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APPENDIX H: SEISMICITY

H.1 INTRODUCTION

The purpose of this appendix is to present detailed information on the latest study of seismic hazards at the Livermore Site. Excerpts from the most recent study (LLNL 2002dk), the *Lawrence Livermore National Laboratory Site Seismic Safety Program: Summary of Findings* (LLNL 2002dk), or Summary of Findings, are presented to supplement the discussion of seismic hazard in Section 4.8 of the *Site-wide Environmental Impact Statement for Continued Operation of Lawrence Livermore National Laboratory and Supplemental Stockpile Stewardship and Management Programmatic Environmental Impact Statement* (LLNL SW/SPEIS). The studies of seismic hazards for Site 300 have not been updated and the calculations presented in the 1992 *Lawrence Livermore National Laboratory Environmental Impact Statement/Environmental Impact Report* (LLNL EIS/EIR) are still used.

The 1992 LLNL EIS/EIR discussed the potential impacts associated with the seismic risks at the Livermore Site and Site 300. It stated that the siting of facilities in areas subject to strong ground shaking at the Livermore Site and Site 300 may result in structural damage and increased exposure to risks associated with ground shaking. Engineering and administrative measures would be taken to prevent and/or mitigate releases of hazardous substances resulting from strong ground shaking at any given facility. This effort was integrated into the safety program at LLNL as part of the analysis and mitigation of all accident risks for buildings and operations at LLNL.

H.2 LAWRENCE LIVERMORE NATIONAL LABORATORY SEISMIC SAFETY PROGRAM

At LLNL, seismic upgrades, retrofits, and a comprehensive furniture and equipment tie-down program are part of an ongoing effort to minimize risks to personnel, the environment, and the public at the laboratory due to a moderate to strong earthquake.

In 1994, Executive Order (EO) 12941, "Seismic Safety of Existing Federally Owned or Leased Buildings," required all federally owned and leased buildings that did not meet current seismic design and construction standards be identified and modified or retrofitted if necessary. Application of the seismic safety screening requirements of EO 12941 and associated standards resulted in the identification of 108 buildings at LLNL as having potential seismic difficulties. The need for seismic upgrading of these buildings was prioritized based on a scoring approach that incorporated building vulnerability, failure consequence, and mission essential factors. The seismic upgrade of the following high priority buildings and facilities are in different stages of planning, approval, design, and implementation.

- B131: Upgrades completed
- B151: Seismic upgrades are in progress
- B216: Upgrades completed
- B231: Upgrades completed

- B241: Seismic retrofit; work in progress. Scheduled for completion by June 2004
- B298: Work in progress. Scheduled completion, January 2004
- B321: Work in progress. Schedule completion, September 2008
- B381/B391: Seismic upgrade necessary to safely optimize use of prime lab space; FY2006
- B511: Work in progress. Scheduled completion, January 2004

LLNL continues to evaluate laboratory facilities in accordance with new seismic and engineering understanding and changing safety requirements. Seismic evaluations performed to date indicate that approximately 88 percent of buildings comply with the federal seismic "life safety" standards and require no further evaluation or mitigation. Of the remaining 12 percent (63 buildings), 22 have been evaluated and identified to have unacceptable seismic risks; 41 still require detailed evaluations to determine their seismic risk levels.

H.3 EXCERPTS FROM *LAWRENCE LIVERMORE NATIONAL LABORATORY SITE SEISMIC SAFETY PROGRAM: SUMMARY OF FINDINGS*

H.3.1 Overview

The *Lawrence Livermore National Laboratory Site Seismic Safety Program: Summary of Findings* (LLNL 2002dk) presents an assessment of the seismic hazard to the LLNL site and employees. Portions of the following text are excerpted from that document, shown here in italicized text. The references cited in the excerpts are from the original document (LLNL 2002dk) and listed in the back of this appendix. Likewise, acronyms and technical terms are not defined in the glossary of this LLNL SW/SPEIS.

