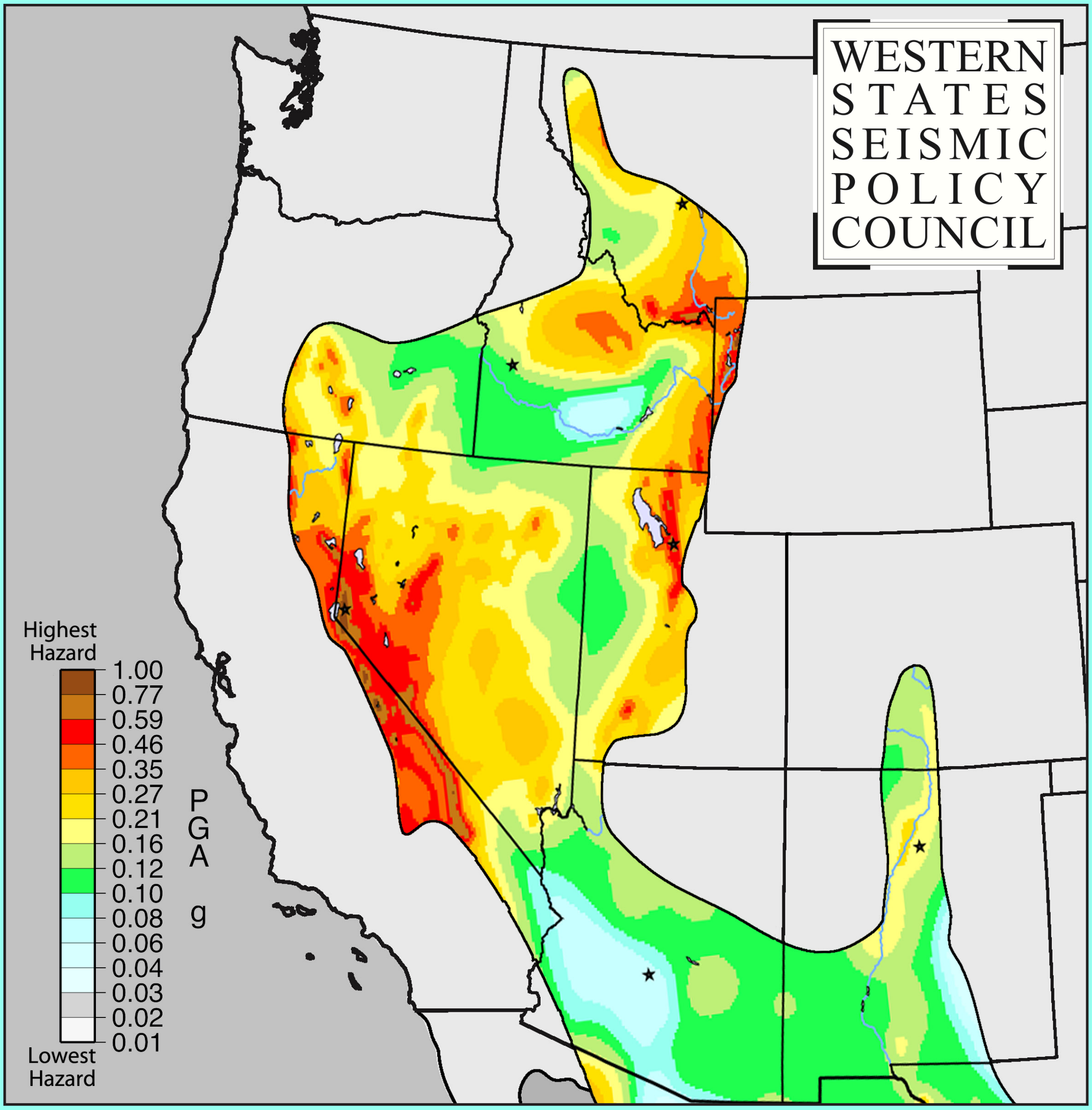
BASIN AND RANGE PROVINCE EARTHQUAKE WORKING GROUP II

RECOMMENDATIONS TO THE U.S. GEOLOGICAL SURVEY NATIONAL SEISMIC HAZARD MAPPING PROGRAM FOR THE 2014 UPDATE OF THE NATIONAL SEISMIC HAZARD MAPS

Edited by William R. Lund



PGA with 2% in 50 year PE. BC rock. 2008 USGS

OPEN-FILE REPORT 591
UTAH GEOLOGICAL SURVEY
a division of
UTAH DEPARTMENT OF NATURAL RESOURCES
2012

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RECOMMENDATIONS TO THE U.S. GEOLOGICAL SURVEY NATIONAL SEISMIC HAZARD MAPPING PROGRAM FOR THE 2014 UPDATE OF THE NATIONAL SEISMIC HAZARD MAPS

Prepared by the
Basin and Range Province Earthquake Working Group II
in cooperation with the
Basin and Range Province Committee
of the
Western States Seismic Policy Council,
the
U.S. Geological Survey,
and the
Utah Geological Survey

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April 2012

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RECOMMENDATIONS TO THE U.S. GEOLOGICAL SURVEY NATIONAL SEISMIC HAZARD MAPPING PROGRAM FOR THE 2014 UPDATE OF THE NATIONAL SEISMIC HAZARD MAPS

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INTRODUCTION

This report presents the consensus recommendations of the Basin and Range Province Earthquake Working Group II (BRPEWG II) to the U.S. Geological Survey National Seismic Hazard Mapping Program (NSHMP) regarding eight Basin and Range Province (BRP) seismic-hazard issues important to the U.S. Geological Survey's (USGS) 2014 update of the National Seismic Hazard Maps (NSHMs). The staff of the NSHMP formulated the eight seismic-hazard issues (four seismologic and four geologic) presented to the BRPEWG II for consideration. The BRPEWG II was jointly convened under the auspices of the Western States Seismic Policy Council (WSSPC), the USGS, and the Utah Geological Survey (UGS).

BACKGROUND

BRPEWG II follows upon BRPEWG I (Lund, 2006; http://ugspub.nr.utah.gov/publications/open_file_reports/OFR-477.pdf) convened in 2006, in response to WSSPC Policy Recommendation (PR) 04-5, which advocated creating a broad-based group of technical experts to evaluate five BRP seismic-hazard issues important to the 2007 update of the NSHMs. Those issues were identified at the Basin and Range Province Seismic Hazard Summit II (Lund, 2005; http://ugspub.nr.utah.gov/publications/misc_pubs/MP-05-2.pdf). WSSPC PR 04-5 was subsequently updated, and is currently WSSPC PR 10-5 *Basin and Range Province Working Group(s)* (http://www.wsspc.org/policy/files/Adopted/Adopted_PR_10-5_BRPWG.pdf). It was in response to WSSPC PR 10-5 that 28 technical experts (table 1) familiar with the geology, seismology, and paleoseismology of the BRP convened as the BRPEWG II on November 14-16, 2011, at the offices of the UGS in Salt Lake City, Utah. The membership of BRPEWG II was drawn from several BRP state geological surveys, federal government agencies, academic institutions, seismological laboratories, and geotechnical consulting firms. Additional information on the BRPEWG process is available on the UGS web page at http://geology.utah.gov/ghp/workgroups/brpewg.htm.

