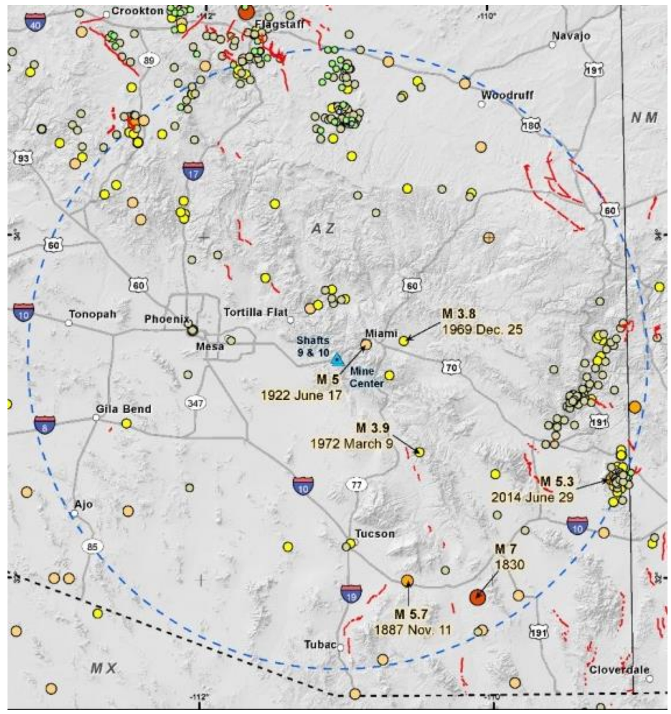
Final Report
Site-Specific Seismic Hazard Evaluation for the Proposed Resolution Copper Mine, Southern Arizona



Prepared for:
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EXECUTIVE SUMMARY

A probabilistic seismic hazard analysis (PSHA) and deterministic seismic hazard analysis (DSHA) were performed for Resolution Copper's Mine site including the area above the deposit (Mine area) and the area covering the East Plant site (Shafts 9/10). The peak horizontal ground acceleration (PGA) value for a return period of 2475 years is 0.06 g. This return period is used in the International Building Code (IBC) for the design of typical buildings and other structures in the U.S. A value of 0.06 g indicates a low level of hazard due to the low level of historical seismicity in southern Arizona and the absence of nearby Quaternary faults near the Mine. By comparison, PGA values along coastal California for a return period of 2475 years often exceed 1 g.

Abbreviations and Acronyms

BADCT	Arizona Mining Guidance Manual (Best Available Demonstrated Control Technology)
DSHA	Deterministic seismic hazard analysis
GMM	Ground motion model
HAZ45	PSHA computer program developed by Norm Abrahamson
MMI	Modified Mercalli intensity
M	Moment magnitude
NGA	Next Generation of Attenuation
PEER	Pacific Earthquake Engineering Research
PGA	Peak horizontal ground acceleration
PSHA	Probabilistic seismic hazard analysis
SA	Spectral acceleration
SBR	Southern Basin and Range Province
UHS	Uniform Hazard Spectrum
USGS	United States Geological Survey
V_S	Shear-wave velocity
V_S30	Time-averaged V_S in top 30 m

INTRODUCTION

At the request of Resolution Copper, this report presents the results of a site-specific probabilistic seismic hazard analysis (PSHA) and deterministic seismic hazard analysis (DSHA) for Resolution Copper's proposed Mine in southern Arizona. The Mine is located east of Phoenix and near the town of Superior (Figure 1) and the analysis was completed on an area covering the East Plant Site (shaft locations) and the area above the Resolution Copper deposit (Mine area).

The objective of this study is to estimate the levels of ground motions that could be exceeded at specified annual frequencies (or return periods) for two locations at the Mine and to compare the site-specific PSHA results with the results of a DSHA. The two locations correspond to the center of the proposed mine (33.2925° N, 111.0566° W) and between Shafts 9 and 10 (33.3051° N, 111.0680° W).

The Mine is located in the Basin and Range Province of southern Arizona, a region characterized by low level of seismicity compared to the rest of the western U.S. (Figure 1). The Mine is located about 56 km southeast of the nearest Quaternary active fault, the Sugarloaf fault zone (Figure 2). Because of the low level of seismicity, this study also assessed whether very active faults such as those in southern California could contribute to the long-period hazard at the Mine.

In this study, geologic and seismologic data were used to evaluate and characterize potential seismic sources, the likelihood of earthquakes of various magnitudes occurring on those sources, and the likelihood of the earthquakes producing ground motions over a specified level. This study builds upon numerous studies that have been performed for dams and other mining facilities in central and southern Arizona, including the 2013 and 2017 analyses for other Resolution Copper projects (Wong *et al*., 2013; 2017).

The PSHA methodology is used in this study for assessing ground motion hazard. The evaluation of seismic hazard required the explicit inclusion of the range of possible interpretations of components in the seismic hazard model, including seismic source characterization and ground motion estimation. These uncertainties particularly in areas like Arizona can be large for several reasons but primarily due to lack of comprehensive studies, which in turn is due to the lack of seismicity. Uncertainties in models and parameters are incorporated into the PSHA through the use of logic trees. The following report presents the seismic source characterization, the ground motion models used in the PSHA and DSHA, and the PSHA and DSHA ground motion hazard results.

Design Guidance

As stated in Appendix E "Engineering Design Guidance" of the Arizona Mining BADCT Guidance Manuel:

The minimum design earthquake is the maximum probable earthquake (MPE). The MPE is defined as the maximum earthquake that is likely to occur during a 100-year interval (80% probability of not being exceeded in 100 years) and shall not be less than the maximum historical event. The design earthquake may apply to structures with a relatively short design life (e.g., 10 years) and minimum potential threat to human life or the environment.

Where human life is potentially threatened, the maximum credible earthquake (MCE) should be used. MCE is the maximum earthquake that appears capable of occurring under the presently known tectonic framework.

- *Potential threat to human life or the environment*
- *Facility life*
- *Potential future property development downstream of the embankment or earth structure*
- *Seismic history in the area*

The MPE 80% probability of not being exceeded in 100 years has an equivalent return period of about 450 years.

PSHA METHODOLOGY

The PSHA approach used in this study is based on the model developed principally by Cornell (1968). The occurrence of earthquakes on a fault is assumed to be a Poisson process. The Poisson model is widely used and is a reasonable assumption in regions where data are sufficient to provide only an estimate of average recurrence rate (Cornell, 1968). The occurrence of ground motions at the site in excess of a specified level is also a Poisson process, if (1) the occurrence of earthquakes is a Poisson process, and (2) the probability that any one event will result in ground motions at the site in excess of a specified level is independent of the occurrence of other events.

Calculations were made using the computer program HAZ45 developed by Norm Abrahamson, which has been validated using the test cases in the Pacific Earthquake Engineering Research (PEER) Center-sponsored “Validation of PSHA Computer Programs” Project (Thomas *et al*., 2010).

Seismic Source Characterization

Two types of earthquake sources are characterized in this PSHA: (1) fault sources; and (2) areal (regional) seismic source zones. Fault sources are modeled as three-dimensional fault surfaces and details of their behavior are incorporated into the source characterization. Areal (regional) source zones are regions where earthquakes are assumed to occur randomly. Seismic sources are modeled in the hazard analysis in terms of geometry and earthquake recurrence.

The geometric source parameters for faults include fault location, segmentation model, dip, and thickness of the seismogenic zone. The recurrence parameters include recurrence model, recurrence rate (slip rate or average recurrence interval for the maximum event), slope of the recurrence curve (*b*-value), and maximum magnitude. For regional source zones, only the areas, seismogenic thickness, maximum magnitude, and recurrence parameters (based on the historical earthquake record) need to be defined.

Uncertainties in the seismic source parameters were incorporated into the PSHA using a logic tree approach. In this procedure, values of the source parameters are represented by the branches of logic trees with weights that define the distribution of values.

Ground Motion Prediction

To characterize the ground motions at a specified site as a result of the seismic sources considered in the PSHA and DSHA, empirical ground motion models (GMMs) for spectral accelerations were used. The models used in this study were selected on the basis of the appropriateness of the site conditions and tectonic environment for which they were developed.

The uncertainty in GMMs was included in the PSHA by using the lognormal distribution about the median values as defined by the standard error associated with each model. Per standard practice, five standard errors about the median value were included in the analysis.

SEISMOTECTONIC SETTING AND HISTORICAL SEISMICITY

Arizona is divided into three physiographic and seismotectonic provinces: the Colorado Plateau in the northeast, the Southern Basin and Range (SBR) in the south and southwest, and the intervening Transition Zone that is roughly 40 to 100-km-wide and northwest-southeast trending. All three provinces are characterized by relatively few late Quaternary faults and low rates of seismicity. These regions are bounded to the east by the Rio Grande Rift, and to the west by the Salton Trough Province. The Mine is located in the SBR near the boundary with the Transition Zone.