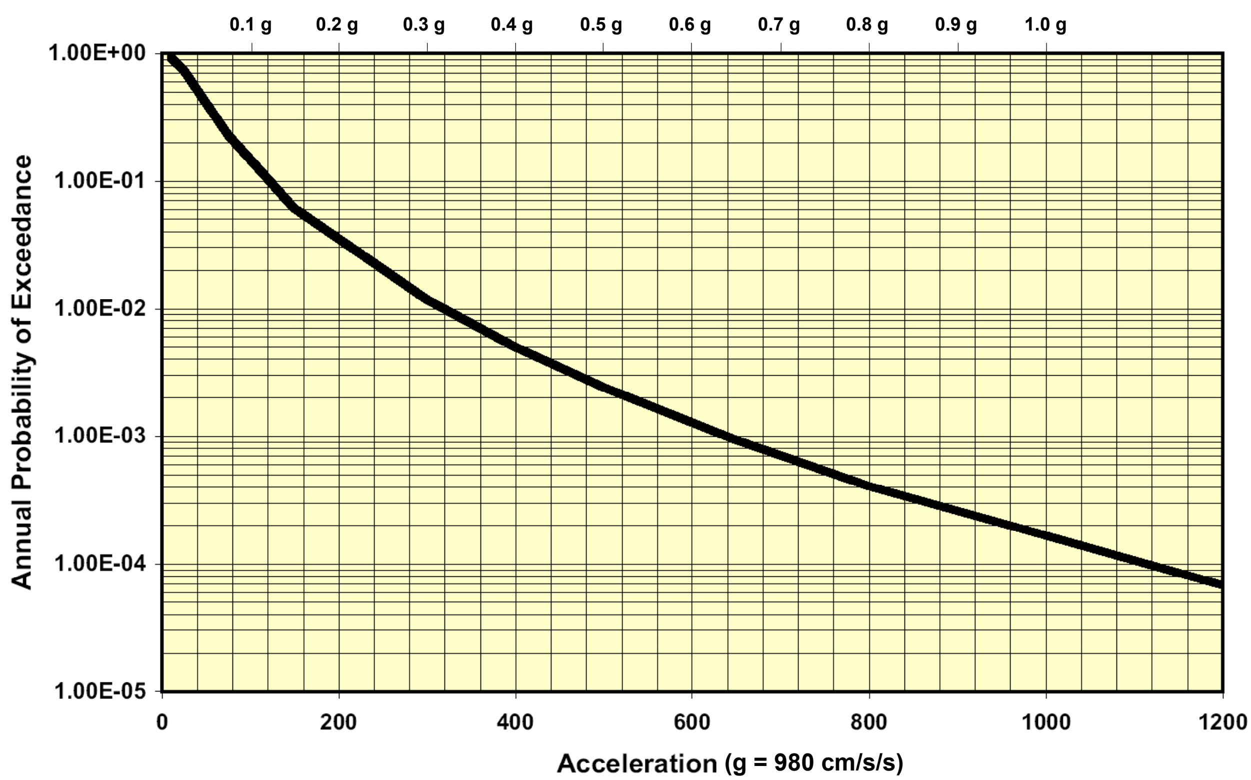
The Summary of Findings presents *the latest assessment of seismic hazard at LLNL, and includes a new estimate of peak ground acceleration to be used for design and evaluation of facilities at the site.*

The last such estimate was based on knowledge, technology, and methodologies that had been developed in the late 1970s. This new assessment is based on the information on the geology and tectonics of the region available in 2001. The assessment includes information from recent and ongoing studies of earthquake potential in the San Francisco Bay Region (SFBR) performed by the United States Geological Survey and other agencies, and fault modeling approaches developed by LLNL jointly with the Southern California Earthquake Center. This update follows the most recent methodology for performing probabilistic seismic hazard analysis, as recommended in the U.S. Department of Energy (DOE) standards (1020 Series) and documented in NUREG/CR-6372, Recommendation for Probabilistic Seismic Hazard Analysis: Guidance on Uncertainty and Use of Experts (Budnitz et al. 1997).

The new assessment shows that the Greenville Fault system dominates these new seismic estimates, followed by the Calaveras and the Corral Hollow fault systems; then, by an order of magnitude less, it is followed by the Springtown and Mount Diablo thrust, and finally by the Las Positas Fault. This is primarily due to the distance of these faults from the Livermore Site.

Although these new estimates are the result of a completely new and independent analysis, there are virtually no differences between the new mean hazard curves and those of the 1991 study.

The results are presented in Figure H–1 showing the estimated mean hazard curve in terms of the annual probability of exceedance of the peak ground acceleration (average of the two horizontal orthogonal components) at the LLNL site, assuming that the local site conditions are similar to those of a generic soil. This assessment of the peak ground acceleration does not take into account engineering factors that reduce the accelerations that would be experienced by individual facilities and their contents.



Source: LLNL 2002dk.