BRPEWGII PROCESS

The charge given to the BRPEWG II by WSSPC PR 10-5 was to:

- Bring together subject-matter experts to discuss evidence of and evaluate eight seismic-hazard issues (four seismologic and four geologic) important to the 2014 update of the NSHMs.
- Define strategies for resolving seismic-hazard issues, and where possible, establish a consensus recommendation(s) to the USGS on each issue for the 2014 update of the NSHMs.
- Where consensus is not possible, outline research programs to resolve outstanding technical questions that the USGS can use when setting future research priorities.

To achieve these goals, two discussion leaders were identified for each seismic-hazard issue (table 1, appendix A). The role of the discussion leaders was to frame their issue succinctly for BRPEWG II as a whole, facilitate discussion during their session, and guide the BRPEWG II to a consensus recommendation(s) to the USGS for the 2014 NSHMs update. Each of the eight sessions lasted approximately two-and-a-half hours, followed by a ninth session used to review and finalize the recommendations generated during the meeting. The discussion leaders organized their sessions as they thought appropriate; however, a generally consistent format was employed for all of the sessions. That format consisted

Table 1. *Members of the Basin and Range Province Earthquake Working Group II.*

Participant	Affiliation	Issue Leader
Anderson, John	University of Nevada, Reno	S4
Arabasz, Walter	University of Utah Seismograph Stations	
Biasi, Glenn	University of Nevada, Reno	
Bowman, Steve	Utah Geological Survey	UGS Liaison
Briggs, Rich	U.S. Geological Survey	
Brune, Jim	University of Nevada, Reno	S2
Crone, Tony	U.S. Geological Survey	G4
dePolo, Craig	Nevada Bureau of Mines and Geology	
DuRoss, Chris	Utah Geological Survey	G1
Gold, Ryan	U.S. Geological Survey	
Haller, Kathy	U.S. Geological Survey	G2, G3
Hecker, Suzanne	U.S. Geological Survey	
Hylland, Mike	Utah Geological Survey	G2
Love, David	New Mexico Geological Survey	
Lund, William	Utah Geological Survey	Coordinator
Moschetti, Morgan	U.S. Geological Survey	
Mueller, Chuck	U.S. Geological Survey	S3, S4
Olig, Susan	URS Corporation	G1
Pearthree, Phil	Arizona Geological Survey	
Pechmann, Jim	University of Utah Seismograph Stations	S1
Personius, Steve	U.S. Geological Survey	
Petersen, Mark	U.S. Geological Survey	S2
Philips, Bill	Idaho Geological Survey	
Schwartz, Dave	U.S. Geological Survey	S1
Stickney, Mike	Montana Bureau of Mines and Geology	
Wesnousky, Steve	University of Nevada, Reno	G3
Wittke, Seth	Wyoming Geological Survey	
Wills, Chris	California Geological Survey	
Wong, Ivan	URS Corporation	S3

of one to several short (15-20 minute) presentations (appendices A and B) either by the discussion leaders or by other subject-matter experts attending the BRPEWG II to frame the issue and present available relevant data. The presentations were followed by open discussion to further explore the issue and elicit opinions from the BRPEWG II as a whole, and finally the end of the session was used to formulate a consensus recommendation(s) to the USGS. Staff from the UGS took careful notes during each session and prepared this meeting summary.

BRPEWG II SEISMIC HAZARD ISSUES AND RECOMMENDATIONS

The BRPEWG II arrived at the following consensus recommendations through a deliberative process. The BRPEWG II relied on the broad technical expertise and experience of its members when considering how the eight BRP seismic-hazard issues posed by the NSHMP should be addressed in the 2014 NSHM update. Where appropriate, BRPEWG II also made recommendations for long-term research that will permit further refinement of the NSHMs beyond the 2014 update.

Seismology Issues

***Issue S1*: How should the magnitude-frequency relations for a single BRP fault be characterized? Do existing seismological data help define these relationships?**

Recommendations to the USGS for the 2014 NSHMs update:

- The BRPEWG II supports the current USGS approach to modeling recurrence rates of moderate-size independent earthquakes (**M** 5.0 to 6.5). This approach is based entirely on earthquake catalog data, and is applied to both fault-specific sources and the background source. The BRPEWG II does not recommend the use of models that define recurrence rates for these earthquakes based on slip rates or recurrence intervals for large surface-faulting earthquakes on major faults.
- For earthquakes of **M** ≥ 6.5, the frequency-magnitude distribution along most BRP faults is currently modeled using a 67% weight for the maximum magnitude model and a 33% weight for the USGS Gutenberg-Richter (floating exponential) model. Although this weighting is somewhat arbitrary, the BRPEWG II sees no compelling reason to change it at the present time. However, it recommends that the USGS explore the effects of different weightings on hazard, for example 90% maximum magnitude and 10% USGS Gutenberg-Richter.
- It is essential that the methodologies used for constructing fault-specific magnitude-frequency recurrence models used in the NSHMs be fully documented. The USGS is urged to publish these methodologies, including a comparison to other models used in state-of-the-practice probabilistic seismic hazard analyses.

Long-term recommendation:

- Conduct research on frequency-magnitude relations for single faults including, for example, the appropriate b-value for exponential distributions.

***Issue S2*: How should the "smoothing" of seismicity be handled in the NSHMs? The current NSHMs use a radial smoothing process, but recent precarious rock studies in California and western Nevada suggest that anisotropic smoothing (i.e., along faults) might be more appropriate. If anisotropic smoothing is used, should it be applied universally across the entire BRP?**

Recommendation to the USGS for the 2014 NSHMs update:

- Further investigate isotropic and anisotropic smoothing methods and parameters. Test the predictive power of these methods, where feasible, and use this information to help optimize parameters (including smoothing distance) that define the smoothing functions. The USGS should compare precarious balanced rock data in this assessment. Whether or not the USGS implements anisotropic or other methodological changes to smoothing will/should depend on results of the above-mentioned investigations, testing, and validation.

***Issue S3*: Does the rate of earthquakes represented on the NSHMs need to match the rate of historical earthquakes? If not, what level of mismatch is acceptable?**

Recommendations for the 2014 NSHMs update:

A comparison of historical and modeled seismicity rates for the northern and more seismically active part of the USGS "Basin and Range" region (California east of the Sierra Nevada Mountains, Nevada, western half of Utah, southeastern Oregon, southern half of Idaho, and westernmost Wyoming and Montana) shows that modeled seismicity rates generally exceed historical rates (creating a seismic "bulge") across a broad range of moment magnitude (M_w), although the bulge is greatest in the M_w 6-7 range. Assuming a 50% characteristic and 50% Gutenberg-Richter recurrence model distribution (NSHMP definitions) in the crustal fault model produces the strongest bulge—a factor of about three near M_w 6.6. By adjusting various modeling assumptions (for example, 67% characteristic and 33% Gutenberg-Richter), it is possible to reduce the bulge to a factor of two or smaller. Short-term recommendations to the USGS NSHMP include:

- Quantify the uncertainty in the historical seismicity rates (for example, by plotting error bars).
- Redo the historical versus modeled seismicity comparison for the northern Basin and Range, excluding the seismicity in the Yellowstone region, to determine what effect that has on the size of the bulge.
- The USGS is already considering several updates for the Intermountain West (IMW) hazard model that will affect modeled seismicity rates including: 1) improving fault inventories, 2) changing dips for crustal faults, 3), modeling fault intersections, 4) computing characteristic magnitudes from area rather than length for some faults, 5) adjusting the weights to the characteristic versus Gutenberg-Richter models and/or including a b = 0 branch, and 6) using regionalized b-values. The BRPEWG II recommends tracking how these possible chang-

es to the hazard model will affect seismicity rates.