The SBR is an area of low historical seismicity, although it has had poor seismographic coverage (Figure 1). In a historical catalog that was compiled for a region that extends out at least 200 km from the Mine, there are 26 events of moment magnitude (**M**) 5 to 5.9, three events of **M** 6 to 6.9, and three events of **M** 7 and greater. One of the **M** 7 events is documented as having occurred in 1830, though it is based on one report made in the mid-1850's and is therefore considered suspect and poorly constrained and documented (DuBois *et al.*, 1982). The event appears on Figure 1, but was excluded from the earthquake recurrence calculations. Three historic events whose effects were likely felt at the location of the site, are described in the following.

1887 Sonora Earthquake

The largest event in the catalog was an earthquake of **M** 7.4 that occurred on 3 May 1887 in northern Sonora, Mexico, approximately 320 km southeast of the site (Dubois *et al.*, 1982; Suter and Contreras, 2002) (south of the area shown in Figure 1). The earthquake ruptured three major normal faults (Otates, Teras, and Pitáycachi faults) and was felt throughout Arizona and New Mexico and as far south as Mexico City (Dubois *et al*., 1982; Suter and Contreras, 2002). The maximum felt intensity was between Modified Mercalli (MM) intensity XI and XII and MM VI would have been observed at the Mine site (DuBois *et al*., 1982).

1922 Miami Earthquake

In the historical seismicity catalog, the closest significant earthquake to the Mine was a **M** 5.0 event that occurred on 17 June 1922 in the vicinity of Miami, Arizona, approximately 21 km east-northeast of the site (DuBois *et al*., 1982) (Figure 1). Although the felt intensity at the Mine site was not included by DuBois *et al*. (1982), the felt intensity likely would have been MM IV based on the proximity to the MM V contour. Although the event was felt throughout the town of Miami, no structural damage was reported (DuBois *et al*., 1982). Wong *et al.* (2008) noted that this event was recorded on a seismograph in Tucson and that the location and size of the event are highly uncertain.

2014 Southeastern Arizona Earthquake

A more recent **M** 5.3 event occurred on 29 June 2014 approximately 193 km east-southeast of the Mine, near the town of Duncan, Arizona and near the Arizona-New Mexico border (Figure 1). This event was widely felt in Arizona and western New Mexico. The maximum reported intensity of MM V was reported near the epicenter. Based on reported intensities surrounding the site, an intensity between MM II and III would have been observed at the Mine. The earthquake occurred at a depth of 6.4 km and the moment tensor solution reported by the USGS shows that the event is consistent with northeast-striking oblique-normal faulting. Subsequent to this event, there have been over 40 likely aftershocks ranging from **M** 2.0 to 4.0.

INPUTS TO ANALYSES

The following section discusses the characterization of the seismic sources and the GMMs selected and used in the PSHA and DSHA. The seismic source model used in this study was based on previous studies in the region performed by the authors (e.g., Wong *et al*., 2013) including the evaluation performed for the update of the Arizona Public Services (APS) Palos Verdes nuclear power plant.

Seismic Sources

Seismic source characterization is concerned with three fundamental elements: (1) the identification, location and geometry of significant sources of earthquakes; (2) the maximum size of the earthquakes associated with these sources; and (3) the rate at which the earthquakes occur. The seismic source model includes crustal faults capable of generating large surface-faulting earthquakes, and a uniform areal source zone and gridded seismicity, which accounts for background crustal seismicity that cannot be attributed to identified faults explicitly included in the seismic source model.

Crustal Fault Sources

Fault parameters required in the PSHA include: (1) rupture model (including independent single plane and potentially linked models); (2) probability of activity; (3) fault geometry including rupture length, rupture width, fault orientation, and sense of slip; (4) maximum or characteristic magnitude [M_{max}]; and (5) earthquake recurrence including both recurrence model and rates. These parameters are generally discussed further below. Selected faults that contribute the most to the hazard are specifically discussed in subsequent sections. We have explicitly incorporated the uncertainties in each parameter through the use of logic trees.

All known active or potentially active faults were included in the analyses within 200 km of the site (Figure 2). We included known faults showing evidence for late Quaternary (≤ 130,000 years) activity or repeated Quaternary (≤ 1.6 million years) activity.

We also included longer, more active faults in southern California and Baja California, such as the southern San Andreas fault, because from previous analyses in the region (e.g., Wong *et al*., 2013), we know that these major fault sources can be significant contributors to the hazard at longer periods, despite their great distances. The Pitaycachi fault, source of the 1887 Sonora earthquake, was also included in the hazard analysis because although it is distant (278 km away) and its slip rate is low (< ~0.1 mm/ yr), it is the source of the largest earthquake in the region.

Our fault characterization is based on our previous PSHAs in Arizona, the APS study, from data compiled in the USGS Quaternary Fault and Fold Database (http://earthquake.usgs.gov/hazards/qfaults/), and other sources.

The Sugarloaf fault zone is the closest Quaternary fault to the site, so it is also discussed below (Figure 2).

Sugarloaf Fault Zone

The Sugarloaf fault zone is expressed as a low, fairly continuous east-facing fault scarp as much as 5 m high at the contact between Precambrian granite and Tertiary basin fill sediments along the western margin of the small sedimentary basin on the flank of the Mazatzal Mountains (Pearthree *et al*., 1995). It is the closest Quaternary fault to the site at 56 km (Figure 2). The relief across the fault is minimal, indicating relatively little Quaternary activity (Pearthree, 1998). Stream bank exposures show down-to-the-east displacement on a northwest-striking fault plane dipping 70° to 80° to the northeast. Fault scarps on alluvium are rare and are poorly preserved. Paleoseismic trenching shows that the fault offsets late to latest Pleistocene deposits, but middle to upper Holocene deposits are not displaced (Pearthree *et al*., 1995). There is evidence for multiple Quaternary events, yet, the timing of individual events cannot be constrained (Pearthree *et al*., 1995; Pearthree, 1998). A preferred slip rate of 0.02 ± 0.01 mm/yr is calculated from ~ 1 m of vertical displacement in late Pleistocene (ca. 50 to 100 ka) deposits. A preferred M_{max} of **M** 6.5, the minimum magnitude for surface-faulting, was assumed for this short 8-km long fault in the PSHA. A slightly larger magnitude, **M** 6.6, was assumed for the DSHA.

<u>Crustal Background Earthquakes</u>

In state-of-the-practice seismic hazard evaluations, the hazard from background earthquakes is addressed. Background earthquakes are those events that do not appear to be associated with known geologic structures. They occur on crustal faults that exhibit no surficial expression (buried faults) or are unmapped due to inadequate studies. In this source characterization, we address the hazard from background earthquakes through: (1) a gridded seismicity model, where locations of past seismicity appear to be likely locations of future seismicity (stationarity); and (2) the use of a regional seismic source zone for the SBR, where earthquakes are assumed to occur randomly. For both approaches, the background earthquakes are assumed to occur uniformly from 2 km to the bottom of the seismogenic crust. The maximum depths of the seismogenic crust is the same distribution used for the crustal faults.

In the western U.S., the conventional approach has been to assume that the minimum threshold for surface faulting represents the upper size limit for background earthquakes. In the Basin and Range Province, this threshold ranges from **M** 6 to 6.75 (e.g., dePolo, 1994). It is believed that larger earthquakes will be accompanied by surface rupture, and repeated events of this size will produce recognizable fault-related geomorphic features. We have adopted a maximum magnitude distribution of **M** 6.2 [0.101], **M** 6.35 [0.244], **M** 6.5 [0.310], **M** 6.65 [0.244], and **M** 6.8 [0.101] for the SBR.

The use of the uniform and gridded seismic source zones were weighted equally at 0.5 and 0.5, respectively. Recent seismicity may be considered more likely representative of seismicity occurring in the next 100 years. However, given the short 187-year long and incomplete historical record the possibility exists that the catalog is not representative of the long-term record of seismicity and thus the two approaches were implemented with equal weight.

Site Characteristics

Both the center of the Mine area and Shafts 9/10 are located on the Apache Leaf Tuff (Tal) (J. Tshisens, Rio Tinto, written communication, 2017). There are no site-specific shear-wave velocity (V_S) measurements for Tal. Laboratory measurements of the Tal indicate a V_S of 2,320 ± 380 m/sec (Fuenkajorn and Daemen, 1991) which would represent an upper-bound value. However, Tal has been compared to the Topapah Springs tuff in southern Nevada (Fuenkajorn and Daemen, 1991). A significant amount of geotechnical analyses has been performed on the Topapah Springs tuff as part of the siting studies for the proposed Yucca Mountain nuclear waste repository. V_S measurements of the Topapah Springs tuff indicate a V_S well in excess of 1200 m/sec (Bechtel SAIC, 2002). Hence for the two Mine sites, we ran the PSHA and DSHA for a time-averaged V_S in the top 30 m (V_S30) of 1,200 m/sec. V_S30 is an input into the GMMs that accounts for the site effects on ground motions. The value of 1,200 m/sec is the upper limit of the strong motion data that was used in the GMMs (see following discussion).