FIGURE H–1.—*Peak Ground Acceleration Hazard Curve for LLNL Site, Generic Soil Conditions*

H.3.2 Seismic Hazard Evaluation Process

There are five steps involved in deriving the distribution of seismic hazard.

Step 1: Evaluation of seismic sources.

Step 2: Assessment of earthquake recurrence and maximum magnitude.

Step 3: Ground motion attenuation.

Step 4: Mathematical model to calculate seismic hazard.

Step 5: Presentation of the hazard results.

The evaluation of the seismic sources, or, faults and fault systems, (Step 1) and a discussion of the associated earthquake recurrence rates and magnitudes (Step 2) are presented below. The calculations associated with attenuation (Step 3) and the modeling of the seismic hazard are (Step 4) described in detail in the Summary of Findings (LLNL 2002dk) and are not described here. The presentation of the results (Step 5) is in Section H.3.3 below.

Evaluation of the Seismic Sources and Assessment of Earthquake Recurrence

Fault geometries for the source model are constrained using available geological mapping and seismicity and geophysical data. Geologic slip rates are estimated from paleoseismic results together with fault kinematic models, within overall geodetic and tectonic plate velocity constraints. Data and interpretations were obtained by a comprehensive review of published and unpublished literature and by elicitation of several experts on SFBR geology and tectonics during several workshops and individual interviews. This process was greatly facilitated by membership (Foxall) on the overview panel of 1999 Working Group (WG99). Historical seismicity data are taken from Bakun (1999), and the U.S. Geological Survey and UC Berkeley catalogs of instrumentally located earthquakes were obtained through the Northern California Earthquake Data Center. The LLNL seismic network provides important data for characterizing sources and recurrence close to the Livermore Site, where numerous small events have occurred.

Selection of Seismic Sources

Figures H–2 and H–3 show the SFBR faults included in the source characterization model. In general, these faults show evidence for Holocene (within the last 8,000 years) and late Quaternary (within the last 15,000 years) *activity of potential significance to hazard at the LLNL site. The sources are divided into two groups: (1) regionally significant faults that are included in the WG99 source characterization (Table H–1); and (2) local and other faults of significance to LLNL site hazard (Table H–2). Group 2 includes the Greenville Fault and Mt. Diablo thrust. These two faults are part of the WG99 characterization, but are dealt with separately and characterized in detail in the present study because of their proximity to the site. Group 2 also includes smaller or slower slip rate faults in the immediate vicinity of the site (Figure H–4), and other potentially significant faults that are not included in WG99. The Ortigalita Fault is relatively long and has an estimated slip rate on the order of 1 millimeter per year. However, it* *is distant from the site and does not make a significant contribution to the hazard, and so is not described further in this report.*

Local and Other Sources

Greenville Fault*: The Greenville fault is the easternmost member of the NW-striking right lateral San Andreas Fault system in the SFBR. Although, based on data presently available, it is considered to have the lowest slip rate of the faults of this system, it makes the largest contribution to the hazard at LLNL because it approaches to within 1 kilometer of the site.*

Characterization of the Greenville fault follows the two-segment model adopted by WG99, but its geometry and slip rate distributions are defined in considerably more detail than is required in that study.

The definition of the source geometry is based on recent detailed geomorphic and structural mapping of the fault by Unruh and Sawyer (1998), which built upon earlier investigations (e.g., Herd 1977; Dibblee 1980a; Hart 1981; Sweeney and Springer 1981). The fault segments are shown in Figure H–3, and segment parameters are given in Table H–2. WG99 defines the boundary between the north and south Greenville Fault segments at the fault's intersection with the Las Positas Fault, based upon the change in the general character and structural setting of the Greenville Fault in this vicinity (T. Sawyer, written communication, February 10, 2000). However, the location of this boundary is subject to large uncertainty, which, because of its proximity to the site, translates to significant hazard uncertainty. When the exact location of a fault is undetermined, the characteristics of the fault are also undetermined. This leads to a higher uncertainty in predictions of the fault's behavior.

Data presently available to constrain the Greenville slip rate are sparse. Earlier estimates (e.g., Sweeney 1982 and Wright et al. 1982) are in the range 0.2–0.7 millimeters per year. This is based upon observations that yield slip rate estimates averaged over widely varying time intervals ranging from tens of millions to 100–200 thousand years. However, the well-defined morphology of the fault zone is consistent with a Quaternary slip rate of 1 millimeter per year or greater (Unruh and Sawyer 1998). This has yet to be verified by data. Sawyer and Unruh (2000) found evidence for one Holocene earthquake in three trenches on Crane Ridge, southeast of LLNL, but were unable to estimate a definitive slip rate. If, as assumed by Sawyer and Unruh, this is the most recent event and using their co-seismic slip estimate of 1.25 ± 0.25 meters, then carbon-14 dating of bulk samples suggests a maximum slip rate in the range 0.25–0.5 millimeters per year; however, this is very tentative.