Long-term recommendation:

- To address the mismatch between modeled and observed seismicity rates in California, the Uniform California Earthquake Rupture Forecast, version 3 (UCERF3) Project (http://www.wgcep.org/node/47) is currently developing a new model that allows complex multi-fault interactions. The BRPEWG II recommends following UCERF3 progress, and evaluating the applicability of such models for the rest of the western United States.

***Issue S4*: What are the sources and levels of uncertainty in the earthquake magnitudes contained in the seismicity catalogs used for the BRP in the NSHMs?**

Recommendations to the USGS for the 2014 NSHMs update:

- Clarify the historical relation between regional network catalogs and the Preliminary Determination of Epicenters (PDE) Bulletin (USGS, 2010).
- Consider using network locations for past earthquakes in authoritative network regions if they differ from the PDE and are of higher quality.
- Since the USGS relies heavily on the PDE catalog (unless there is a specialized regional study) to determine background seismicity, the question of source and level of uncertainty needs to be assessed by the USGS for many regions, including the IMW and the Walker Lane belt, with help as needed from regional network operators.
- The Tinti and Mulargia (1985) adjustment to earthquake rates may have comparable size but opposite sign from the adjustment due to magnitude conversions. The statistical methodology used by the NSHMP for addressing bias in earthquake rates should be carefully reviewed for internal consistency.

Long-term recommendations:

- Encourage regional networks to:
  - Use station corrections in M_L determinations.
  - Carefully document changes in magnitude determination practices (past and future), and whenever changes have been (are) made, to develop/recommend relations between the old and new system, and to M_W.
  - Assign version numbers to catalogs for quality control and referencing.
- Encourage efforts to improve regional catalogs, including:
  - Review magnitudes of past earthquakes, starting with the largest events and thoughtfully assign uncertainties to reviewed magnitudes.
  - Compare catalogs.
  - Use state-of-the-art techniques to relocate events.

Geology Issues

***Issue G1*: How should we calculate maximum characteristic magnitude (M_{max}) for BRP faults based on surface-rupture lengths, fault areas, and available displacement data (an M_{max} of 7.5 is currently in the NSHMs based on the magnitude of the 1959 Hebgen Lake earthquake)? What is the source or explanation of the discrepancy between M calculated using surface-rupture length versus using the average or maximum displacement (site bias, underestimation of surface rupture length, other?)? How should the discrepancy in the magnitude determined from these two measurements be handled in the NSHMs?**

Recommendations to the USGS for the 2014 NSHMs update:

- Capping M_{max} for BRP faults in the NSHMs:
  - Keep the present M_W 7.5 ± 0.2 cap on M_{max} for BRP normal faults, but revise the documentation for the physical basis for the cap to be the M_W 7.5 1887 Sonora, Mexico earthquake (Bakun, 2006; Suter, 2006).
  - Consider segmented or other alternative rupture models where paleoseismic studies provide good evidence for differences in rupture patterns and behavior along a fault (e.g., West Cache, Steens, Lost River, Lemhi, Mission, Sangre de Cristo, and others).
- Best approach to determining M_{max} for BRP faults in the NSHMs:
  - Use the same approach for determining M_{max} for strike-slip faults in the BRP as is used for strike-slip faults in California (Petersen and others, 2008).
  - There are significant epistemic uncertainties in determining M_{max} for BRP normal faults due to possible scaling differences for the low-strain rate environment, normal slip earthquakes, and larger events. To better address these uncertainties, consider using multiple regression relations from the following list to determine M_{max} for BRP faults in the NSHMs:
    - » Wells and Coppersmith (1994) –

SRL for all fault types

- » Anderson and others (1996) – SRL for all fault types and slip rate
- » Wells and Coppersmith (1994) – SRL for normal faults
- » Stirling and others (2002) – censored instrumental
- » Wells and Coppersmith (1994) – RA for all fault types

(SRL = surface rupture length; RA = fault rupture area)

Long-term recommendation:

- Sponsor research to update or develop empirical regressions on magnitude appropriate for BRP normal faults.

Issue G2: **How should antithetic fault pairs be modeled in the NSHMs? For example, what is the relation and seismogenic significance of antithetic fault pairs such as the East and West Cache faults, and strands of the Salt Lake City segment of the Wasatch fault and the West Valley fault zone?**

Recommendations to the USGS for the 2014 NSHMs update:

- Explore using metrics (such as fault length, topographic relief, and overlap) to guide selection of master and subsidiary faults.
  - Evaluate dataset for overlapping relations to select the master fault based on length.
  - Evaluate using aspect ratio (length/width) for individual antithetic fault pairs.
  - Where data allow, structural throw should be used rather than topographic relief.
  - Evaluate using length times throw as a parameter for selecting the master fault.
- Use subsurface data (e.g., seismic reflection) where available to guide master fault selection.
- Where available data do not give a clear indication of the master versus subsidiary fault, model both alternatives using a logic tree approach.
- Use rupture area (rather than surface rupture length) to determine magnitude for truncated faults.
- Conduct sensitivity studies on the impact on ground motions of antithetic fault pairs in urban areas.
- Develop and test a methodology for modeling antithetic fault pairs and present those results at the USGS IMW workshop in summer 2012.

Issue G3: **The USGS seeks guidance on how to estimate the uncertainty for the slip rates on BRP normal-slip faults, especially for faults that have little or no slip-rate data. The method used in California to estimate the uncertainty has varied the upper and lower bounds of the slip rate by plus-or-minus 50%. Thus, the uncertainty bounds for a fault that has a slip rate of 5 mm/yr would be 7.5 mm/yr and 2.5 mm/yr. Do these bounding values encompass the fifth and ninety-fifth percentiles for this fault?**

Recommendations to the USGS for the 2014 NSHMs update:

- Engage state geological survey scientists to contribute and review slip-rate uncertainty for IMW sources.
- Conduct sensitivity studies of ground motions that incorporate assigned slip rates for sources in the IMW.
- Test assigned parameters and present results at the USGS IMW workshop in summer 2012.

