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Title:	Preliminary Assessment of the Surface Fault Rupture Hazard in the Vicinity of the Biosafety Level 3 Laboratory (BSL-3)
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Preliminary Assessment of the Surface Fault Rupture Hazard in the Vicinity of the Biosafety Level 3 Laboratory (BSL-3)

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Introduction

The probability of seismic hazards, in particular fault rupture hazard under or in the close proximity to the BSL-3 structure has been considered based on earlier estimates of surface fault rupture hazard (SFRH) conducted for the CMR site. Although the CMR probabilistic fault displacement hazard assessment (PFDHA) predates the most recent LANL ground motion assessment, there are relatively simple adjustments that can made to the PFDHA so that a conservative estimate can be made for the BSL-3 structure.

Background

The BSL-3 structure is in close proximity to a mapped fault showing vertical (~ 0.6-m down to the west) displacement over the last 1.22 myr (Gardner et al., Schultz-Fellenz, 2011). According to Emily Schultz-Fellenz (personal communication), the fault was identified based on the vertical offset of the contact of Qbt4 and Qbt3 at a single location on the northern wall of Mortandad Canyon south of BSL-3. There is no known geologic evidence supporting the basis for the length (~ 110 m) of the fault. In addition there is no evidence of the fault on the southwest site of the parking lot. The strike was selected to be consistent with mapped faults in the area. The fault is likely associated with the Rendija Canyon fault and is likely associated with the termination of the fault where displacement is distributed over a series of faults sometimes referred to as a “horsetail-shape” rupture distribution (Schult-Fellenz personal communication).

Because the strike of this hypothetical fault traverses an area once used as a borrow pit and fill storage, the depth to tuff ranges from 2 to more than 12 m. Consequently, investigations to identify the strike of the hypothetical fault in the site vicinity (for purposes of rupture assessment) would probably require trenching to depths of 8 to more than 16 meters. A trenching investigation to such depths was not advised by Schultz-Fellenz because of logistics involved with deep excavations of this nature, the accompanying safety concerns and the known limitations on geologic data in the site vicinity.

Methodology

An alternative to trenching is to consider the applicability of the WCC (1998) fault rupture hazard report and apply conservative assumptions and adjustments based on the more recent geologic investigations for the laboratory. Based on adjustments to the WCC

(1998) displacement hazard estimates, determine whether a PFDHA methodology might be an appropriate approach for assessing DOE design requirements for the BSL-3 facility. A probabilistic approach to surface rupture can be used for design of a proposed facility or could be used to support a fault avoidance variance criterion for planned or existing facilities. For the BSL-3 facility the PFDHA is used as a basis for the fault acceptance criterion that might otherwise apply. A site-specific hazard result indicating that the probability of surface fault rupture is significantly less than the performance requirements for BSL-3 facility ($5x10^{-4}$/yr) (DOE, 1995, 2002)[1] is a sufficient criterion.

Summary of WCC (1998) fault rupture hazard analysis

WCC (1998) conducted a PFDHA for primary and secondary faulting at the CMR, SCC and NIS locations associated with the Pajarito, Guaje Mountain and Rendija Canyon faults. The methodology for computing the SFRH was taken from previous SFRH assessments conducted for the proposed Yucca Mountain High Level Waste Repository and correspondingly had the highest level of oversight, external peer review and QA. The PFDHA methodology follows from the probabilistic seismic hazard assessment (PSHA) methodology. The annual probability of exceeding a specified surface displacement along a fault P(d>di) is determined from the annual probability of an earthquake of given magnitude, P(E(M)), and then empirical and/or analytical models of surface rupture or rupture radius for a given earthquake magnitude are used to compute the annual probability of surface displacement depending on the source magnitude, depth, geometry of the fault and site location. These probabilities are summed over earthquake magnitude and averaged over the possible rupture geometries. The PFDHA methodology is described in ANSI 2.30 “Criteria for Assessing Tectonic Surface Fault Rupture and Deformation at Nuclear Facilities” which is currently being prepared and will be finalized in 2012.

Because there was uncertainty about the possible extension of the Rendija Canyon fault under the facilities of interest, faulting assumptions considered fault offsets as a result of distributed (or secondary faulting) and primary faulting. The assumed maximum magnitudes, earthquake distributions, slip rates, recurrence intervals and traces of the modeled faults were taken from Wong et al. (1995). Two methodologies were employed to compute fault rupture hazard: (1) displacement approach; and (2) earthquake approach. The displacement approach uses point estimates of observed surface fault displacements over an estimated period of time to establish a slip rate. Then depending on the assumed rupture displacements of earthquakes that could have occurred, an annual probability is established. The earthquake approach uses the inferred rate of earthquakes on a fault that includes recurrence rates and slip-rates.

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[1] Section 3.1.4 of DOE STD-1023 states: “In addition to ground shaking, another direct effect of earthquakes can be surface expression of fault offset. A probabilistic assessment of the ground failure mode may be necessary if potential fault rupture may occur near a facility. If the annual probability of this ground failure mode is greater than the necessary performance goal, either the site should be avoided, mitigation measures taken, or an evaluation performed of the effects of fault offset.”