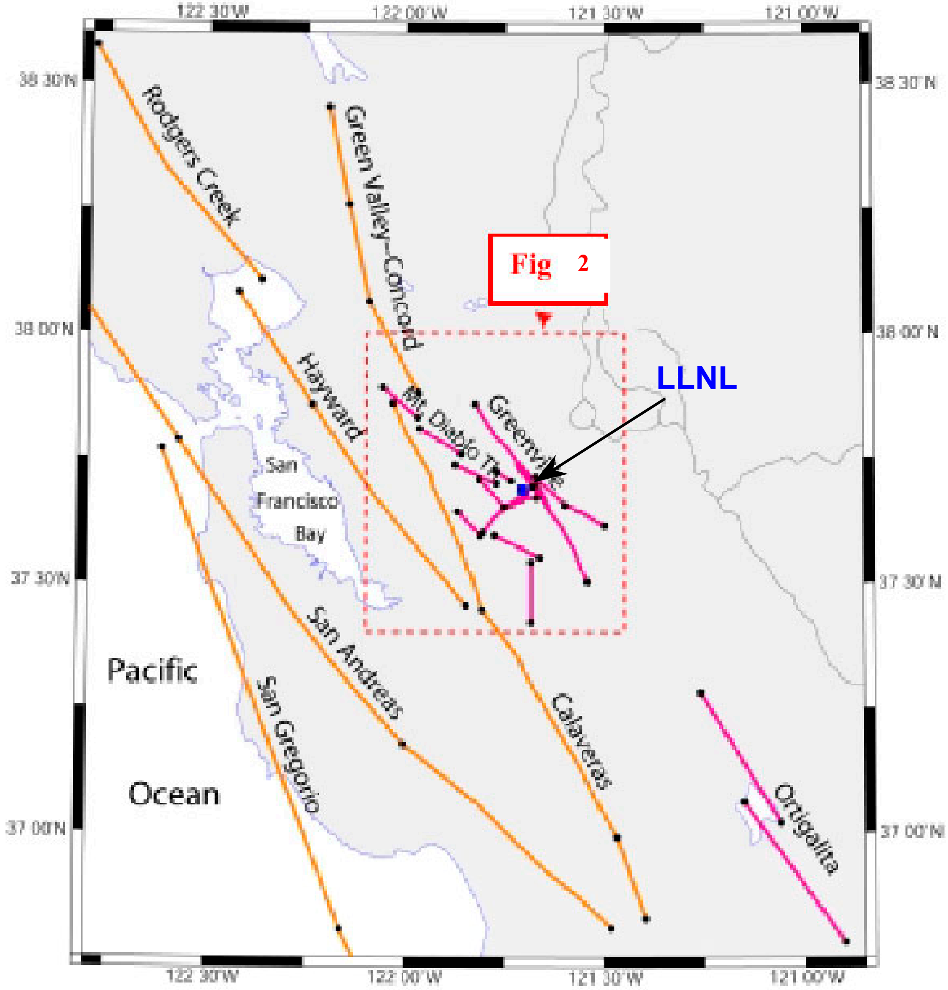


FIGURE H–2.— *Map of the San Francisco Bay Region showing characterization of faults of significance to seismic hazard at the LLNL. The LLNL is represented by the blue square, and major right-lateral strike slip faults included in the WG99 source characterization (Schwartz 2002) are shown in orange. Significant local and other faults are shown in magenta.*

