**SUMMARY**
**FIFTH MEETING**
**WORKING GROUP ON UTAH EARTHQUAKE PROBABILITIES**
**Tuesday & Wednesday, June 28 & 29, 2011**
**Utah Department of Natural Resources Building, Room 2000**
**1594 West North Temple, Salt Lake City**

## WELCOME AND INTRODUCTION

Working Group on Utah Earthquake Probabilities (WGUEP) Coordinator Bill Lund called the fifth WGUEP meeting to order at 8:00 a.m. After welcoming the Working Group members, other topic presenters, and visitors (attachment 1), Bill turned the meeting over to Ivan Wong (WGUEP Chairperson) who reviewed the meeting agenda (attachment 2) and recapped WGUEP progress to date.

## WGUEP TASK LIST REVIEW

Ivan then reviewed the current WGUEP task list and revisited other issues related to the WGUEP process to ensure that the Working Group had achieved consensus on those topics.

### Current Task List

1. Recurrence Model Subgroup (Ivan, Walter, and Jim) to develop a set of strawman recurrence model weights for the Working Group's consideration. (*Delayed until after the Basin and Range Province Earthquake Working Group II [BRPEWGII] meeting in November.)*

2. Validate comparison of geodetic, historical earthquake, and geologic moment rates and provide a recommendation of how to incorporate GPS horizontal extension data in the WGUEP probability forecast. (*Christine Puskas (Robert Smith proxy) has accepted a job outside Utah and is no longer available to perform this function. Jim Pechmann has agreed to perform this task with Mark Petersen, and is working with Christine to resolve some issues with her previous comparison. Dave Schwartz recommended making a comparison of vertical and horizontal geologic rates with geodetic rates at all points across the Wasatch fault zone [WFZ] where data are available and displaying the results on a map.)*

3. Weight WFZ rupture scenarios, sum moment release per segment per scenario, and compute and plot magnitude frequency distributions for rupture scenarios. (*Presentation by the Paleoseismology Subgroup to follow on this topic.)*

*4.* Evaluate software for running a Brownian Passage Time probability model/evaluate other probability models. *(Have obtained the software used for California Working Group 2002 (WG02) – a presentation by Patricia Thomas will follow on this topic.)*

5. Revise historical earthquake catalog – Seismology Subgroup (Walter, Ivan, Jim, and Mark). *(A presentation by Walter Arabasz and Jim Pechmann will follow on this topic.)*

6. Decide on final WGUEP products (full model building or simplified product; Ivan and Mark). *(A presentation by Ivan Wong will follow on this topic.)*

7. Recompute vertical slip rates and $M_{max}$, and devise a reliability indicator for the paleoseismic data in the WGUEP "Other Fault" database. *(A presentation by Bill Lund will follow on this topic.)*

8. Determine what to use as the maximum magnitude background earthquake (M 6.75±, M 6.6 ± 0.2, other?); Ivan, Mark). *(This topic will receive further discussion at this meeting.)*

### Other Issues

1. Range of fault dips. *(This topic was discussed at WGUEP meeting #4 [see meeting #4 summary at http://geology.utah.gov/ghp/workgroups/pdf/wguep/WGUEP-2011A_Summary.pdf ]. The Working Group decided at that time to use 50±15 degrees as the dip for all faults in the "Other Fault" database for the WGUEP study area. A decision regarding the range of dips to use for the WFZ was not finalized at meeting #4. The working group's consensus at meeting #5 was to use 50±15 degrees for all range-bounding faults in the WGUEP study area.)*

2. Range of seismogenic depths. *(This topic was also discussed at WGUEP meeting #4. The Working Group decided at that time to use a range of 15±2 kilometers as the seismogenic depth for faults in the WGUEP study area. That decision was confirmed at meeting #5.)*

3. Northern three (Malad, Clarkston Mountain, Collinston) and southern two (Levan and Fayette) WFZ segments – model them separately or combine them and float an earthquake along their combined length? *(Given the uncertainties regarding both slip rate and surface rupture length for these segments, the Working Group is considering modeling both scenarios and weighting them 50/50, but a final decision is still pending.)*

4. Unsegmented rupture model. *(Working Group members agreed that the unsegmented rupture model for the central WFZ should be allowed to include the end segments. Working Group members also discussed magnitude distributions for earthquakes in the unsegmented model. The consensus was to use a maximum magnitude of 7.5 considering the WFZ $M_{max}$ data (discussed below) and the Hebgen Lake earthquake; however, the Working Group considered minimum magnitudes between 6.5 and 6.8. The Working Group did not reach consensus regarding minimum M.)*

## TECHNICAL PRESENTATIONS

The meeting then moved into a series of technical presentations and issue updates.

