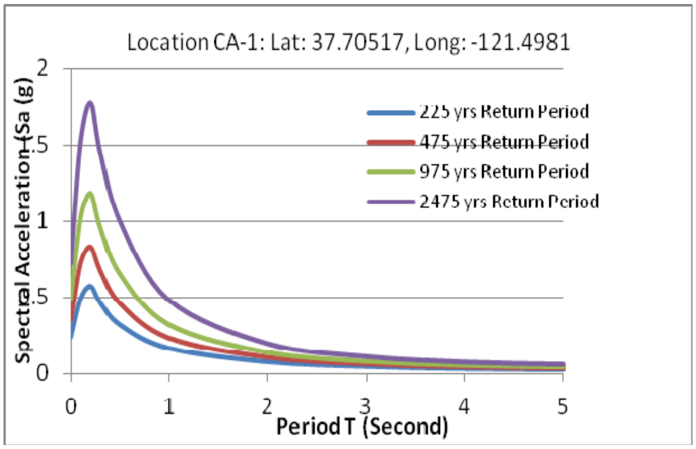


Figure A.10
Banks Pumping Plant Estimated Ground Motions

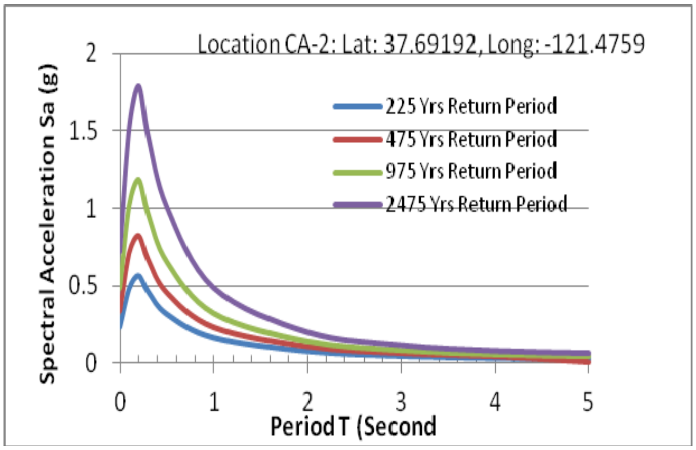
(CDWR, 2012; Figure A.10)



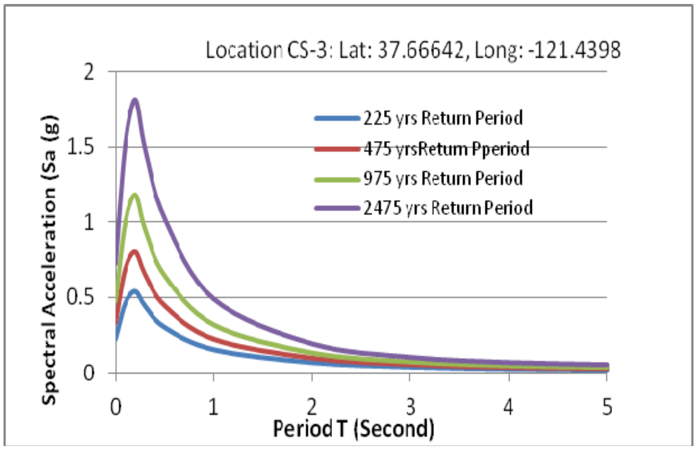
CHECK STATION CS-2 (See Figure 5)



