Table 3-1: Probabilistic Seismic Hazards for Modified Pipeline/Tunnel Clifton Court Option Facilities

Location[a]	500-year PGA mean	500-year PGA 85th %	1,000-year PGA mean	1,000-year PGA 85th %
Intake No. 2	0.23	0.25	0.27	0.30
Intake No. 3/Junction Structure	0.23	0.25	0.27	0.30
Intake No. 5	0.24	0.26	0.29	0.32
Intermediate Forebay	0.24	0.26	0.29	0.31
Staten Island Reception Shafts	0. 27	0.29	0.32	0.35
Bouldin Island Drive Shafts	0.31	0.33	0.37	0.40
Bacon Island Reception Shafts	0.35	0.40	0.45	0.51
Clifton Court Forebay (North & South CCF)	0.40	0.45	0.50	0.57

[a] Stiff Soil, Site Class D was assumed for each location.
Notes:
% = percent(ile)
PGA = peak ground acceleration

For a more detailed description of Delta probabilistic ground motions, see Appendix A and the DRMS Seismology report (DWR, 2007).

The preliminary probabilistic ground motions provided above represent the PGA at the ground surface, underlain by stiff soil conditions. These ground motions should be confirmed and verified during preliminary and final design based upon facility locations and site-specific subsurface exploration, testing, and ground motion analyses. For ground motions at depth, it can be assumed that the ground motions generally decrease with depth bgs. The attenuation of the ground motion with depth can be determined through site-specific dynamic site response analyses to account for subsurface conditions and site geometry. At 100-foot depth, the horizontal acceleration is estimated to be 70 percent of the ground surface motion (Federal Highway Administration [FHWA], 2009). The proposed depths of the tunnels are between 100 to 200 feet bgs. For the conceptual level design, and in the absence of more rigorous analyses, a value of approximately one-half of the surface PGA was assumed for structural analyses of the buried tunnel linings.

3.4.1.2 Deterministic Seismic Hazard Analyses for Forebay Locations

The IF and CCF embankments will be under the jurisdiction of DSOD, based on the embankment height and water storage volumes exceeding the conditions for a low hazard, non-jurisdictional dam. Per current DSOD guidelines, the design seismic ground motion should be based on a deterministic analysis of nearby fault sources. The hazard level for the deterministic analysis is dependent upon the consequences of failure of the dam. Based on the estimated hazard level (moderate, bordering on high) for the forebay embankments, the appropriate statistical level of acceleration for deterministic seismic hazard analyses is between the 50th and 84th percentile, or between the mean and 1 standard deviation above the mean values from attenuation relationships. The actual value used between the DSOD-required statistical range is dependent upon the recurrence interval that is reasonable for the project. A maximum average annual return period of 1,000 years is being used as a ceiling for the forebay deterministic values.

For the deterministic seismic hazard analysis at the forebay locations, PGA values were estimated from the occurrences of earthquakes on the crustal faults near the forebays. For the crustal faults, the next generation attenuation (NGA) attenuation relationships, as developed by Abramson and Silva (2008), Boore and Atkinson (2008), Campbell and Bozorgnia (2008), and Chiou and Youngs (2008), were used to estimate the PGA values. The deterministic PGA values reported herein are the average of the four attenuation relationships. For faults of similar magnitude, only the nearest fault was analyzed, unless the fault type mechanism was different and warranted an evaluation.

Intermediate Forebay. A summary of the considered nearby active faults and preliminary deterministic PGA values resulting from attenuation using the NGA relationships for controlling faults is provided in Table 3-2 for the IF. Faults with the same or lower magnitude than other faults closer to the project facilities were not analyzed. These PGA values should be confirmed and verified during preliminary and final design.