Issue G4: **Based on the recommendations from BRPEWG I (Lund, 2006), the current NSHMs use a dip of 50° ± 10° for normal faults in the BRP. Are the 50° dip value and the ± 10° uncertainty range valid and acceptable to cover the probable range of dips for BRP normal faults?**

Recommendations to the USGS for the 2014 NSHMs update:

- Following a review of published data summarizing the dips of normal faults in the BRP and worldwide, the BRPEWG II concludes that a dip of 50° ± 15° best represents the range of dips for normal faults in the BRP. The BRPEWG II recommends this range be used in updates of the NSHMs; the 50° value defines the mean dip value and the ± 15° range represents the 5th and 95th percentiles.
- For those faults having geological, geophysical, seismological, or geodetic data that convincingly constrains a specific fault's dip within the seismogenic crust, the NSHMs should use these fault-specific data to calculate the fault's hazard.
- The BRPEWG II recommends that the USGS evaluate the impact of increasing the range of recommended fault dips (from ± 10° to ± 15°) on the overall hazard.
- The BRPEWG II recommends that the USGS evaluate whether the range in fault dips determined from global data is better represented by non-Poissonian distribution around the mean value versus assuming a simple Poisson distribution.

ACKNOWLEDGMENTS

The BRPEWG II organizers (WSSPC, USGS, UGS) thank the members of BRPEWG II, all of whom freely volunteered their time to help improve the next generation of NSHMs in the BRP. Special thanks are offered to the session organizers and to the BRPEWG II members who prepared and presented talks during the sessions—no small imposition on their al¬ready very busy schedules. Thanks also to Steve Bowman, UGS, who coordinated the meeting facilities and logistics; to Chris DuRoss, UGS, and Dean Ostenaa, Fugro, Inc., whose timely reviews materially improved this report; and to Patti Sutch, WSSPC Executive Director, who facilitated WSSPC's participation in the BRPEWG II process. This work was supported by the U.S. Geological Survey National Earthquake Hazards Reduction Program (award no. G11AP20187), Western States Seismic Policy Council, and the Utah Geological Survey.

REFERENCES

This reference list was compiled from references cited in the BRPEWG II Power Point presentations (appendix A). A small number of discrepancies were discovered between the citations in the presentations and the actual references. Because the presentations are part of the official meeting record, they were not corrected in the Compilation of BRPEWG II Presentations (appendix B); however, to the extent possible, those discrepancies have been resolved here.

Abe, K., 1981, Magnitudes of large shallow earthquakes from 1904 to 1980: Physics of the Earth and Planetary Interiors, v. 27, p. 72–92.

Abers, G.A., Mutter, C.Z., and Fang, J., 1997, Shallow dips of normal faults during rapid extension—earthquakes in the Woodlark-D'Entrecasteaux rift system, Papua New Guinea: Journal of Geophysical Research, v. 102, no. B7, p. 15,301–15,317.

Abrahamson, N.A., and Silva, W.J., 1997, Empirical response spectral attenuation relations for shallow crustal earthquakes: Seismological Research Letters, v. 68, p. 94–127.

Aki, K., 1966, Generation and propagation of G waves from the Niigata earthquake of June 16, 1964—Part 2, Estimation of earthquake movement, released energy, and stress-strain drop from the G wave spectrum: Tokyo, Bulletin of the Earthquake Research Institute, v. 44, p. 73–88.

Anderson, J.G, Wesnousky, S.G., and Stirling, M.W., 1996, Earthquake size as a function of fault slip rate: Bulletin of the Seismological Society of America, v. 86, no. 3, p. 683–690.

Anderson, L.W., 2008, Evaluation of the seismogenic potential of the Joes Valley fault zone—Joes Valley Dam, Emery County Project, Utah: U.S. Department of the Interior, Bureau of Reclamation Technical Memorandum No. 86-68321-2008-10, 12 p., 2 attachments.

Anderson, L.W., Olig, S.S, and Forman, S., 2005, Paleoseismic investigation of the Canyon Ferry fault, west-central Montana, *in* Lund, W.R., editor, Proceedings Volume Basin and Range Province Seismic Hazard Summit II: Utah Geological Survey Miscellaneous Publication 05-2, p. 285–302, CD.

Arabasz, W.J., Burlacu, R., and Pankow, K.L., 2007, An overview of historical and contemporary seismicity in central Utah, *in* Willis, G.C., Hylland, M.D., Clark, D.L., and Chidsey, T.C., Jr., editors, Central Utah—diverse geology of the dynamic landscape: Utah Geological Association Publication 36, p. 237–253.

Arabasz, W.J., Pechmann, J.C, and Brown, E.D., 1992, Observational seismology and the evaluation of earthquake hazards and risk in the Wasatch Front area, Utah, *in* Gori, P.L. and Hays, W.W., editors, Assessment of regional earthquake hazards and risk along the Wasatch Front, Utah: U.S. Geological Survey Professional Paper 1500-A-J, p. D1–D36.

Arabasz, W.J., Richins, W.D., and Langer, C.J., 1981, The Pocatello Valley (Idaho–Utah border) earthquake sequence of March to April 1975: Bulletin of the Seismological Society of America, v. 71, no. 3, p. 803–826.

Bakun, W.H., 2006, MMI attenuation and historical earthquakes in the Basin and Range Province of western North America: Bulletin of the Seismological Society of America, v. 96, no. 6, p. 2206–2220, doi: 10.1785/0120060045.

Barrientos, S.E., Stein, R.S., and Ward, S.N., 1987, Comparison of the 1959 Hebgen Lake, Montana, and the 1983 Borah Peak, Idaho, earthquakes from geodetic observations: Bulletin of the Seismological Society of America, v. 77, no. 3, p. 784–808.

Biasi, G.P., and Weldon, R.J., II, 2006, Estimating surface rupture length and magnitude of paleoearthquakes from point measurements of rupture displacement: Bulletin of the Seismological Society of America, v. 96, no. 5, p. 1612–1623.

Biasi, G.P., and Weldon, R.J., II, 2009, San Andreas fault rupture scenarios from multiple paleoseismic records—Stringing pearls: Bulletin of the Seismological Society of America, v. 99, no. 2A, p. 471–498, doi: 10.1785/0120080287.

Bonilla, M.G., Mark, R.K., and Leinkaemper J.J., 1984, Statistical relations among earthquake magnitude, surface rupture, and surface fault displacement: Bulletin of the Seismological Society of America, v. 74, no. 6, p. 2379–2411.

Boore, D.M., Joyner, W.B., and Fumal, T.M., 1997, Estimation of response spectra and peak accelerations from western North American earthquakes—a summary of recent work: Seismological Research Letters, v. 66, p. 128–153.

Brozzetti, F., Boncio, P., Lavecchia, G., and Pace, B., 2009, Present activity and seismogenic potential of a low-angle normal fault system (Citta di Castello, Italy)—Constraints from surface geology, seismic reflection data, and seismicity: Tectonophysics, v. 463, p. 31–46, doi: 10.1016/j.tecto.2008.09.023.

Bruhn, R.L., Gibler, P.R., and Parry, W.T., 1987, Rupture characteristics of normal faults—An example from the Wasatch fault zone, Utah, *in* Coward, M.P., Dewey, J.F., and Hancock, P.L., editors, Continental extensional tectonics: Geological Society of London, Special Publication No. 28, p. 337–353.