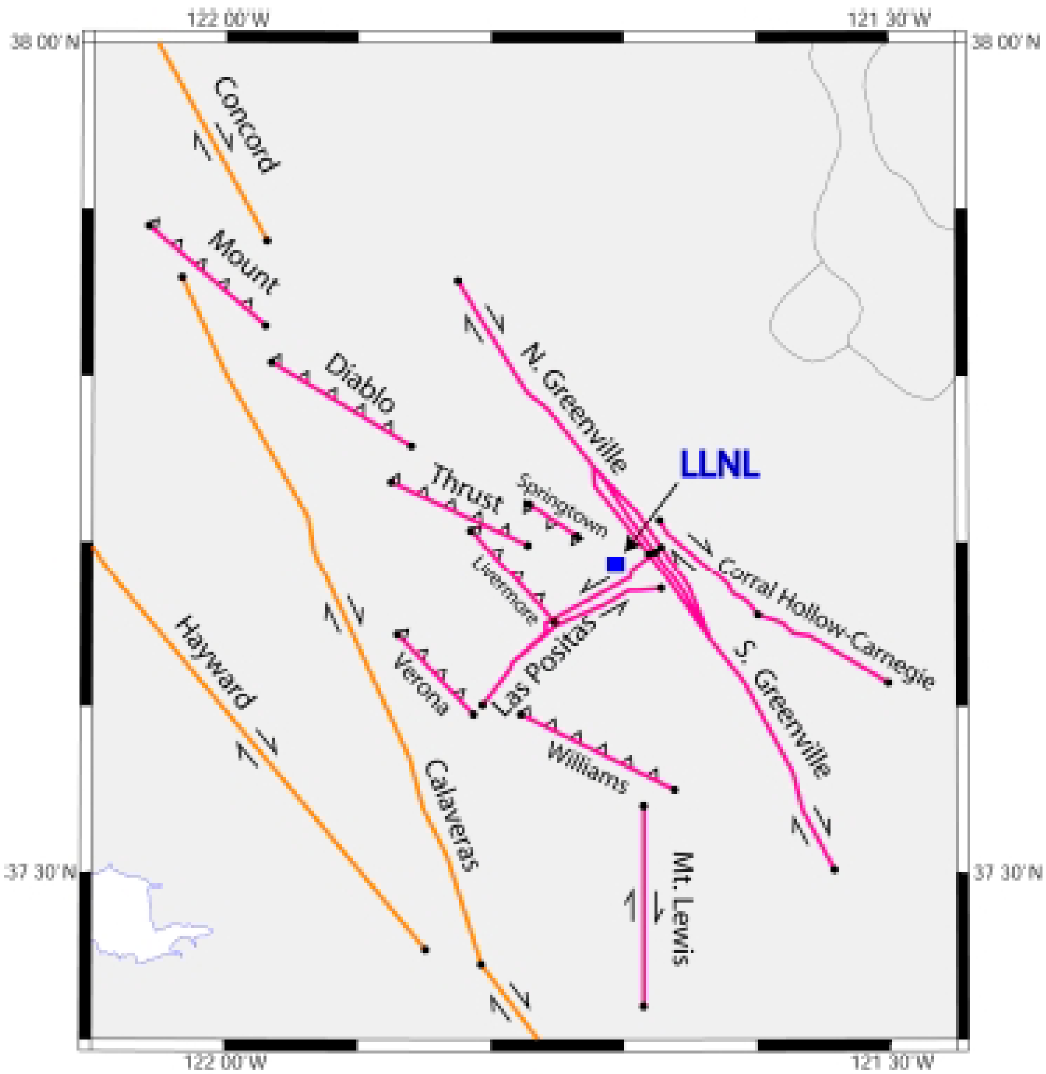


FIGURE H–3.—*Map of the East San Francisco Bay Area showing characterization of active and potentially active faults in the vicinity of the LLNL. Teeth indicate dip direction of thrust and reverse faults. Mt. Diablo thrust and Livermore Fault are blind; traces shown represent the buried upper tips of these faults.*

TABLE H–1.—*WG99 Earthquake Sources*

Fault System and Fault Segment(s)		Slip Rate (mm/yr)
San Andreas	Offshore	24 ±3
	N. Coast	24 ±3
	Peninsular	17 ±4
	Santa Cruz	17 ±4
Rodgers Creek		9 ±2
Hayward	North	9 ±2
	South	9 ±2
Calaveras:	North	6 ±2
	Central	15 ±3
	South	15 ±3
Green-Valley	North	5 ±3
	South	5 ±3
Concord		4 ±2
San Gregorio	North	7 ±3
	South	3 ±2

TABLE H–2.—*Local Earthquake Sources*

Fault Segment		Slip Rate (mm/yr)
Greenville	North	2.0 +2.5/-1.8
	South	2.0 +2.5/-1.8
Las Positas		0.6 +1.0/-0.5
Mt. Diablo Th.	NW	2.5 ±1.5
	Cent.	2.5 ±1.5
	SE	2.5 ±1.5
Verona		0.7 +0.7/-0.6
Williams		0.2 +1.1/-0.2
Corral Hollow		0.7 +1.3/-0.65
Carnegie		0.7 +1.3/-0.65
Livermore		1.0 +0.5/-0.9
Springtown		1.0 +0.5/-0.9
Mt. Lewis		1.0 +1.0/-0.9
Ortigalita	North	1.5 +0.6/-1.0
	South	0.5 +0.5/-0.4