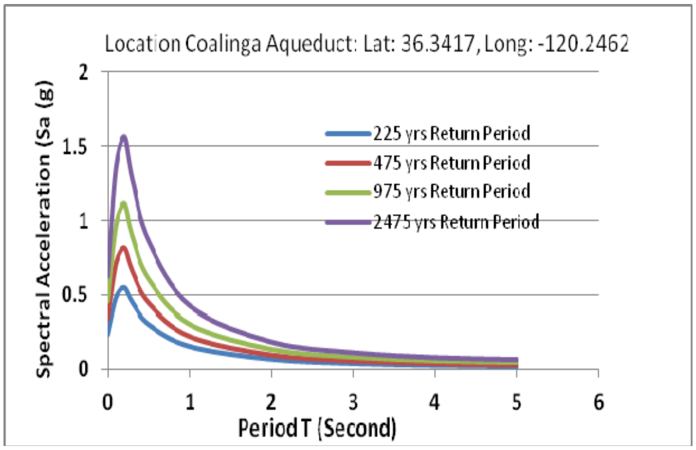
CALIFORNIA AQUEDUCT STATION CA-1 (See Figure 5)



CALIFORNIA AQUEDUCT STATION CA-2 (See Figure 5)



CALIFORNIA AQUEDUCT STATION CS-3 (See Figure 5)



COALINGA PLEASANT VALLEY PUMP STATION CS-3

FIGURE 6A – USGS Response Spectra: State Water Project Banks Pumping Plant, Four Representative Site Area, and the 1983 Coalinga Earthquake

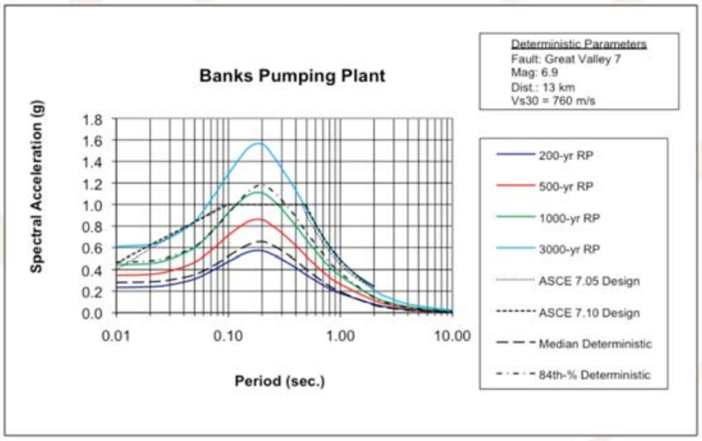
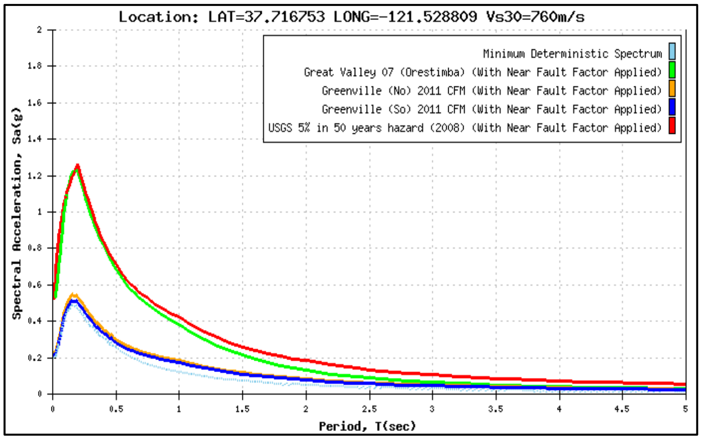
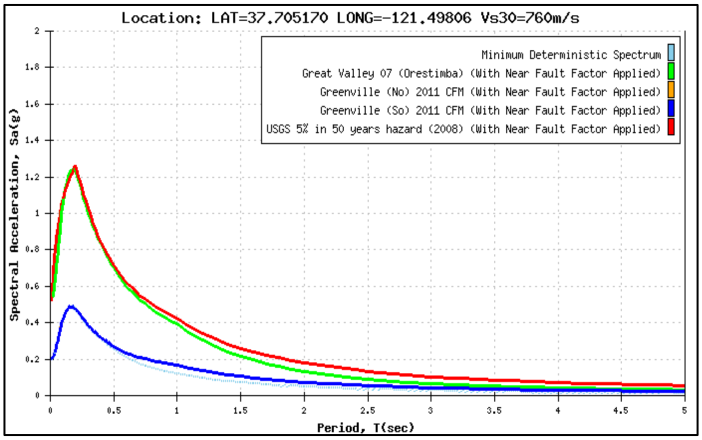


