TECHNICAL SUPPLEMENT

Methodology for Seismic Landsliding Hazard Assessment for the RCFZ Earthquake Scenario

San Diego Earthquake Planning Scenario - M6.9 Earthquake on the Rose Canyon Fault Zone

As discussed in Section 4.3 of this report, earthquake-induced landsliding on the U.S. side of the border was assessed in general accordance with the Recommended Criteria for Delineating Seismic Hazard Zones in California Special Publication 118 by the California Geologic Survey (2004). CGS criteria delineates seismic landslide hazard areas based on the calculated seismic slope displacements. Seismic slope displacements were calculated using Newmark's sliding block analysis (1965) assuming an infinite slope and Bray and Travasarou's 2007 method. These methodologies calculate seismic slope displacements based on geologic material strength of the sliding plane, slope inclination, seismic demand, and earthquake magnitude.

Geologic material strengths in terms of internal friction angles (ϕ) were assigned using CGS criteria (2004) based on shear strength data gathered from various available geologic maps as well as engineering experience with the various geologic units. Mapped geologic units in the region were divided into six groups each having an associated angle of internal friction, as shown below in Table B-1.

Table B-1. Geologic Group Strengths

Group	Group Description	ϕ (degrees)
Group 1	Granitic rocks, gneissic basement rock, some metasedimentary rocks, some metavolcanics rocks, some Cretaceous-age sediments, and few Tertiary-age sediments	38
Group 2	Cretaceous and Tertiary-age sediments with favorable bedding and volcanic rocks	33
Group 3	Cretaceous and Tertiary-age units with unfavorable bedding, artificial fill, and some alluvial units which include marine terraces and colluvium	28
Group 4	Tertiary-age sediments with high clay content and some alluvium	24
Group 5	Existing landslide deposits	16
Group 6	Most alluvial deposits and other unconsolidated deposits	31

It should be noted that friction-only Mohr-Coulomb strength characterization used in this analysis represents a simplified form of strength parameterization. Many soils may have a cohesive component of Mohr-Coulomb strength and many rock materials may be more aptly characterized using Hoek-Brown failure criteria (Hoek et al., 2002) or blocky rock mass methods. Furthermore, the seismic slope stability analyses assumed unsaturated slope conditions, which predominate most of the year for the areas in the San Diego region which have a potential for earthquake-induced landsliding. However, it should be noted that if slopes are saturated, such as after a significant rainfall event, seismic landsliding probability would likely be increased. We adopted the friction-based strength and unsaturated slope criteria based on CGS guidelines and since this level of simplicity facilitates the calculations needed to efficiently perform this type of broad regional analysis.

The slope inclination for the San Diego region was determined based on the elevation data from the USGS National Elevation Dataset (NED) (USGS, 2009). The seismic demand for the analyses consisted of the spatially-distributed PGA values from the earthquake scenario and the magnitude used in the analyses was the earthquake scenario magnitude of M6.9.

Seismic slope displacements were calculated using GIS software. Based on Newmark's infinite slope method (1965), yield acceleration values were calculated as shown in Equations B-1 and B-2:

$$K_y = (FS-1)\sin(b) \quad \text{(Eq. B-1)}$$

$$FS = \tan(\phi) / \tan(b) \quad \text{(Eq. B-2)}$$

where K_y is the yield acceleration, FS is the static factor of safety against slope instability, and b is the slope inclination. Once the yield acceleration values were calculated, the amount of non-zero seismic slope displacements were calculated assuming the slide mass acted like a rigid block (i.e. fundamental period of the sliding block mass is zero) using Equation 6 from Bray and Travasarou (2007) as shown herein as Equation B-3:

$$D = \exp[-0.22 - 2.83\ln(K_y) - 0.333(\ln(K_y))^2 + 0.566\ln(K_y)\ln(PGA) + 0.566\ln(K_y)\ln(PGA) + 3.04\ln(PGA) - 0.244(\ln(PGA))^2 + 0.278(M-7) \quad \text{(Eq. B-3)}$$

where D is the amount of non-zero seismic slope displacements in units of centimeters and the other parameters are as previously defined. The value determined using Equation B-3 assumes that the probability of negligible displacements (i.e. displacements less than 0.4 inches (1 cm)) occurring during a given seismic event is zero. In other words, the probability of displacements greater than 0.4 inches (1 cm) is 100 percent. In areas with higher yield coefficients, due to the strength of the geologic unit and/or the slope of the area, the probability of negligible displacements occurring increases for a given seismic event. It is therefore important to consider the probability of negligible displacements occurring during a seismic event by determining the median amount of seismic displacements. The median amount of seismic displacements was calculated in accordance with Bray and Travasarou (2007) as shown herein using Equations B-4 and B-5:

$$D_{median} = \exp\{\ln(D) + \sigma\, \phi^{-1}[1 - (P(D>d) / (1 - P(D=0)))]\} \quad \text{(Eq. B-4)}$$

$$P(D=0) = 1 - \phi[-1.76 - 3.22\ln(K_y) + 3.52\ln(PGA) \quad \text{(Eq. B-5)}$$

where D_{median} is the median amount of seismic displacements in centimeters, σ is the standard deviation of random error which is equal to 0.66 for this analysis, ϕ^{-1} is the inverse of the standard normal cumulative distribution function, P(D>d) is the probability of seismic displacements exceeding zero displacements (equal to 50 percent for median value), and P(D=0) is the probability of zero displacements.

The D_{median} values were estimated for the scenario earthquake for the San Diego region and the resulting earthquake-induced landslide hazard map is provided in Section 4 of the report. It should be noted that geographically broad seismic slope instability analyses require significant reliance on crude strength characterization, relatively coarse topographic data, and simplified seismic slope displacement estimation methods. As such, these analyses are not considered a precise predictor of seismic slope displacements for the scenario earthquake but rather as an index of regional relative seismic slope instability susceptibility. Therefore, these analyses are used in this earthquake planning scenario project to identify zones where building development and infrastructure may be most susceptible to damage.