In 2001, Sawyer and Unruh opened four new trenches across the fault at Laughlin Road, north of LLNL, where their working hypothesis of a stream channel offset across the fault suggests a slip rate of 1–2 millimeters per year or greater. Age dating of samples from these trenches is currently being carried out at the LLNL Center for Accelerator Mass Spectroscopy. An alternative way of estimating the Greenville slip rate is by inferring it from the transpressional kinematic model proposed by Unruh and Sawyer (1997) and Unruh (2000). In this model, slip is transferred from the Greenville to the Concord–Green Valley Fault via the blind Mt. Diablo thrust (see Figure H–4, and below), so that estimates of the slip rates on the Concord Fault and Mt. Diablo thrust can be used to infer the slip rate on the Greenville Fault. This yields an estimate in the range of 1 to 4 millimeters per year.

Mt. Diablo Thrust. *Unruh and Sawyer (1997) propose that the Mt. Diablo blind thrust underlying the Livermore and Sycamore valleys is the source of the major fold structures in the area, including Mt. Diablo and the Mt. Diablo and Tassajara anticlines. Unruh and Sawyer modeled these anticlinal structures as fault-propagation folds over the blind tip of the proposed Mt. Diablo thrust. The folds, and hence the underlying fault, are assumed to be active because they deform late Pleistocene (within the last 100,000 to 200,000 years) and early Holocene sediments (Unruh and Sawyer 1997, Unruh 2000). The geometry and slip rate on the thrust are inferred largely from structural modeling, although the existence of the thrust is consistent with seismic reflection data from the southeastern Tassajara Hills (Unruh 2000). This blind thrust is the only fault included in the WG99 characterization that is not part of the right-lateral San Andreas system, and is a significant new local source for the LLNL Probabilistic Seismic Hazard Assessment (PSHA). Mt. Diablo Thrust fault's contribution to the seismic hazard had not been considered in earlier studies.)*

The Mt. Diablo Thrust is identified by Unruh and Sawyer as part of what they term the Mt. Diablo fold and thrust belt, which includes the surface Williams and Verona faults southwest of the Livermore Valley, and the Livermore and Springtown structures in the immediate vicinity of the LLNL site (see Figure H–3 and below). Unruh and Sawyer hypothesize that this system formed in a left-stepping transpressional step-over between the right lateral Greenville and Concord–Green Valley faults, and propose a kinematic model in which slip on the Greenville Fault is transferred via the Mt. Diablo Thrust to the Concord Fault. Present modeling results constrain estimates only of the minimum slip rate on the Mt. Diablo Thrust averaged over several million years, which depend upon the timing of initiation of folding. The maximum age of initiation is estimated to be between 6.2 million years ago (Ma) and 3.3 Ma, which yields a minimum slip rate in the range of 1.3 to 2.4 millimeters per year (Unruh 2000). According to the Unruh and Sawyer transpressional model, this range is generally consistent with the 4 to 2 millimeters per year slip rate estimate for the Concord Fault assigned by WG99. At present, there is no evidence to constrain the minimum age of the onset of folding; if this occurred later than 3.3 Ma, then the average slip rate would be greater than 2.4 millimeters per year.

Las Positas Fault. *Based on its estimated area and slip rate, the Las Positas Fault appears capable of generating relatively infrequent moderate earthquakes. However, it makes a substantial contribution to the hazard because it passes within 1 kilometer of the Livermore Site. Characterization of the Las Positas Fault is based largely on the original mapping of Herd (1977), fault evaluation reports by the California Division of Mines and Geology (T.C. Smith 1981, Hart 1981), and particularly on the extensive field geological and geophysical* *investigations and analyses by LLNL Geosciences (Carpenter and Clark 1982, Carpenter et al. 1984). There is moderately strong evidence for latest Pleistocene–Holocene activity, and equivocal evidence that the fault may have experienced historical events (Carpenter et al. 1984, Hart 1981). However, despite the detailed field investigations carried out by LLNL, the fault remains poorly understood and its slip rate uncertain although apparently low (in the range ~0.1 to ~1 millimeters per year).*