Table 3-2: Summary of Active Faults Surrounding Intermediate Forebay and Deterministic Ground Motions

Fault Name	Distance to Fault Surface Trace from Project (kilometers and direction)	Characteristic Magnitude[a]	Slip Rate (mm/year)[a]	Deterministic Median PGA (g)	Deterministic 84th % PGA (g)
Thorton Arch Zone	0	6.5	0.2	0.36	0.57
Northern Midland Zone	16 west	6.5	1	Not analyzed	Not analyzed
Montezuma Hills Zone	22 southwest	6.5	0.5	Not analyzed	Not analyzed
Pittsburg-Kirby Hills Fault	38 northwest	6.7	0.7	Not analyzed	Not analyzed
Coast Ranges-Sierran Block	43 west	6.8	2.0	0.14	0.23
Foothills Fault Zone	52 east	7.0	0.8	0.10	0.17
Greenville Fault	56 southwest	6.9	6	0.08	0.13
South Hayward Fault	80 southwest	7.3	9	0.08	0.13
San Andreas Fault	109 southwest	7.9	24	0.08	0.13

[a] Characteristic magnitudes and slip rates are based on maximum values from the DRMS report (DWR, 2007).

Notes:

% = percent(ile)
g = measurement of peak ground acceleration
mm/year = millimeter(s) per year
PGA = peak ground acceleration

The largest estimated site acceleration for the IF is from possible active blind faults beneath the Delta.

From Table 3-2, the maximum deterministic mean PGA at the IF is 0.36 g, while the maximum 84th percentile PGA is 0.57 g. From Table 3-1, the 1,000-year 85th percentile probabilistic PGA of 0.31 is lower than the 50th percentile deterministic ground motions. The 84th percentile deterministic ground motions will be used for the conceptual design PGA at the IF.

North and South Clifton Court Forebay. A summary of nearby active faults and deterministic PGA values is provided in Table 3-3 for the NCCF and the SCCF.

The West Tracy fault passes through the NCCF and SCCF area; however, the slip rate and seismic recurrence rate for the West Tracy fault is low. This explains why the probabilistic values presented in Table 3-1 are lower than the deterministic values shown in Table 3-3 for recurrence intervals of less than 1,000 years. The probabilistic 85th percentile, 1,000-year PGA for the NCCF is 0.57 g, which is bracketed by the 50th and 84th percentile maximum deterministic ground motions of 0.47 g and 0.75 g (as shown in Table 3-3). Therefore, the probabilistic 85th percentile was used as the ground motion for the conceptual design at the NCCF.

Table 3-3: Summary of Active Faults Surrounding North and South Clifton Court Forebay and Deterministic Ground Motions

Fault Name	Distance to Fault Surface Trace from Project (kilometers and direction)	Characteristic Magnitude[a]	Slip Rate (mm/year)[a]	Deterministic Median PGA (g)	Deterministic 84th % PGA (g)
West Tracy Fault	0	6.75	0.5	0.47	0.75
Southern Midland Fault	5 northwest	6.6	1	Not analyzed	Not analyzed
Midway/Black Butte Faults	7 southwest	6.75	1	Not analyzed	Not analyzed
Vernalis Fault	8 southeast	6.75	0.5	Not analyzed	Not analyzed
Greenville Fault	16 southwest	6.9	6	0.21	0.35
Montezuma Hills Zone	17 northwest	6.5	0.5	Not analyzed	Not analyzed
Mt. Diablo – South Fault	25 west	6.7	5	0.27	0.44
Calaveras Fault	35 southwest	6.9	20	Not analyzed	Not analyzed
Concord/Green Valley Fault	38 northwest	6.7	5	Not analyzed	Not analyzed
South Hayward Fault	45 southwest	7.3	9	0.13	0.21
Foothills Fault Zone	73 East	7.0	0.8	0.08	0.13
San Andreas Fault	76 southwest	7.9	24	0.11	0.19

[a] Characteristic magnitudes and slip rates are based on maximum values from the DRMS report (DWR, 2007).

Notes:

% = percent(ile)
g = measurement of peak ground acceleration
mm/year = millimeter(s) per year
PGA = peak ground acceleration

3.4.1.3 Surface Fault Rupture Hazard

None of the faults or fault sources in the Delta are known to have produced surface rupture in the Holocene (approximately the last 12,000 years). Of the four seismic sources described previously, the Southern Midland fault is perhaps the most likely to rupture to the ground surface during a future earthquake. Recent research described in the DRMS Seismology Report (DWR, 2007) indicates that the Southern Midland fault may offset the contact between Holocene peat deposits and the underlying sandy deposits by approximately 2 to 4 meters. However, this relationship is not well constrained, and it is possible that the apparent offset may result from landscape features existing prior to encroachment of sea level and formation of peat in the Delta. The above-described potentially fault-related offset of a geologic horizon thought to be 6,000 to 7,000 years old is the strongest evidence for potential surface rupture in the Delta. The risk of surface rupture occurring in the Delta is therefore low.