Bruhn, R.L., and Schultz, R.A., 1996, Geometry and slip distribution in normal fault systems—Implications for mechanics and fault-related hazards: Journal of Geophysical Research, v. 101, no. B2, p. 3401–3412.

Caskey, S.J., Wesnousky, S.G., Zhang, P., and Slemmons, D.B., 1996, Surface faulting of the 1954 Fairview Peak (M_S 7.2) and Dixie Valley (M_S 6.8) earthquakes, central Nevada: Bulletin of the Seismological Society of America, v. 86, no. 3, p. 761–787.

Chang, W.L., and Smith, R.B., 2002, Integrated seismic-hazard analysis of the Wasatch Front, Utah: Bulletin of the Seismological Society of America, v. 92, no. 5, p. 1904–1922.

Chang, W.L., Smith, R.B., Meertens, C.M., and Harris, R.A., 2006, Contemporary deformation of the Wasatch Front, Utah, from GPS measurements with implications for interseismic fault behavior and earthquake hazard—Observations and kinematic analysis: Journal of Geophysical Research, v. 111, B11405, doi: 10:1029/2006JB004326.

Collettini, C., and Sibson, R.H., 2001, Normal faults, normal friction?: Geology, v. 29, no. 10, p. 927–930.

Daniels, K.E., and Hayman, N.W., 2008, Force chains in seismogenic faults visualized with photoelastic granular shear experiments: Journal of Geophysical Research, v. 113, B11411, doi: 10.1029/2008JB005781.

dePolo, C.M., Clark, D.G., Slemmons, D.B., and Ramelli, A.R., 1991, Historical surface faulting Basin and Range Province, western North America—implications for fault segmentation: Journal of Structural Geology, v. 13, p. 123-136.

Doser, D.I., 1985, Source parameters and faulting processes of the 1959 Hebgen Lake, Montana, earthquake sequence: Journal of Geophysical Research, v. 90, no. B6, p. 4537–4555.

Doser, D.I., 1989, Extensional tectonics in northern Utah—southern Idaho, U.S.A., and the 1934 Hansel Valley sequence: Physics of the Earth and Planetary Interiors, v. 54, p. 120–134.

Doser, D.I., and Smith, R.B., 1989, An assessment of source parameters of earthquakes in the Cordillera of the western United States: Bulletin of the Seismological Society of America, v. 79, no. 5, p. 1393–1409.

Electric Power Research Institute, 1988, Seismic hazard methodology for the central and eastern United States—Volume 1, Part 2, Methodology (Revision 1): Electric Power Research Institute Final Report, EPRI-NP-4726-A-1(1), variously paginated.

Engdahl, E.R., and Villaseñor, A., 2002, Global seismicity—1900–1999, *in* Lee, W.H.K., Kanamori, H., Jennings, P.C., and Kisslinger, C., editors, International Handbook of Earthquake and Engineering Seismology: International Association of Seismology and Physics of the Earth's Interior (IASPEI), p. 665–690.

Faulds, J.E., Henry, C.D., and Hinz, N.H., 2005, Kinematics of the northern Walker Lane—An incipient transform fault along the Pacific-North American plate boundary: Geology, v. 33, p. 505–508.

Field, E.H., 2000, A modified ground motion attenuation relationship for southern California that accounts for detailed site classification and a basin-depth effect: Bulletin of the Seismological Society of America, v. 6B, p. S209–221.

Felzer, K.R., 2007, Appendix I—Calculating California seismicity rates: Earthquake Rate Model 2.2 of the Working Group on California Earthquake Probabilities, online <http://www.wgcep.org>.

Felzer, K.R., 2008, Appendix I—Calculating California seismicity rates, *in* The Uniform California Earthquake Rupture Forecast, version 2 (UCERF 2): U.S. Geological Survey Open-File Report 2007-1437I and California Geological Survey Special Report 203I, 42 p.

Felzer, K.R., and Cao, T., 2007, Appendix H—WGCEP historical California earthquake catalog: Earthquake Rate Model 2.2 of the Working Group on California Earthquake Probabilities, online <http://www.wgcep.org>.

Ferrill, D.A., Morris, A.P., Stamatakos, J.A., and Sims, D.W., 2000, Crossing conjugate normal faults: American Association of Petroleum Geologists Bulletin, v. 84, no. 10, p. 1543–1559.

Frankel, A., 1995, Mapping seismic hazard in the central and eastern United States: Seismological Research Letters, v. 66, p. 8–21.

Frankel, A., Mueller, C., Barnard, T., Perkins, D., Leyendecker, E.V., Dickman, N., Hanson, S., and Hopper, M., 1996, National Seismic Hazard Maps documentation: U.S. Geological Survey Open-File Report 96-532, 41 p.

Griscom, M., and Arabasz, W.J., 1979, Local magnitude (M_L) in the Wasatch Front and Utah region—Wood-Anderson calibration, coda-duration estimates of M_L, and M_L versus M_b, *in* Arabasz, W.J., Smith, R.B., and Richens, W.D., editors, Earthquake studies in Utah, 1850 to 1978: University of Utah Seismograph Stations Special Publication, p. 433–443.

Gutenberg, B., and Richter, C.F., 1956, Earthquake magnitude, intensity, energy, and acceleration: Bulletin of the Seismological Society of America, v. 46, p. 105–145.

Hanks, T.C., and Bakun, W.H., 2002, A bilinear source-scaling model for M-logA observations of continental earthquakes: Bulletin of the Seismological Society of America, v. 92, no. 5, p. 1841–1846.

Hanks, T.C., and Bakun, W.H., 2008, M-logA observations for recent large earthquakes: Bulletin of the Seismological Society of America, v. 98, p. 490–494, doi: 10.1785/0120070174.

Hanks, T.C., and Kanamori, H., 1979, Moment magnitude scale: Journal of Geophysical Research, v. 84, p. 2348–2350.

Hecker, S., 1993, Quaternary tectonics of Utah with emphasis on earthquake-hazard characterization: Utah Geological Survey Bulletin 127, 157 p., map scale 1:50,000.

Hemphill-Haley, M.A., and Weldon R.J., II, 1999, Estimating prehistoric earthquake magnitude from point measurements of surface rupture: Bulletin of the Seismological Society of America, v. 89, no. 5, p. 1264–1279.

Horsfield, W.T., 1980, Contemporaneous movement along crossing conjugate normal faults: Journal of Structural Geology, v. 2, no. 3, p. 305–310.

Jackson, J.A., 2002, Using earthquakes for continental tectonic geology, *in* International Handbook of Earthquake and Engineering Seismology: International Association of Seismology and Physics of the Earth's Interior (IASPEI), v. 81A, p. 491–503.

Jackson, J.A., and White, N.J., 1989, Normal faulting in the upper continental crust—Observations from regions of active extension: Journal of Structural Geology, v. 11, no. 1/2, p. 15–36.