Ground Motion Models

To predict ground motions in hazard analyses, empirical GMMs appropriate for tectonically active crustal regions were used. These models, developed as part of the Next Generation of Attenuation (NGA) Project-West2 sponsored by PEER Center Lifelines Program, have been published and are available on the PEER website (http://peer.berkeley.edu/). In this study, the models of Campbell and Bozorgnia (2014), Chiou and Youngs (2014), Abrahamson *et al*. (2014), and Boore *et al.* (2014) are used. The models are weighted equally in both the PSHA and DSHA.

SEISMIC HAZARD RESULTS

The PSHA and DSHA hazard results for ground motions are described below.

PSHA Results

The results of the PSHA for the two sites are presented in terms of ground motion as a function of annual exceedance frequency. The annual exceedance frequency is the reciprocal of the average return period. The results for the two sites are within a few percent of each other and so results for Shafts 9/10 are presented in Figures 3 to 13. Figures 3 and 4 show the mean, median (50th percentile), 5th, 15th, 85th, and 95th percentile hazard curves for peak horizontal ground acceleration (PGA) and 1.0 sec horizontal spectral acceleration (SA), respectively. The range of uncertainty between the 5th and 95th percentile (fractiles) at a return period of 2,500 years is 3.4 and 2.3 for PGA and 1.0 sec SA, respectively. These fractiles indicate the range of epistemic uncertainty about the mean hazard. The hazard can be characterized as low to moderate even at a long return period of 10,000 years.

The contributions of the various seismic sources to the mean PGA and 1.0 sec SA hazard are shown on Figures 5 and 6. At both PGA and 1.0 sec SA, the contribution from the SBR background earthquakes dominate the hazard. There are also contributions from the relatively distant Cerro Prieta fault and southern San Andreas fault to the 1.0 sec SA hazard (Figure 6).

The hazard can also be de-aggregated in terms of the joint magnitude-distance-epsilon probability conditional on the ground motion parameter (PGA or SA exceeding a specific value). Epsilon is the difference between the logarithm of the ground motion amplitude and the mean logarithm of ground motion (for that M and R) measured in units of standard deviation (σ). Thus positive epsilons indicate larger than average ground motions. By de-aggregating the PGA and 1.0 sec SA hazard by magnitude, distance and epsilon bins, we can illustrate the contributions by events at various periods. Figures 7 and 8 illustrate the contributions by events for return periods of 1,000 and 2,500 years. At PGA and all return periods, background earthquakes within 80 to 100 km of the sites dominate the hazard (Figure 7). At 1.0 sec SA, the contributions from more distant faults are apparent (Figure 8).

Uniform Hazard Spectra (UHS) for the four return periods are shown for Shafts 9/10 on Figure 9. A UHS depicts the ground motions at all spectral periods with the same annual exceedance frequency or return period. The difference between the UHS for the center of the Mine site and Shafts 9/10 is less than 1%.

DSHA Results

The most significant seismic source to the site in a deterministic sense is the Sugarloaf fault although this fault is quite distant (Figure 2). The maximum event that was modeled in the DSHA is a **M** 6.6 earthquake on the Sugarloaf fault at a rupture distance of 56.3 km. Figure 10 shows the median and 84th percentile 5%-damped horizontal acceleration response spectra and the individual spectra from each of the GMMs for the 84th percentile. The 84^{th} percentile PGA is 0.05 g.

Figure 11 show comparisons of the horizontal deterministic spectra with UHS for a range of return periods. The 84th percentile spectra has an equivalent return period of between 1,000 and 2,500 years. The equivalent return period of the deterministic ground motions is controlled by the level of the probabilistic hazard at the site. For this site, the low seismicity around the site results in relatively long equivalent return periods for the deterministic ground motions.

REFERENCES

Abrahamson, N.A. and Silva, W.J., and Kamai, R., 2014, Summary of the ASK14 ground-motion relation for active crustal regions: Earthquake Spectra, v. 30, p. 1025-1055.

Bechtel SAIC, 2002, Geotechnical data for a potential waste handling building and for ground motion analyses for the Yucca Mountain Site Characterization Project, unpublished report prepared for U.S. Department of Energy.

Boore, D.M., Stewart, J.P., Seyhan, E., Atkinson, G.M., 2014, NGA-West2 equations for predicting PGA, PGV, and 5%-damped PSA for shallow crustal earthquakes: Earthquake Spectra, v. 32, p. 979-1004.

Campbell, K.W. and Bozorgnia, Y., 2014, NGA-West2 ground motion model for the average horizontal components of PGA, PGV, and 5%-damped linear acceleration response spectra: Earthquake Spectra, v. 30, p. 1087-1115.

Chiou, B-S.J. and Youngs, R.R., 2014, Update of the Chiou and Youngs NGA ground motion model for average horizontal component of peak ground motion and response spectra: Earthquake Spectra, v. 30, p. 1117-1153.

Cornell, C.A., 1968, Engineering seismic risk analysis: Bulletin of the Seismological Society of America, v. 58, p. 1583-1606.

dePolo, C.M., 1994, The maximum background earthquake for the Basin and Range Province, western North America: Bulletin of the Seismological Society of America, v. 84, p. 466-472.

DuBois, S.M., Smith, A.W., Nye, N.K., and Nowak, T.A., 1982, Arizona earthquakes, 1776-1980: Arizona Bureau of Geology and Mineral Technology Bulletin, v. 192, 456 p.

Fuenkajorn, K. and Daemen, J.J.K., 1991, Mechanical characterization of densely welded apache leap tuff: report prepared for U.S. Nuclear Regulatory Commission, NUREG-CR 5688.

Pearthree, P.A., 1998, Quaternary fault data and map of Arizona: Arizona Geological Survey Open-File Report 98-24, 122 p.

Pearthree, P.A., Vincent, K.R., Brazier, R., Fellows, L.D., and Davis, O.K., 1995, Seismic hazard posed by the Sugarloaf fault, central Arizona: Arizona Geological Survey Open-File Report 95-7, 41, p.

Suter, M. and Contreras, J., 2002, Active tectonics of northeastern Sonora, Mexico (southern Basin and Range Province) and the 3 May 1887 MW 7.4 earthquake: Bulletin of the Seismological Society of America, v. 92, p. 581-589.

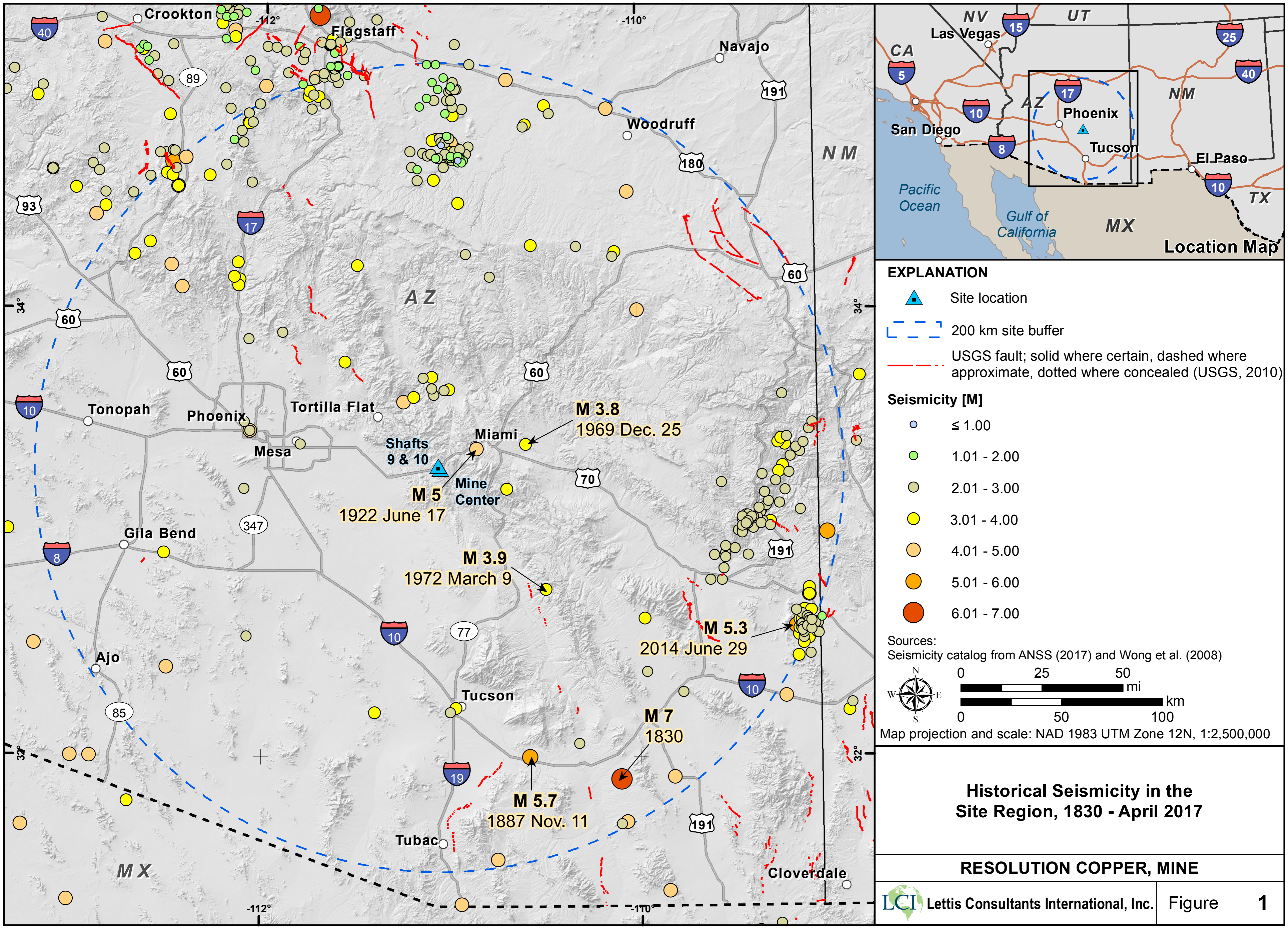
Thomas, P.A., Wong, I.G., and Abrahamson, N., 2010, Verification of probabilistic seismic hazard analysis software programs: PEER Report 2010/106, Pacific Earthquake Engineering Research Center, College of Engineering, University of California, Berkeley, 173 p.