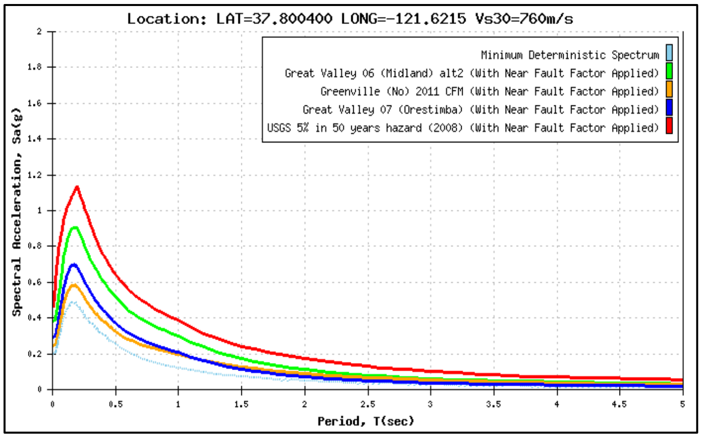
Figure A.10
Banks Pumping Plant Estimated Ground Motions (CDWR, 2012; Figure A.10)



CHECK STATION CS-2 (See Figure 5)



CALIFORNIA AQUEDUCT STATION CA-1 (See Figure 5)



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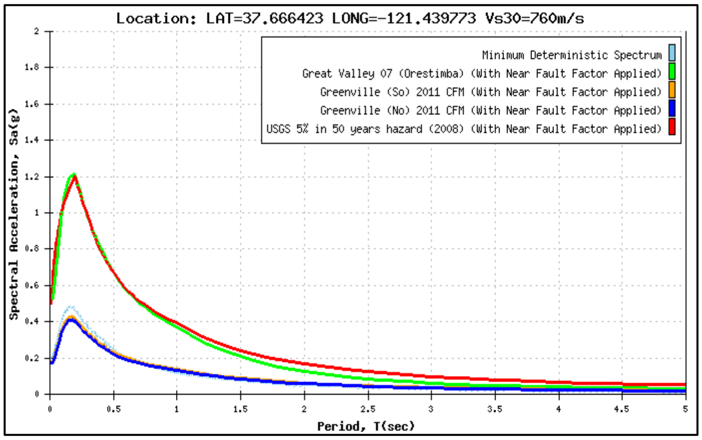

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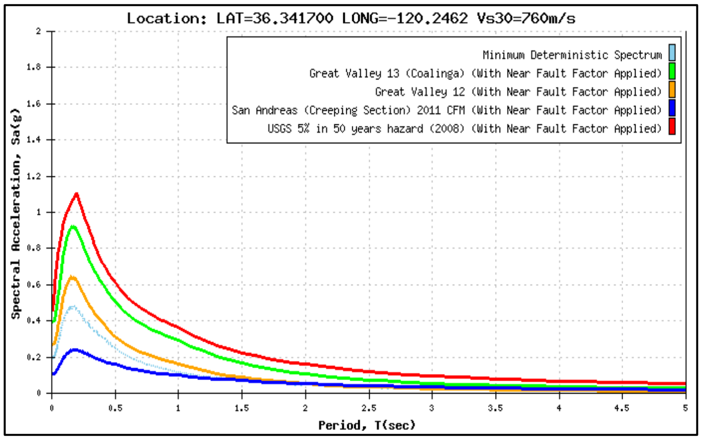

COALINGA PLEASANT VALLEY PUMP STATION CS-3

FIGURE 6B – Caltrans Response Spectra State Water Project Banks Pumping Plant, Four Representative Site Area, and the 1983 Coalinga Earthquake