Characterization of the Las Positas Fault requires consideration of its structural and kinematic relationships to the Greenville, Verona, and Williams faults and to the hypothesized Livermore and Springtown blind reverse faults. However, these relationships are largely a matter of conjecture, since the subsurface geometries of all the faults except the Greenville are unconstrained. One interpretation (T. Sawyer personal communication 2001) is that the assumed subvertical, left-lateral Las Positas Fault acts as a tear fault separating the thrust/reverse Williams and Verona faults, in which case the slip rates on the individual faults have to be kinematically balanced. Alternatively, the Verona and Williams faults may be continuous below some depth, in which case the Las Positas Fault is a hanging wall structure, antithetical to the Greenville Fault, and its slip rate is not directly coupled to the underlying thrust. Each of these alternatives forms a separate branch in the logic tree input to the hazard calculations.

Verona and Williams Faults*. The Verona Fault was the subject of considerable debate in the late 1970s, yet it remains very poorly understood (Rice et al. 1979). There is still insufficient information to definitely identify the structure as tectonic (Herd and Brabb 1980), rather than a massive landslide feature. California Division of Mines and Geology designated the northernmost 5.65 kilometers of the feature as mapped by Herd (1977) as an active fault according to the State of California Alquist–Priolo Act. The favored interpretation (Herd and Brabb 1980) is that the fault dips gently northeast, although the sub-surface geometry is unconstrained. Splays of the fault displace Holocene material. The only slip rate estimate for the Verona Fault is 0.12 millimeters per year (Jahns and Harding 1982), but this is highly uncertain. The trace geometry shown in Figure H–3 is based on the original Herd (1977) map.*

The Williams Fault is even more poorly understood. There is no definitive evidence for Holocene activity, although the fault cuts Quaternary sediments. The appearance (Dibblee 1980b) that the Williams trace continues the trend of the Verona Fault suggests one plausible model is that the Verona and Williams traces are the surface expressions of a single fault at depth. If this fault dips gently northeast, as suggested by near-surface splays of the Verona Fault, then this thrust could be a component of the Mt. Diablo fold and thrust belt of Unruh and Sawyer (1998) and Unruh (2000). On a more local scale, T. Sawyer (personal communication 2001) hypothesizes that the Verona, Williams, Las Positas, Livermore, and Springtown faults are components of a "Verona thrust system." As described earlier, the Las Positas Fault would be either a hanging wall or tear fault within this system, depending on whether the slip rates of the Verona and Williams faults are assumed to be equal or not. Another alternative is that the Williams Fault (and/or the Verona Fault) is inactive; note that D.P. Smith (1981, reported in Carpenter et al. 1984) interpreted the trace geometry and geomorphology of the Williams Fault to suggest a southwest dip and right-normal displacement. Slip rates on the Verona–Williams system are estimated indirectly from the sparse data available for the Las Positas Fault and the Springtown blind fault (see below) according to the different structural/kinematic interpretations of the Verona fold and thrust system.

***Livermore and Springtown Faults**: The existence and activity of the Livermore Fault have been the subjects of some debate since the fault was proposed by the California Department of Water Resources (CDWR 1966, 1974; reported in Carpenter et al. 1984), based primarily on a groundwater barrier and an apparent outcrop in Plio-Pleistocene sediments at Oak Knoll in Livermore. California Department of Water Resources (CDWR 1979, reported in Carpenter et al. 1984) also proposed that the fault extends to the southeast to Del Valle reservoir, based on observed shears within Plio-Pleistocene sediments (but not overlying colluvium). However, this interpretation is in conflict with the more compelling evidence for the activity of the Las Positas Fault, since the postulated Livermore Fault would cut across the Las Positas without offset. California Division of Mines and Geology does not consider the fault active for Alquist–Priolo zoning. An alternative possibility is that the Livermore Fault exists only north of the Las Positas Fault. To our knowledge, no estimates of either the sense of slip or slip rate have been attached to the fault as postulated by California Department of Water Resources, although right-lateral displacement is suggested based on the strike, which is subparallel to the Greenville Fault.*