Thomas, P., Wong, I., Zachariasen, J., Olig, S., and Terra, F., 2015, Updated site-specific probabilistic and deterministic seismic hazard analyses, Sierrita Tailings Dam, Green Valley, Arizona: unpublished report prepared for Freeport-McMoran Copper & Gold, Inc. by URS Corporation.

Wong, I.G., Nemser, E., Dober, M., Olig, S., Bott, J., and Terra, F., Darragh, R., and Silva, W., 2013, Site-specific Seismic hazard analyses for the Resolution Mining Company tailings storage facilities options, Southern Arizona: unpublished report prepared for Resolution Copper Mining.

Wong, I., Thomas, P., Lewandowski, N., Lindvall, S., and Seifried, A., 2017, Updated site-specific seismic hazard and development of time histories for Resolution Copper's near west site, southern Arizona: unpublished report prepared for Resolution Copper.

FIGURES



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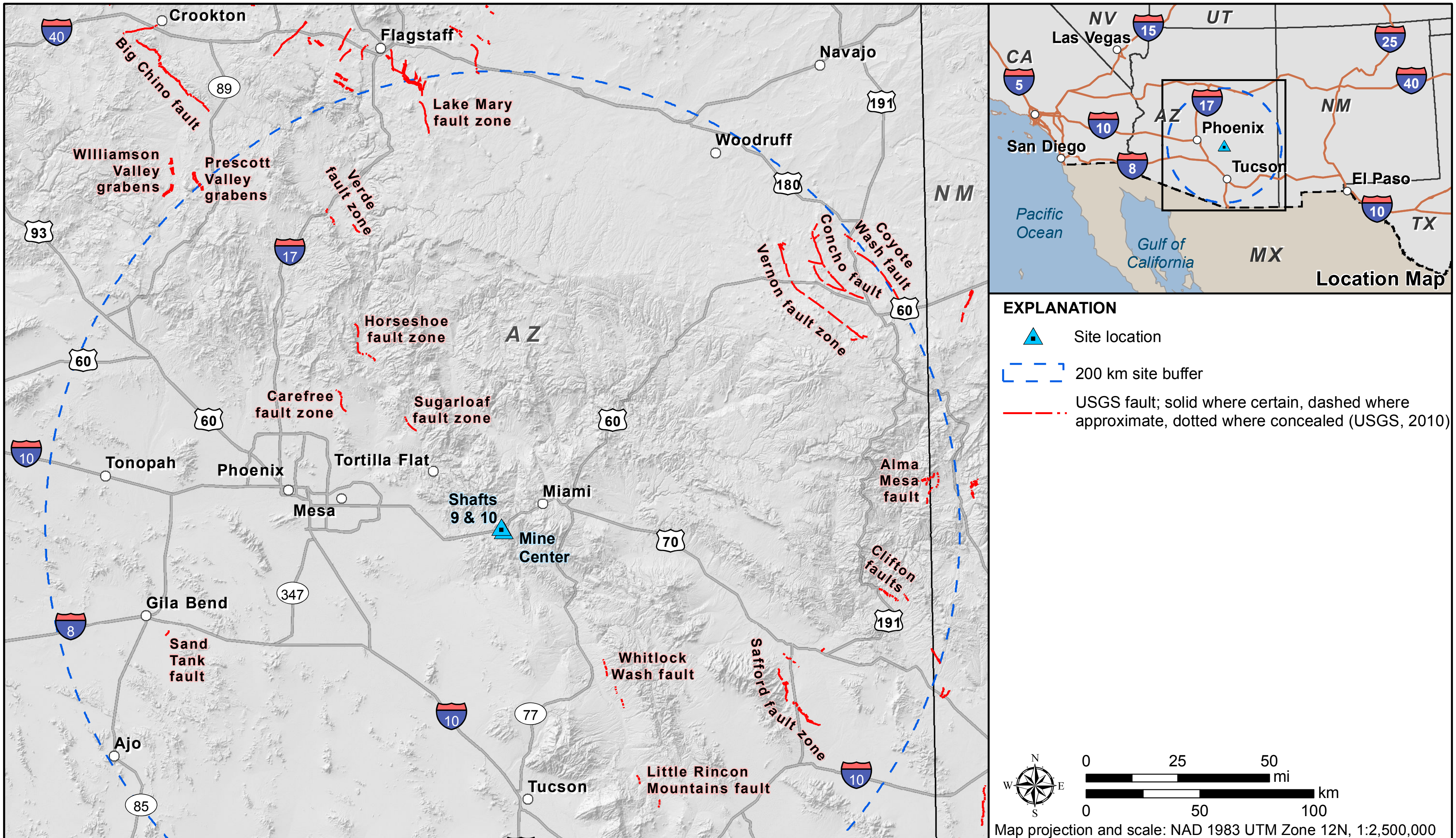

Quaternary Faults in the Site Region

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Figure 2

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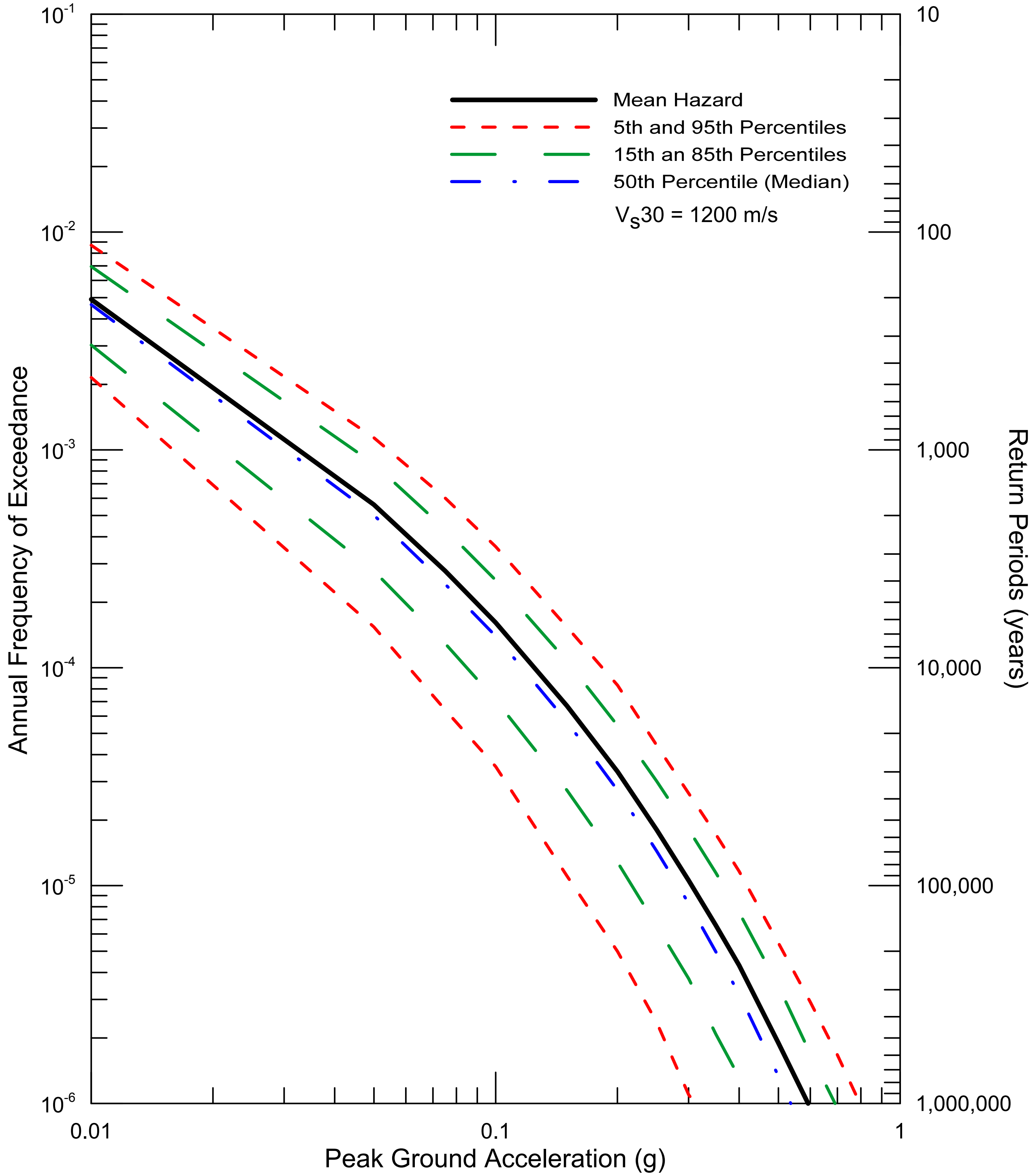