Kafka, A.L, 2002, Statistical analysis of the hypothesis that seismicity delineates areas where future large earthquakes are likely to occur in the central and eastern United States: Seismological Research Letters, v. 73, no. 6, p. 990–1001.

Kafka, A.L., 2005, see http://earthquake.usgs.gov/hazards/about/workshops/CEUS-WORKSHP/Tuesday/Kafka-NSHM_06.pdf.

Leonard, M., 2010, Earthquake fault scaling—Self-consistent relating of rupture length, width, average displacement, and moment release: Bulletin of the Seismological Society of America, v. 100, no. 5A, p. 1971–1988, doi: 10.1785/0120090189.

Limpert, E., Stahel, W., and Abbt, M., 2001, Lognormal distributions across the sciences—Keys and clues: BioSciences, v. 51, p. 341–352, doi: 10.1641/0006-3568(2001)051[0341: LNDATS]2.0.CO;2.

Lund, W.R., editor, 2005, Proceedings volume Basin and Range Province Seismic Hazards Summit II: Utah Geological Survey Miscellaneous Publication 05-2, CD.

Lund, W.R., editor, 2006, Basin and Range Province Earthquake Working Group seismic-hazard recommendations to the U.S. Geological Survey National Seismic Hazard Mapping Program: Utah Geological Survey Open-File Report 477, 22 p.

Mason, D.B., 1996, Earthquake magnitude potential of the Intermountain Seismic Belt, USA, from surface-parameter scaling of late Quaternary faults: Bulletin of the Seismological Society of America, v. 86, no. 5, p. 1487–1506.

McCalpin, J.P., and Slemmons, D.B., 1998, Statistics of paleoseismic data: Final Technical Report, Contract 1434-HQ-96-GR-02752, submitted by GEO-HAZ Consulting, to the U.S. Geological Survey, 62 p.

McGuire, R.K., 2004, Seismic hazard and risk analysis: Earthquake Engineering Research Institute MNO-10, 221 p.

Myers, W.F., and Hamilton, W., 1964, Deformation accompanying the Hebgen Lake earthquake of August 17, 1959: U.S. Geological Survey Professional Paper 435, p. 37-98.

Nicol, A., Walsh, J.J., Watterson, J., and Bretan, P.G., 1995, Three-dimensional geometry and growth of conjugate normal faults: Journal of Structural Geology, v. 17, no. 6, p. 847–862.

Okaya, D.A., and Thompson, G.A., 1985, Geometry of Cenozoic extensional faulting—Dixie Valley, Nevada: Tectonics, v. 4, no. 1, p. 107–125.

Olig, S.S., Knuepfer, P.L.K., and Hemphill-Haley, M., 1997, Temporal clustering of characteristic and non-characteristic earthquakes in the northern Basin and Range Province—Typical extensional behavior or localized hot-spot effects? [abs.]: Geological Society of America Abstracts with Programs, v. 29, no. 6, p. A-72.

Page, M., Felzer, K., Weldon, R., and Biasi, G., 2008, The magnitude-frequency distribution on the southern San Andreas fault follows the Gutenberg-Richter distribution: Eos, Transactions of the American Geophysical Union, v. 89, no. 53, Fall Meeting Supplement, also online at < http://adsabs.harvard.edu/abs/2008AGUFM.S31C.06P>.

Pancha, A., Anderson, J.G., and Kreemer, C., 2006, Comparison of seismic and geodetic scalar moment rates across the Basin and Range Province: Bulletin of the Seismological Society of America, v. 96, no. 1, p. 11–32, doi: 10.1785/0120040166.

Parsons, T., 2008, Monte Carlo method for determining earthquake recurrence parameters from short paleoseismic catalogs—Example calculations for California: Journal of Geophysical Research–Solid Earth, v. 113, no. B3, article number B03302, doi: 10.1029/2007JB004998.

Payne, S.J., Zollweg, J.E., and Rodgers, D.W., 2004, Stress triggering of conjugate normal faulting—Late aftershocks of the 1983 M_S 7.3 Borah Peak, Idaho, earthquake: Bulletin of the Seismological Society of America, v. 94, no. 3, p. 828–844.

Pechmann, J.C., and Arabasz, W.J., 1995, The problem of the random earthquake in seismic hazard analysis—Wasatch Front region, Utah, *in* Lund, W.R., editor, Environmental and Engineering Geology of the Wasatch Front Region—1995 Symposium and Field Conference: Utah Geological Association Publication 24, p. 77–93.

Pechmann, J.C., Nava, S.J., Terra, F.M., and Berrnier, J., 2007, Local magnitude determinations for Intermountain Seismic Belt earthquakes from broadband digital data: Bulletin of the Seismological Society of America, v. 97, no. 2, p. 557–574, doi: 10.1785/0120060114.

Petersen, M.D., Frankel, A.D., Harmsen, S.C., Mueller, C.S., Haller, K.M., Wheeler, R.L., Wesson, R.L., Zeng, Y., Boyd, O.S., Perkins, D.M., Luco, N., Field, E.H., Wills, C.J., and Rukstales, K.S., 2008, Documentation for the 2008 update of the United States National Seismic Hazard Maps: U.S. Geological Survey Open-File Report 2008–1128, 128 p., online, < http://pubs.usgs.gov/of/2008/1128/>.

Pezzopane, S.K., and Dawson, T.E., 1996, Fault displacement hazard—A summary of issues and information, *in* Seismotectonic framework and characterization of faulting at Yucca Mountain, Nevada: U.S. Geological Survey Administrative Report prepared for the U.S. Department of Energy, chapter 9, 160 p.

Richins, W.D., Pechmann, J.C., Smith, R.B., Langer, C.J., Goter, S.K., Zollweg, J.E., and King, J.J., 1987, The 1983 Borah Peak, Idaho, earthquake and its aftershocks: Bulletin of the Seismological Society of America: v. 77, no. 3, p. 694–723.

Rogers, A.M., Algermissen, S.T., Hays, W.W., Perkins, D.M., Van Strien, D.O., Hughes, H.C., Hughes, R.C., Lagorio, H.J., and Steinbrugge, K.V., 1976, A study of earthquake losses in the Salt Lake City, Utah area: U.S. Geological Survey Open-File Report 76-89, 357 p. [*Also referenced as USGS (1976)*].

Romney, C. 1957, Seismic waves from the Dixie Valley–Fairview Peak earthquakes: Bulletin of the Seismological Society of America, v. 47, no. 4, p. 301–319.

Ryall, A., 1962, The Hebgen Lake, Montana, earthquake of August 18, 1959–P waves: Bulletin of the Seismological Society of America, v. 52, no. 2, p. 235–271.

Sarmiento, A.C., Wesnousky, S.G., and Bormann, J.M., 2011, Paleoseismic trenches across the Sierra Nevada and Carson Range fronts in Antelope Valley, California, and Reno, Nevada: Bulletin of the Seismological Society of America, v. 101, no. 5, p. 2542–2549, doi: 10.1785/0120100176.