Since the WCC (1998) PFDHA assessment, LANL has completely updated and revised the fault and deformation rate assessments for the Pajarito Fault System. New trenching investigations and mapping of faults in the LANL vicinity have significantly increased the perceived hazard. URS (2007) reevaluated the ground motion hazard, but have not done a corresponding update of the SFRH. Consequently the fault maps, assumed deformation and recurrence rates, maximum magnitudes, earthquake recurrence distributions and fault rupture scenarios have significantly changed since 1995. In addition, since 1995 the worldwide empirical database for surface rupture producing normal faulting earthquakes has increased.

Adjustments to WCC (1998) displacement hazard

A very conservative initial approach is to approximately update and modify the WCC (1998) displacement hazard to consider the fault segment mapped to the southwest of BSL-3 as part of the RC fault and furthermore assume it is through-going to the northeast under the southeast corner of the facility and that it defines the principal fault rupturing segment of the RC fault. The mean slip rate is taken from URS (2007) for the heavily weighted (0.85) best estimate case corresponding to the unsegmented floating earthquake scenario (Rupture Model C) that includes the Rendija Canyon fault. Rupture Model B, weighted 0.15, assumed segmented fault rupture and had correspondingly lower probabilities of fault rupture along the Rendija Canyon fault. Rupture Model A was discarded in URS (2007) as an implausible model. The URS (2007) Rupture Model C uses a weighted mean slip-rate of 0.21 mm/yr for the PFS. Applying this slip-rate to the Rendija Canyon fault is very conservative because: (1) it assumes that the BSL-3 structure is on the main rupture surface of the Rendija Canyon fault and not the termination; (2) it ignores the nearby point estimate of apparent slip rate ~ 0.0005 mm/yr (0.6-m/1.22myr); and (3) ignores geologic evidence that the facility may be located at the termination of the Rendija Canyon fault where fault ruptures may be expected to be spatially distributed (i.e., small vertical displacement in 1.22 my; no evidence of through-going fault rupture).

For the Rendija Canyon fault, the WCC (1998) most probable assumed slip-rate was 0.01-0.02 mm/yr. The assumed slip-rate uncertainty range was 0.01-0.25 mm/yr for the Rendija Canyon fault. This range corresponds to a factor of ~25 in surface fault rupture hazard exceedance. The upper end of that uncertainty is approximately the mean slip-rate assumed along the Rendija Canyon and PFS in Model C of URS (2007). This fault rupture displacement hazard sensitivity of a factor of 25 in the slip-rate is shown in Figure 4-16 of WCC (1998). Because the slip rate is directly proportional to the annual fault rupture hazard, and assuming that the RC fault slip rate is ~ 0.21 mm/yr, results in an annual probability of exceedence for surface fault rupture of ~$4x10^{-4}$. This exceedance is marginally less than the performance requirement of the proposed facility, however, because other necessary hazard model updates are not included in this simple analysis, this exceedance estimate alone is judged too close to the annual performance requirement of this PC2 facility to be acceptable for a siting variance. Note that this analysis conservatively assumes a probability of facility failure of 1.0 given a surface fault rupturing event of any displacement.

Emily Schultz-Fellenz (personal communication) notes that the displacements near the BSL-3 facility are very likely a result of distributed faulting and not surficial expressions of the main trace of the RC fault. Consequently, there is additional margin for surface fault rupture exceedance for BSL-3. Based on Basin and Range empirical observations of primary and secondary rupture displacements (WCC, 1998) a conservative factor of 3 reduction in displacement is obtained (95^{th} percentile for hanging wall). A reduction of a factor of 3 in displacement at an annual exceedance of ~ 10^{-4}/yr corresponds to an approximate factor of 3 in annual probability of exceedance. Based on this additional adjustment, we judge that the annual probability of significant fault rupture hazard under BSL-3 is ~ $1x10^{-4}$/yr.

Point Displacement Approach

The point displacement approach to SFRH should also be considered in an update for WCC (1998). For a perspective, using the vertical displacement of 0.6-m slip in 1.22 myr suggests an annual rate of exceedance of > ~$8x10^{-7}$/yr for the occurrence of one 60-cm offset and > ~$8x10^{-6}$/yr for 10 surface slip occurrences each having 1-cm offsets.

Conclusions

For BSL-3 fault rupture assessments, it is most desirable to conduct a new site specific study updating the WCC (1998) surface fault rupture hazard study. However, despite conservative assumptions and adjustments to those results, the probability of significant surface fault rupture hazard is below the DOE performance requirements for this facility. This assumes that any sub-foundation displacement would cause certain failure of the facility. Because the more recent hazard model for LANL includes different magnitude distributions, recurrence and rupture models for the Pajarito Fault System, this displacement exceedance estimate can only be considered approximate. There is high confidence that a site-specific assessment of SFRH would result in a mean annual exceedance of $<10^{-4}$ for potentially damaging surface rupture. This probability is less than the acceptable annual probability of failure for the PC2 facility

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