Seismic Hazard Curves for Peak Horizontal Acceleration

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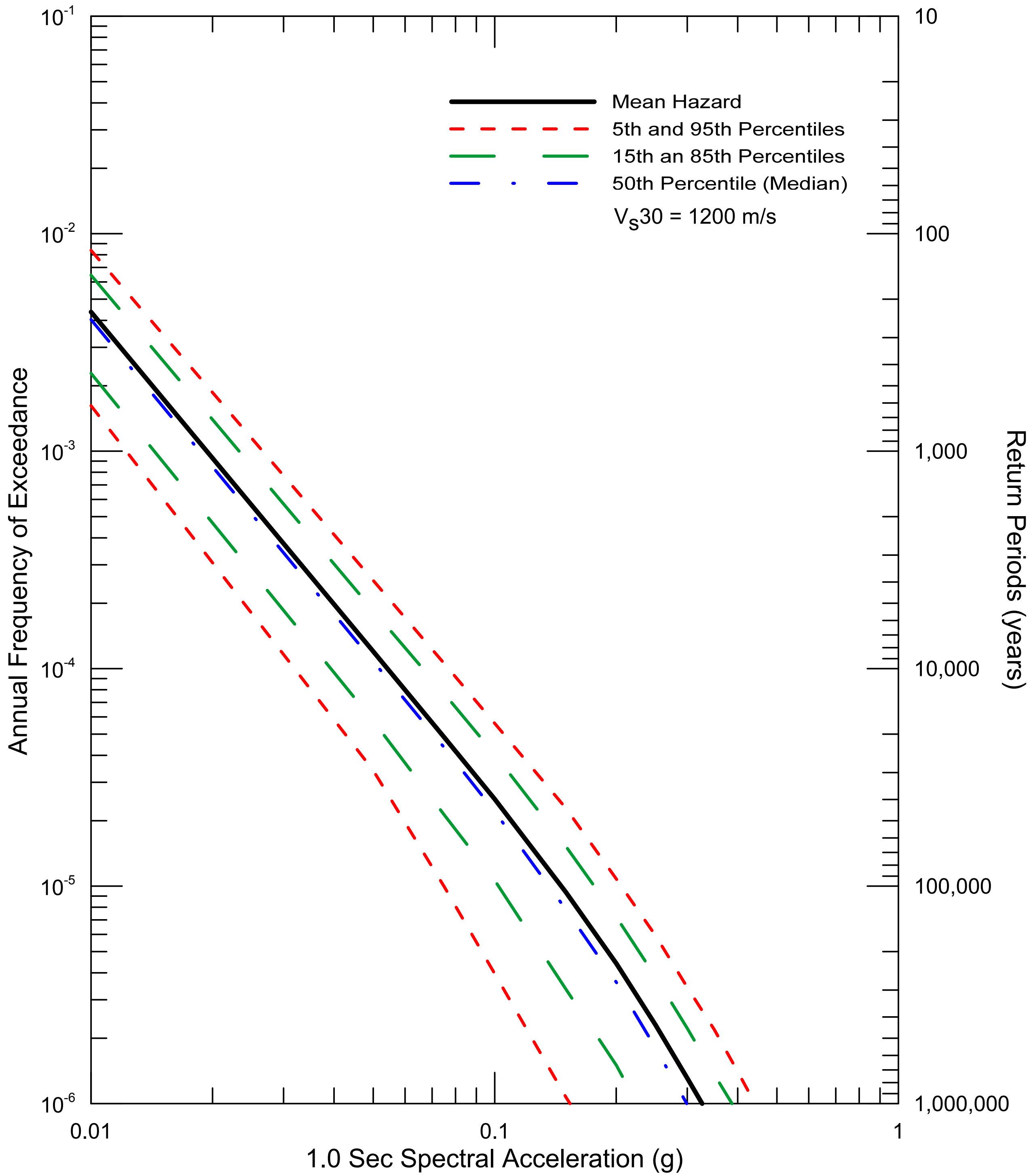
Lettis Consultants International, Inc. | **Figure 3**



Seismic Hazard Curves
for 1.0 Sec Horizontal Spectral Acceleration

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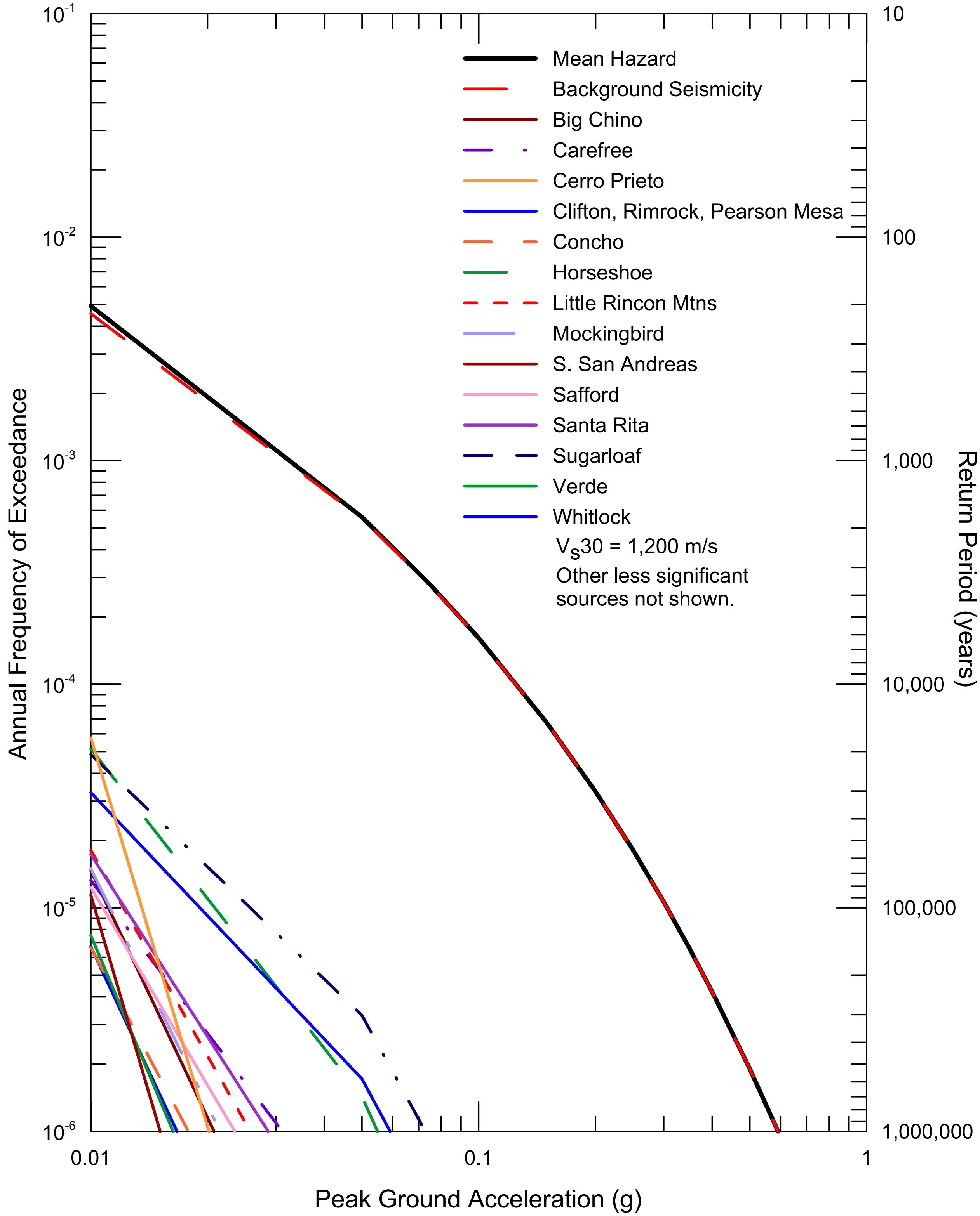