Schwartz, D.P., and Coppersmith, K.J., 1984, Fault behavior and characteristic earthquakes—Examples from the Wasatch and San Andreas fault zones: Journal of Geophysical Research, v. 89, no. B7, p. 5681–5698.

Shearer, P., Hauksson, E., and Lin, G., 2005, Southern California hypocenter relocation with waveform cross-correlation, Part 2—Results using source-specific station terms and cluster analysis: Bulletin of the Seismological Society of America, v. 95, no. 3, p. 904–915, doi: 1785/0120040168.

Sieh, K.E., 1978, Slip along the San Andreas fault associated with the great 1857 earthquake: Bulletin of the Seismological Society of America, v. 68, no. 65, p. 1421–1448.

Sipkin, S.A., Person, W.J., and Presgrave, B.W., 2000, Earthquake bulletins and catalogs at the USGS National Earthquake Information Center: U.S. Geological Survey, online <http://earthquake.usgs.gov/regional/neic/neic_bulletins.php>.

Slemmons, D.B., 1957, Geological effects of the Dixie Valley–Fairview Peak, Nevada, earthquakes of December 16, 1954: Bulletin of the Seismological Society of America, v. 47, no. 4, p. 353–375.

Smith, R.B., and Arabasz, W.J., 1991, Seismicity of the Intermountain Seismic Belt, *in* Slemmons, D.B., Engdahl, E.R., Zoback, M.D., Zoback, M.L., and Blackwell, D., editors, Neotectonics of North America: Geological Society of America, Decade Map Volume 1, p. 185–228.

Smith, R.B., and Bruhn, R.L., 1984, Intraplate extensional tectonics of the Eastern Basin-Range—Inferences on structural style from seismic reflection data, regional tectonics, and thermal-mechanical models of brittle-ductile deformation: Journal of Geophysical Research, v. 89, no. B7, p. 5733–5762.

Stein, R.S., and Barrientos, S.E., 1985, Planar high-angle faulting in the Basin and Range—Geodetic analysis of the 1983 Borah Peak, Idaho, earthquake: Journal of Geophysical Research, v. 90, no. B13, p. 11,355–11,366.

Stirling, M, Rhoades, D, and Berryman, K., 2002, Comparison of earthquake scaling relations derived from data of the instrumental and preinstrumental era: Bulletin of the Seismological Society of America, v. 92, no. 2, p. 812–830.

Stover, C.W., and Coffman, J.L., 1993, Seismicity of the United States, 1568–1989 (revised): U.S. Geological Survey Professional Paper 1527, 418 p.

Stover, C.W., Reagor, G., and Algermissen, S.T., 1984, United States earthquake data file: U.S. Geological Survey Open-File Report 84–225, 123 p.

Suter, M., 2006, Contemporary studies of the 3 May 1887 M_W 7.5 Sonora, Mexico (Basin and Range Province) earthquake: Seismological Research Letters, v. 77, no. 2, p. 134–147.

Suter, M., and Contreras, J., 2002, Active tectonics of northeastern Sonora, Mexico (southern Basin and Range Province) and the 3 May 1887 $M_W = 7.4$ earthquake: Bulletin of the Seismological Society of America, v. 92, no. 2, p. 581–589.

Tinti, S., and Mulargia F., 1985, Effects of magnitude uncertainties on estimating the parameters in the Gutenberg-Richter frequency magnitude law: Bulletin of the Seismological Society of America, v. 75, no. 6, p. 1681–1697.

U.S. Geological Survey, 2010, The preliminary determination of epicenters (PDE) bulletin: U.S. Geological Survey Earthquake Hazards Program, online <http://earthquake.

usgs.gov/research/data/pde.php>, accessed March 1, 2012.

Veneziano, D., and Dyck, J., 1986, Seismic parameter estimation methods, *in* Seismic hazard methodology for nuclear facilities in the eastern United States—Volume 2, Appendix A: Electric Power Research Institute, EPRI NP-4726, variously paginated.

Weichert, D.H., 1980, Estimation of the earthquake recurrence parameters for unequal observation periods for different magnitudes: Bulletin of the Seismological Society of America, v. 70, no. 4, p. 1337–1356.

Wells, D.L., and Coppersmith, K.J., 1994, New empirical relationships among magnitude, rupture length, rupture width, rupture area, and surface displacement: Bulletin of the Seismological Society of America, v. 84, no. 4, p. 974–1002.

Wesnousky, S.J., 1994, The Gutenberg-Richter or characteristic earthquake distribution—Which is it?: Bulletin of the Seismological Society of America, v. 84, no. 6, p. 1940–1959.

Wesnousky, S.J., 2005, The San Andreas and Walker Lane fault systems, western North America—Transpression, transtension, cumulative slip, and the structural evolution of a major transform plate boundary: Journal of Structural Geology, v. 27, no. 8, p. 1505–1512.

Wesnousky, S.J., 2008, Displacement and geometrical characteristics of earthquake surface ruptures—Issues and implications for seismic-hazard analysis and the process of earthquake rupture: Bulletin of the Seismological Society of America, v. 98, no. 4, p. 1609–1632, doi: 10.1785/0120070111

Westaway, R., 1992, Revised hypocenter and fault rupture geometry for the 1980 November 23 Campania–Basilicata earthquake in southern Italy: Geophysical Journal International, v. 109, p. 376–390.

Witkind, I.J., 1964, Reactivated faults north of Hebgen Lake: U.S. Geological Survey Professional Paper 435, p. 37-50.

Wills, S., and Anders, M.H., 1999, Tertiary normal faulting in the Canyon Range, eastern Sevier Desert: Journal of Geology, v. 107, no. 6, p. 659–681.

Wong, I., Silva, W., Olig, S., Thomas, P., Wright, D., Ashland, F., Gregor, N., Pechmann, J., Dober, M., Christenson, G., and Gerth, R., 2002, Earthquake scenario and probabilistic ground shaking maps for the Salt Lake City, Utah, metropolitan area: Utah Geological Survey Miscellaneous Publication MP 02-5, 50 p.

Youngs, R.R., 2011, Personal communication to W. J. Arabasz, University of Utah Seismograph Stations.

Youngs, R.R., and Coppersmith, K.J., 1985, Implications of fault slip rates and earthquake recurrence models to probabilistic seismic hazard estimates: Bulletin of the Seismological Society of America, v. 75, no. 4, p. 939–964.

Youngs, R.R., Swan, F.H., Power, M.S., Schwartz, D.P., and Green, R.K., 1987, Probabilistic analysis of earthquake ground shaking hazard along the Wasatch Front, Utah, *in* Gori, P. L., and Hays, W. W., editors, Assessment of regional earthquake hazards and risk along the Wasatch Front, Utah: U.S. Geological Survey Open-File Report 87-585, p. M1–M110.

Youngs, R.R., Swan, F.H., Power, M.S., Schwartz, D.P., and Green, R.K., 2000, Probabilistic analysis of earthquake ground shaking hazard along the Wasatch Front, Utah, *in* Gori, P. L., and Hays, W. W., editors, Assessment of regional earthquake hazards and risk along the Wasatch Front, Utah: U.S. Geological Survey Professional Paper 1500 K-R, p. M1–M74.