An entirely different interpretation was proposed by Sawyer (1998) in the context of the Mt. Diablo fold and thrust belt. The Livermore trend is characterized by uplifted alluvial surfaces cut by wind gaps that Sawyer interprets as ancestral courses of Arroyo Mocho. The elevations of the wind gaps decrease progressively from southeast to northwest. A plausible explanation of these observations is that the Livermore trend is an active anticline that is growing laterally and deflecting Arroyo Mocho to the northwest. The anticline is truncated (or offset) on the southeast by the Las Positas Fault. Like the large-scale active folds, Sawyer proposes that the anticline is a fault propagation fold above the blind tip of an active northeast-dipping reverse fault. Similarly, the active Springtown anticline (Unruh and Sawyer 1997, Sawyer 1998) is interpreted as a fault propagation fold above a blind southwest-dipping backthrust off the Livermore Fault. These anticlines/faults are relatively short and are considered to be secondary structures within the fold and thrust belt. Like the Verona and Williams faults, the subsurface geometries of the postulated Livermore and Springtown faults are unconstrained; depending on the dip of each fault, the Livermore Fault could root into the Verona/Williams Fault, extend to the base of the seismogenic crust, or splay off the Greenville Fault.

A single carbon-14 date yields a maximum estimate of the Holocene uplift rate on the Springtown anticline of 0.7 to 0.9 millimeters per year (Unruh and Sawyer 1997), suggesting a maximum dip slip rate of about 1 millimeters per year. The average late Quaternary slip rate is estimated as 0.1 to 0.25 millimeters per year. This long-term average is consistent with a tentative uplift and slip rate estimate on the order of 0.1 millimeters per year for the Livermore Fault, based on the stream incision rate for Arroyo Mocho (Sawyer 1998).

***Corral Hollow and Carnegie Faults**. The Corral Hollow–Carnegie Fault zone as mapped by Dibblee (1980c) and Crane (1995) passes about 3 kilometers east of LLNL at its closest approach. Carpenter et al. (1991) found evidence for repeated movement during the Pleistocene and Holocene on a fault strand within Site 300, between the mapped traces of the Corral Hollow and Carnegie faults, and suggested that the fault zone as a whole should be considered potentially active. Dibblee (1980) mapped the Corral Hollow Fault as a right-lateral fault sub-parallel to and east of the Greenville Fault, and shows it offsetting the Corral Hollow syncline in a right-lateral sense. Age control on slip rates by Carpenter et al. (1991) was based on soil stratigraphy, so estimates have large uncertainties. Schlemon (Appendix B in Carpenter et al.*

[1991]) speculates that an earthquake may have ruptured the fault zone during the past few hundred years, which would imply a slip rate of 1 to 2 millimeters per year, comparable to that of the Greenville Fault. Longer-term average estimates over the last 60–70 thousand years, however, are very low, in the range 0.05–0.07 millimeters per year.

***Mt. Lewis Fault**. Characterization of the Mt. Lewis Fault is based on the March 31, 1986, ML5.7 earthquake and its immediate aftershock distribution (Zhou et al. 1993), which sharply delineates a 16-kilometer long north–south trend, consistent with the right-lateral focal mechanism of the main shock. The background microseismicity suggests that the fault may extend as far north as the Williams Fault. A cross-section through the seismicity clearly defines a sub-vertical plane to a depth of about 10 kilometers. The fault had not been recognized before the 1986 event, although it corresponds to a lineament on Landsat images (D. Schwartz, personal communication 2000). There are no direct observations to constrain the slip rate on this fault. Kinematic modeling of geodetic data suggests a slip rate on the order of 1 millimeter per year.*

H.3.3 Comparison with Previous Results

Compared with the 1991 results, *the mean hazard estimates in the generic soil case are essentially identical for the two studies. However, it must be noted that the uncertain estimates are different. The 5th and 95th percentiles provided in the Rev. 1, 1991, study define a larger band of uncertainty than the 5th to 95th percentiles in the new (Rev 2) study; the 95th percentiles are approximately equal. Therefore, this study narrowed down the estimates of the uncertainties by eliminating the alternatives that would lead to very low estimates of the seismic hazard. Our estimates of the uncertainties in the dispersion of the ground motion from the predictions with the attenuation models (the "sigma" values) are smaller than in the previous studies. The same is true for some of the occurrence models. We have included a more realistic representation of the uncertainties in the geometry of the dominant faults, as well as a number of conceptually different alternatives for the general tectonics of the region. The addition of the Mount Diablo thrust as a series of three possibly disjoint segments also contributed to raising the hazard as well as increasing the overall uncertainty.*

In the end, these effects have worked in opposition to finally provide a set of estimates of the mean hazard that is close to the results of the 1991 study, in spite of the different approach to the treatment of the uncertainties, the different set of alternative tectonic models, and the large quantity of new information that was generated in the last decade. This new study provides more insights into the identification of the dominant seismic sources, and it determines the ground motion in terms of uniform hazard response spectra.

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