Seismic Source Contributions for Mean Peak Horizontal Acceleration Hazard

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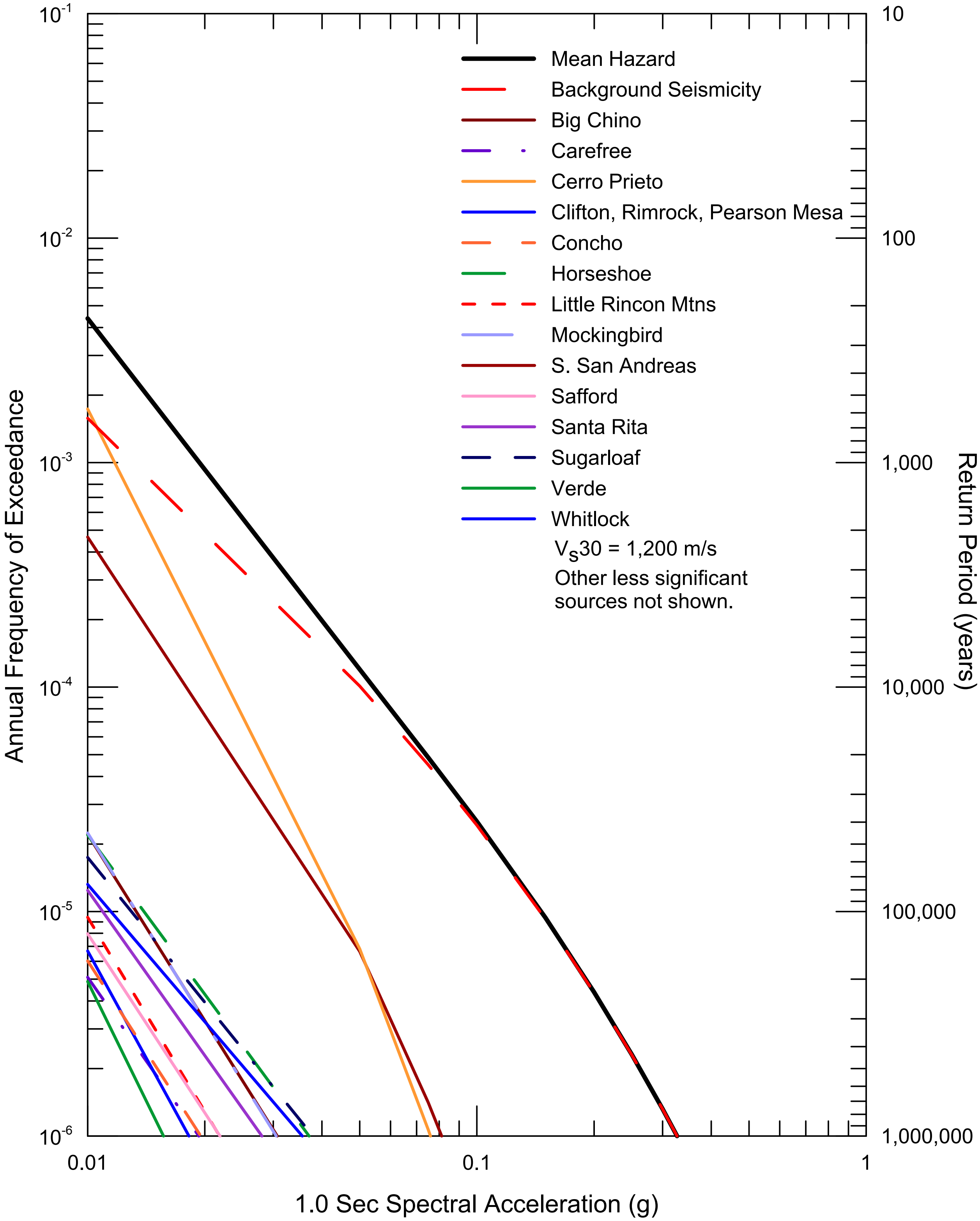
Figure 5



Seismic Source Contributions for Mean 1.0 Sec Horizontal Spectral Acceleration Hazard

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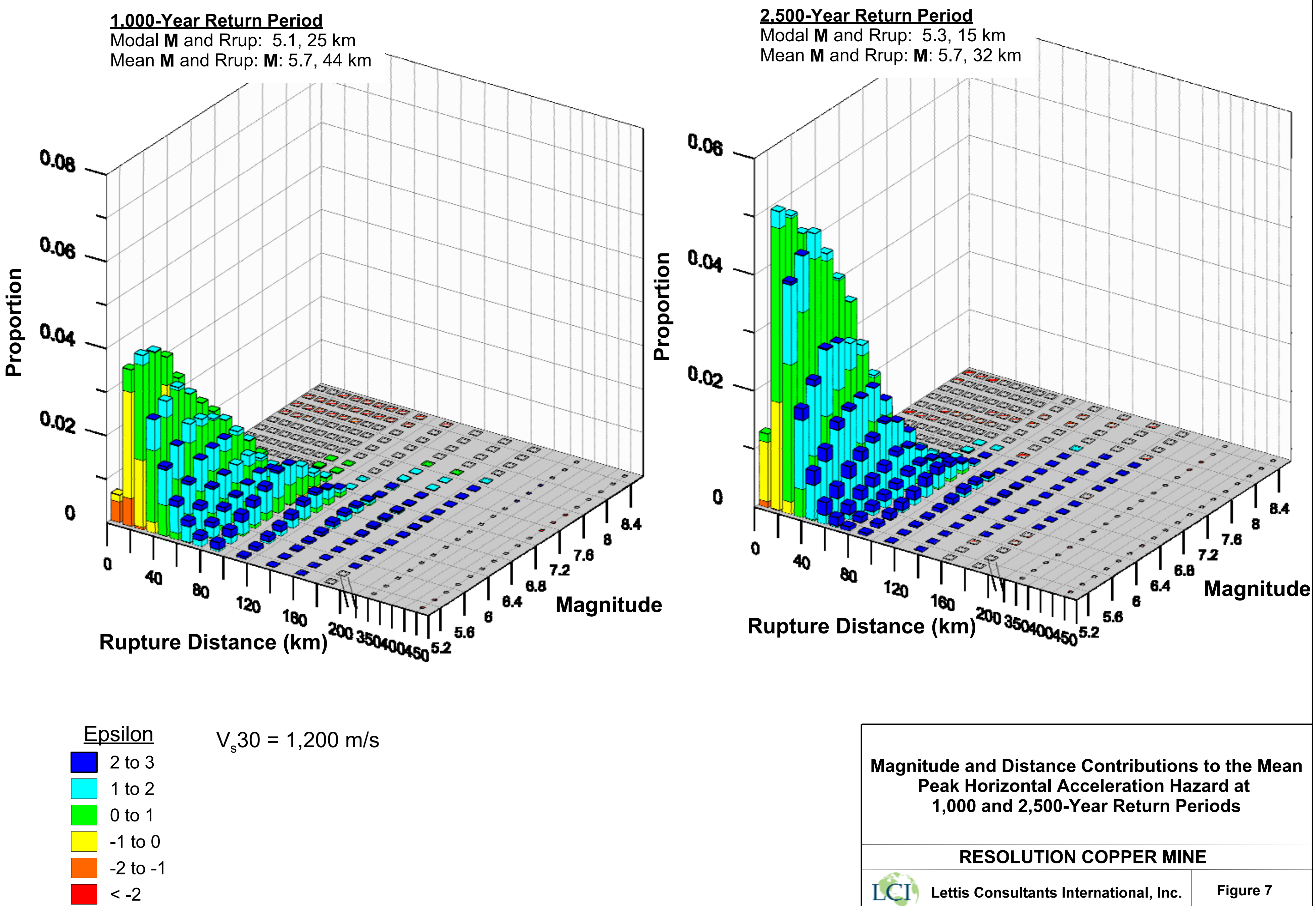
Lettis Consultants International, Inc. | **Figure 6**