Zechar, D.J., and Frankel, K.L., 2009, Incorporating and reporting uncertainties in fault slip rates: Journal of Geophysical Research, v. 114, B12407, doi: 10.1029/2009JB006325.

Zielke, O., Arrowsmith, J.R., Ludwig, L.G, and Akciz, S.O., 2010, Slip in the 1857 and earlier earthquakes along the Carrizo Plain, San Andreas fault: Science, v. 26, p. 1119–1122, doi: 10.1126/science.1182781.

Zoback, M.L., 1992, Superimposed late Cenozoic, Mesozoic, and possible Proterozoic deformation along the Wasatch fault zone in central Utah, *in* Gori, P.L., and Hayes, W.W., editors, Assessment of regional earthquake hazards and risk along the Wasatch Front, Utah: U.S. Geological Survey Professional Paper 1500–E, p. E-1–E-20.

APPENDIX A

LIST OF PRESENTATIONS ON BRPEWG II SEISMIC-HAZARD ISSUES

[1]Sessions and presentations are listed in the order that they occurred during the BRPEWG II meeting.

[2]See appendix B for a compilation of available BRPEWG II presentations.

SESSION S1

How should the magnitude-frequency relations for a single BRP fault be characterized? Do existing seismological data help define these relationships?

Session Leaders

David Schwartz, U.S. Geological Survey, Menlo Park, California

Jim Pechmann, University of Utah Seismograph Stations, Salt Lake City, Utah

Presentations

Pechmann	Introduction and specific questions
Petersen	Magnitude-frequency distribution for NSHM's
Hecker	Evaluating frequency-magnitude models for individual faults using a global data set of slip at a point (Power Point not available)
Arabasz	Observed seismicity and recurrence modeling on the Wasatch fault (revisited)
Biasi	Fault-specific magnitude-frequency distributions

SESSION G1

How should we calculate maximum characteristic magnitude (M_{max}) for BRP faults based on surface-rupture lengths, fault areas, and available displacement data (an M_{max} of 7.5 is currently in the NSHMs based on the magnitude of the 1959 Hebgen Lake earthquake)? What is the source or explanation of the discrepancy between M calculated using surface-rupture length versus using the average or maximum displacement (site bias, underestimation of surface rupture length, other?)? How should the discrepancy in the magnitude determined from these two measurements be handled in the NSHMs?

Session Leaders

Susan Olig, URS Corporation, Oakland, California

Chris DuRoss, Utah Geological Survey, Salt Lake City, Utah

Presentations

Olig	Calculating moment magnitudes for Basin and Range Province faults
Haller	Magnitude in the NSHM
Olig/DuRoss	Issue G1 – Part 1: Capping M_{max} (Putting a lid on M_{max} for long, unsegmented, normal-slip BRP faults)
DuRoss	Issue G1 – Part 2: Calculating moment magnitudes for Basin and Range Province faults—Case study: Wasatch fault zone (WFZ)
dePolo	Estimating surface lengths for prehistoric ruptures in the Basin and Range Province
Biasi	Pre-historic earthquake displacement
Hecker	Stress-drop scaling in the Western Cordillera: Evidence for a dependence on fault maturity (Presentation not available in compilation)

SESSION S2

How should the "smoothing" of seismicity be handled in the NSHMs? The current NSHMs use a radial smoothing process, but recent precarious rock studies in California and western Nevada suggest that anisotropic smoothing (i.e., along faults) might be more appropriate. If anisotropic smoothing is used, should it be applied universally across the entire BRP?

Session Leaders

Mark Petersen, U.S. Geological Survey, Denver, Colorado

Jim Brune, University of Nevada Reno, Nevada Seismological Laboratory, Reno, Nevada

Presentations

Moschetti/Petersen	BRPEWG Issue S2: Smoothing parameters for NSHM
Brune	PBRs [Precariously Balanced Rocks] and seismic hazard
Brune	Background seismicity

SESSION G2

How should antithetic fault pairs be modeled in the NSHMs? For example, what is the relation and seismogenic significance of antithetic fault pairs such as the East and West Cache faults, and strands of the Salt Lake City segment of the Wasatch fault and the West Valley fault zone?

Session Leaders

Kathy Haller, U.S. Geological Survey, Denver, Colorado

Mike Hylland, Utah Geological Survey, Salt Lake City, Utah

Presentation

Haller/Hylland Modeling graben-bounding faults in the NSHMs

SESSION S3

Does the rate of earthquakes represented on the NSHMs need to match the rate of historical earthquakes? If not, what level of mismatch is acceptable?

Session Leaders

Ivan Wong, URS Corporation, Oakland, California

Chuck Mueller, U.S. Geological Survey, Denver, Colorado

Presentations

Wong Does the rate of earthquakes represented on the NSHMs need to match the rate of historical earthquakes?

Mueller Does the rate of earthquakes represented on the NSHMs need to match the rate of historical earthquakes – USGS WUS hazard model

SESSION G3

The USGS seeks guidance on how to estimate the uncertainty for the slip rates on BRP normal-slip faults, especially for faults that have little or no slip-rate data. The method used in California to estimate the uncertainty has varied the upper and lower bounds of the slip rate by plus-or-minus 50%. Thus, the uncertainty bounds for a fault that has a slip

rate of 5 mm/yr would be 7.5 mm/yr and 2.5 mm/yr. Do these bounding values encompass the fifth and ninety-fifth percentiles for this fault?

Session Leaders

Kathy Haller, U.S. Geological Survey, Denver, Colorado

Steve Wesnousky, University of Nevada Reno, Reno, Nevada

Presentation

Haller	Addressing slip-rate uncertainty in the NSHM

SESSION S4

What are the sources and levels of uncertainty in the earthquake magnitudes contained in the seismicity catalogs used for the BRP in the NSHMs?

Session Leaders

John Anderson, University of Nevada Reno, Nevada Seismological Laboratory, Reno, Nevada

Chuck Mueller, U.S. Geological Survey, Denver, Colorado

Presentations

Anderson	BRPEWG II introduction to Issue S4 – magnitude uncertainty
Mueller	Why it matters
Arabasz	University of Utah earthquake catalog—magnitude “uncertainties” and comparison with the NSHM catalog
Stickney	Montana regional seismograph network magnitude issues
Anderson/Biasi	Nevada’s catalog

SESSION G4

Based on the recommendations from BRPEWG I (Lund, 2006), the current NSHMs use a dip of 50° ± 10° for normal faults in the BRP. Are the 50° dip value and the ± 10° uncertainty range valid and acceptable to cover the probable range of dips for BRP normal faults?

Session Leader

Tony Crone, U.S. Geological Survey, Denver, Colorado

Presentation

Crone	Dip angles for Basin and Range normal faults

APPENDIX B

COMPILATION OF BRPEWG II PRESENTATIONS

[1]See appendix A for a list of presentations in this compilation.

Compilation is available at
http://geology.utah.gov/ghp/workgroups/pdf/brpewg/BRPEWGII_Presentations.pdf