3.4.1.4 Liquefaction

Minimum penetration resistance values of levee foundation materials have been compiled from thousands of borings during the DRMS study (DWR, 2008a). A large fraction of the borings contains loose sands with blow count values less than 15. When saturated, these foundation loose sands, which are most common in the west central part of the Delta, are highly susceptible to liquefaction. In addition, levee fills in many places are composed of silty sands that also are susceptible to liquefaction. The Delta levees that have loose, saturated sand in their foundations, and are composed of silty sand, may liquefy during future moderate to strong shaking, resulting in levee failure (DWR, 2008b).

A preliminary assessment of the potential for liquefaction occurring at the proposed MPTO/CCO intake facility locations and in the vicinity of the general project alignment was evaluated using the data obtained from recent borings and CPT soundings. The liquefaction analyses were performed in general accordance with procedures that were developed by a consensus of the participants of the National Center for Earthquake Engineering Research workshops (Youd et al., 2001). The potential for liquefaction is estimated by calculating the estimated cyclic stress ratio induced by the design ground motion and compared with the capacity of the soil to resist liquefaction, expressed in terms of the cyclic resistance ratio. The risk of liquefaction is considered significant where the ratio of cyclic resistance ratio to cyclic stress ratio, or factor of safety, is less than 1.0.

For purposes of the preliminary liquefaction analyses, a horizontal PGA corresponding to the probabilistic 85th percentile, 1,000-year ground motion was used for the forebay locations, and the probabilistic median 500-year ground motion was used for all other facility locations. An earthquake magnitude of M6.75 was assumed, as defined in Appendix A. The depth to groundwater that was observed at each boring or CPT location was assumed to be the water level at the time of the earthquake event.

At each project facility, the borings and/or CPT soundings that were observed to have the most critical conditions for liquefaction, based on the presence of sand and silt materials with either low blow counts or low cone resistance, were evaluated as described above.

Final design liquefaction analyses should be performed when final seismic design criteria for the MPTO/CCO facilities have been adopted and design-level site-specific geotechnical exploration and testing have been completed.

Intakes. The risk of liquefaction at two of the three intake locations (Intakes No. 2 and 5) was preliminarily identified as high for a significant portion of the soils above elevation -65 feet. The estimated ground settlement following the selected earthquake for analysis (probabilistic 500-year average annual return period) was estimated to be 24, 17, and 24 inches at Intakes No. 2, 3, and 5, respectively. It should be noted that the nearest subsurface information available at the intake locations was from borings conducted from over the water adjacent to the intake sites. Additional exploration is currently proposed at the intake locations over land, which could encounter significantly different conditions.

Intermediate Forebay. No site specific subsurface information was available for the Glanville Tract IF. Based on information from a soil boring (DCE-DH-003) and a CPT (DCE-CPT-009) completed in the year 2009 and located about one mile and a half from the IF, it appears that the risk of liquefaction would be low. However, historical borings completed in the year 1966 and located about a mile from the IF show the presence of sandy materials susceptible to liquefaction at depths of 12 to 15 feet and 30 to 35 feet below ground surface.

North and South Clifton Court Forebays. Available subsurface information indicates that the potential for liquefaction exists along all sides of the expanded Clifton Court Forebay. Preliminary liquefaction analysis shows that the estimated ground settlement following the design earthquake at the forebay site to be 1 to 6 inches along the west and south sides, which, given the relatively flat embankment slopes, is not considered likely to result in failure of the embankment. As more subsurface data is collected, additional liquefaction analyses should be performed to evaluate embankment stability and to determine potential mitigation measures

North Tunnels. For the North Tunnels, the liquefaction results from the intakes and the IF were judged to be representative, in the absence of additional data. The North Tunnel appears to be founded below the elevation where liquefaction has been identified at these locations. Liquefaction-induced settlement of pad fill at the intake tunnel shafts, and the junction structure near Intake No. 3 can be expected.

Main Tunnels. For the Main Tunnels, extensive liquefaction of the upper 40 to 60 feet is predicted in areas with soft and loose soils, and liquefaction-induced settlement of the Main Tunnel drive shafts and reception shafts working pad fills can be expected.