Magnitude and Distance Contributions to the Mean Peak Horizontal Acceleration Hazard at 1,000 and 2,500-Year Return Periods

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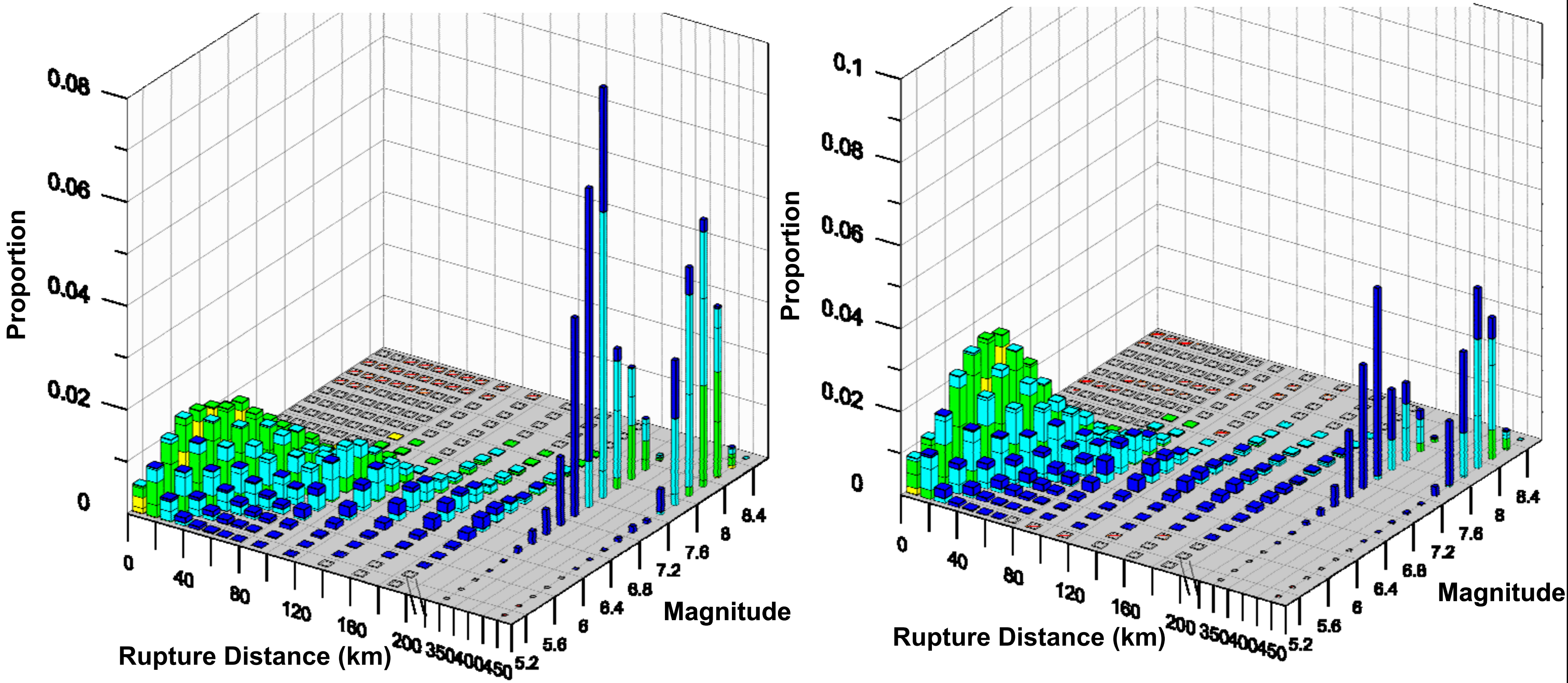
Lettis Consultants International, Inc. | **Figure 7**

1,000-Year Return Period
Modal **M** and Rrup: 7.3, 350 km
For sources < 200 km: Mean **M** and Rrup: **M**: 6.0, 53 km
For sources > 200 km: Mean **M** and Rrup: **M**: 7.4, 388 km

2,500-Year Return Period
Modal **M** and Rrup: 7.3, 350 km
For sources < 200 km: Mean **M** and Rrup: **M**: 6.0, 39 km
For sources > 200 km: Mean **M** and Rrup: **M**: 7.5, 395 km



Epsilon
- 2 to 3
- 1 to 2
- 0 to 1
- -1 to 0
- -2 to -1
- < -2

V_s30 = 1,200 m/s

Magnitude and Distance Contributions to the Mean 1.0 Sec Horizontal Spectral Acceleration Hazard at 1,000 and 2,500-Year Return Periods

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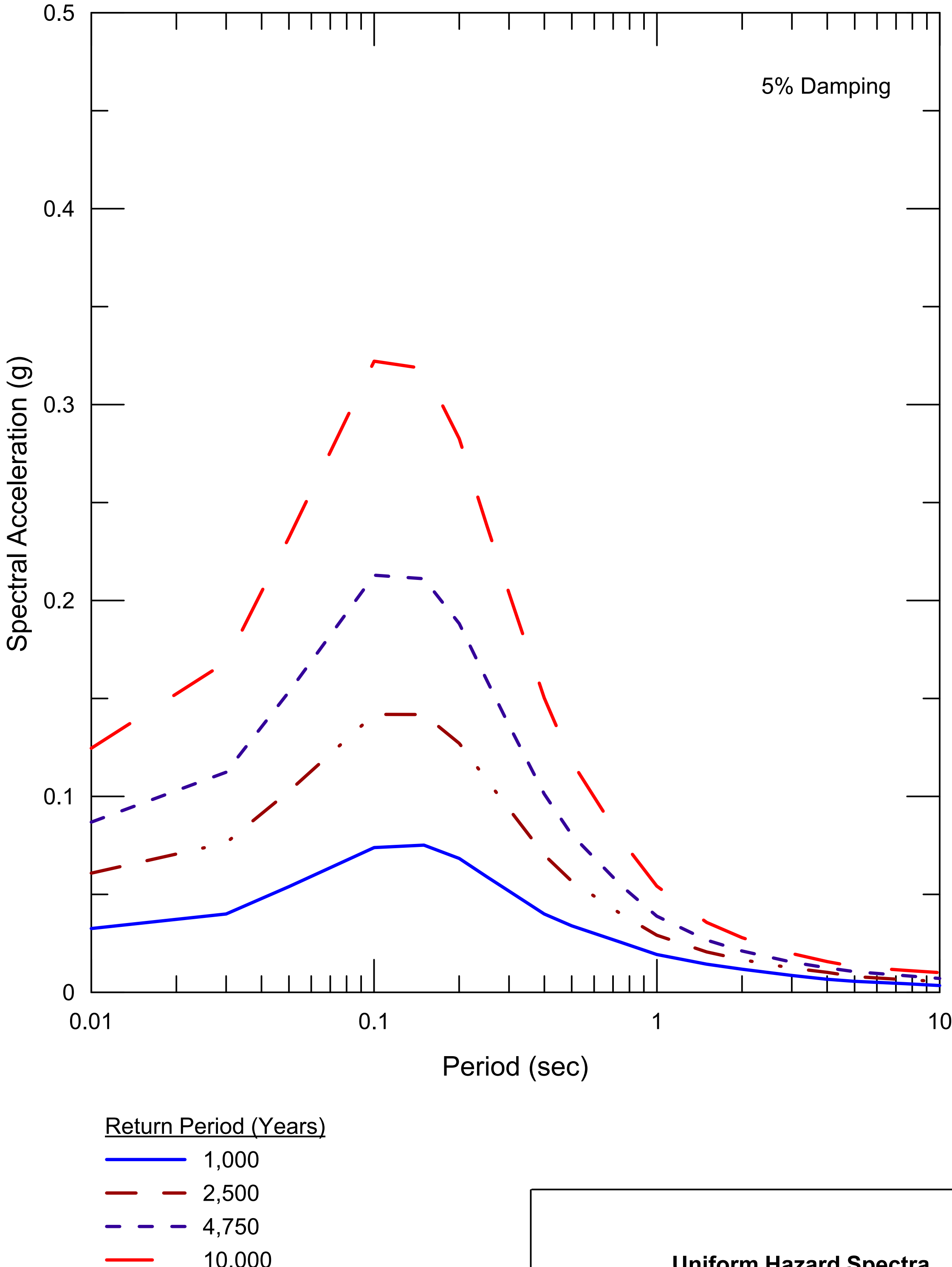

Uniform Hazard Spectra

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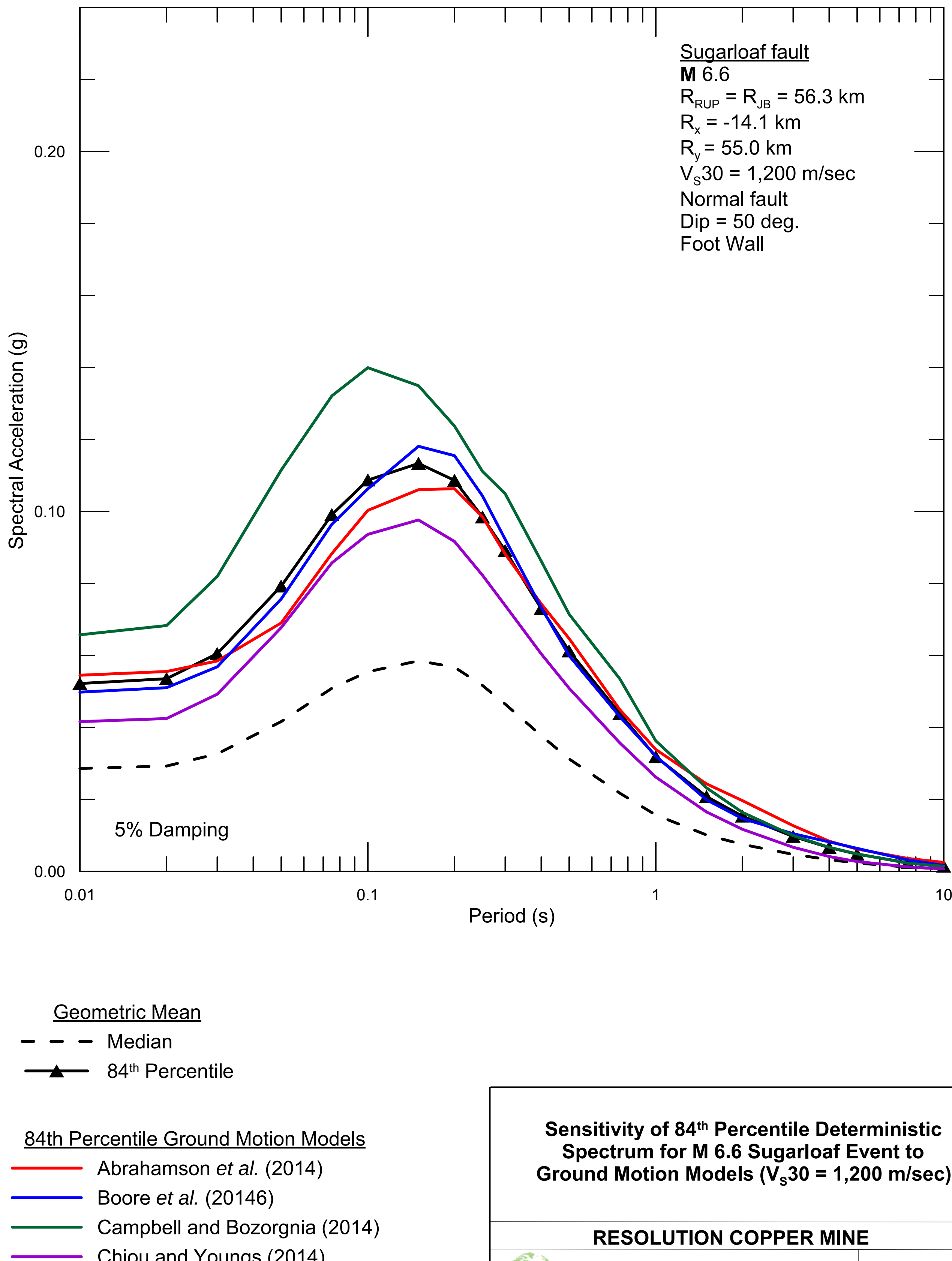
Lettis Consultants International, Inc. | **Figure 9**



Sensitivity of 84th Percentile Deterministic Spectrum for M 6.6 Sugarloaf Event to Ground Motion Models (V_S30 = 1,200 m/sec)

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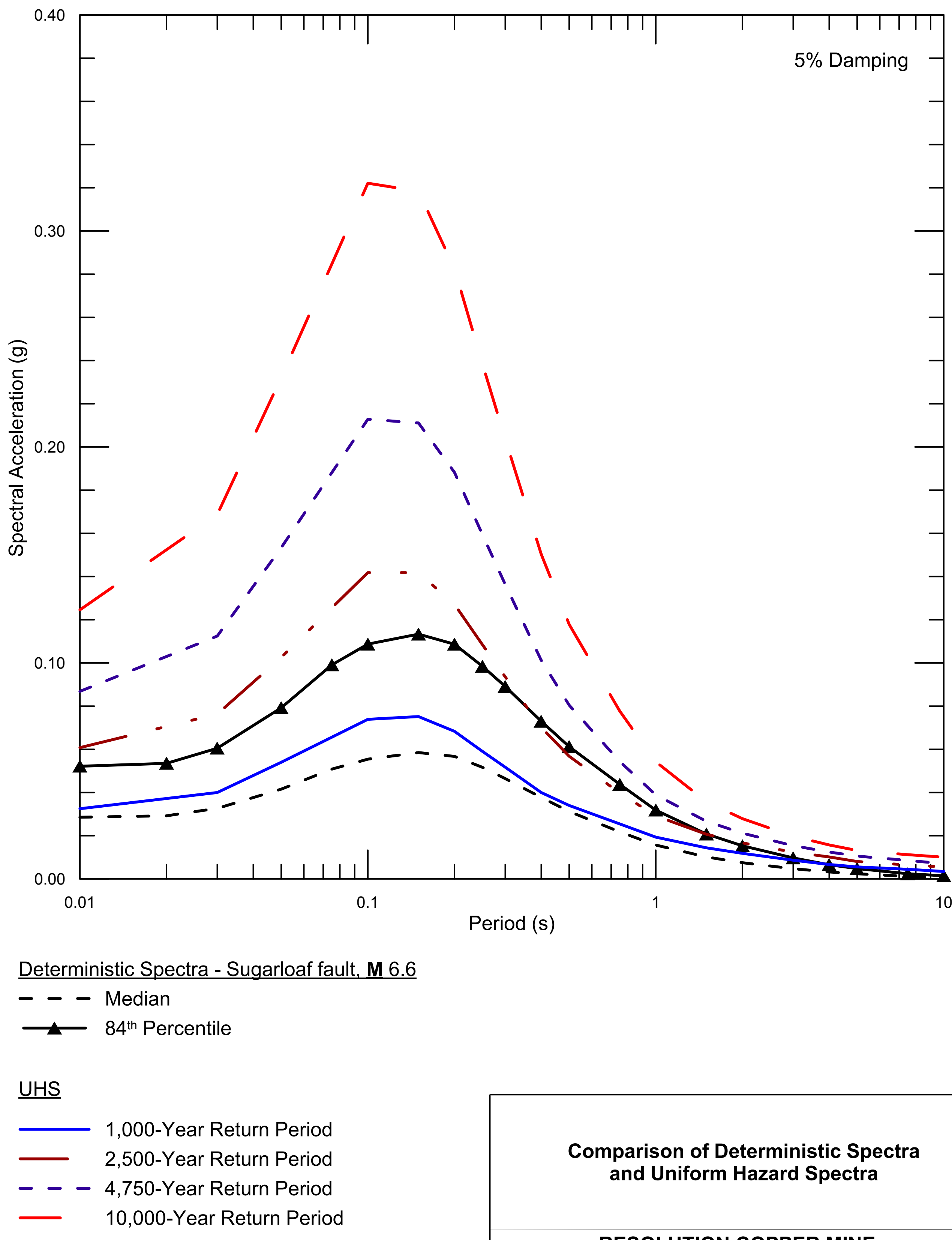
Figure 10



Comparison of Deterministic Spectra and Uniform Hazard Spectra

RESOLUTION COPPER MINE

Lettis Consultants International, Inc.

Figure 11

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January 25, 2018

Mr. Neil Bosworth
Apache Leap SMA
PO Box 34468
Phoenix, AZ 85067-4468

Subject: Resolution Copper response: Baseline Data Request #4 - Request for Information on Geologic/Geotechnical – Item E-3

As a follow-up to Resolution Copper's January 9, 2018 letter responding to Baseline Data Request #4, please see the attached technical report providing a discussion of the seismic setting for the East Plant Site and mine area.

Respectfully,

Vicky Peacey,
Senior Manager, Permitting and Approvals; Resolution Copper Company, as Manager of Resolution Copper Mining, LLC

Cc: Ms. Mary Morissette; Senior Environmental Specialist; Resolution Copper Company

Attachments:
Lettis Consultants International, Inc. (LCI): Final Report Site-Specific Seismic Hazard Evaluation for the Proposed Resolution Copper Mine, Southern Arizona