PowerPoint presentations made at the meeting are available at
http://geology.utah.gov/ghp/workgroups/pdf/wguep/WGUEP-2011B_Presentations.pdf.

**Tuesday, June 28**

- WGUEP Products and Issue of Consistency with USGS Maps – Ivan Wong
- BRPEWGII Workshop Issues – Tony Crone
- Update on Recurrence Models – Ivan Wong
- Update on Final Wasatch Central Segment Recurrence Rates and COVs – Chris DuRoss

**Wednesday, June 29**

- Update on West Valley Fault Zone and Coseismic Rupture – Mike Hylland
- Update on "Other" Faults – Bill Lund
- Path Forward on Use of Geodetic Data – Jim Pechmann
- Inputs for Forecast and Moment Balancing – Patricia Thomas
- Update on Consensus Wasatch Front Earthquake Catalog – Walter Arabasz/Jim Pechmann
- Spatial Smoothing Versus Uniform Source Zone(s) – Ivan Wong
- $M_{max}$ for Background Earthquakes – Ivan Wong

## ISSUE DISCUSSIONS

Technical presentations and the ensuing discussions they generated are summarized below.

### WGUEP Products

- Segment-specific time-dependent and time-independent probabilities of the characteristic earthquake on the five central segments of the WFZ. (Note that time-dependent probabilities may be calculated with some weight given to a time-independent approach.)
- Time-dependent and time-independent probabilities for the whole WFZ for $\geq$M 6.5 and $\geq$M 7.0 and events.

- Segment-specific and fault-specific time-dependent and time-independent probabilities for the Great Salt Lake fault zone.

- Time-independent probabilities for each of the "Other" faults in the Wasatch Front.

- Time-dependent and time-independent probabilities for the Wasatch Front study area for a range of magnitudes starting at M ≥ 5.0.

- Time-independent probability for background earthquakes in the Wasatch Front study area for a range of magnitudes starting at M ≥ 5.0.

- Map of time-dependent probabilities for the Wasatch Front study area.

## Basin and Range Province Earthquake Working Group II Issues

The Basin and Range Province Earthquake Working Group II (BRPEWGII) is patterned after BRPEWGI (http://ugspub.nr.utah.gov/publications/open_file_reports/OFR-477.pdf, convened in Salt Lake City in 2006. In a manner similar to BRPEWGI, the objective of BRPEWGII is to provide recommendations to the U.S. Geological Survey's (USGS) Seismic Hazard Mapping Project on Basin and Range Province (BRP) related topics important to the 2013 update of the National Seismic Hazard Maps (NSHMs). The Working Group will meet in Salt Lake City on Nov. 14–16, 2011, and will include participants from federal and state government agencies, academia, and private industry. The USGS, Western States Seismic Policy Council, and Utah Geological Survey are providing support for BRPEWGII. Discussions will focus on (1) seismological topics, and (2) topics related to the geological evaluation of seismic sources. Geodetic issues will be discussed in a separate NSHM national workshop.

**Topic I: Seismology**

S1. How should the magnitude-frequency relations for a single Basin and Range Province (BRP) fault be characterized? Does existing seismological data help define this relationship?

S2. How should the "smoothing" of seismicity be handled in the National Seismic Hazard Maps (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?

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?

S4. What are the sources and levels of uncertainty in the earthquake magnitudes contained in the seismicity catalogs used in the NSHMs?

**Topic II: Geologic Evaluation of Seismic Sources**

G1. How should we calculate $M_{max}$ for BRP faults based on rupture lengths, fault areas, and available displacement data ($M_{max}$ of 7.5 currently is used in the NSHMs and is 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?

G2. How should antithetic fault pairs be modeled in the NSHMs? For example, what is the relation and seismogenic significance of 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?

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?

G4. Based on the recommendations from BRPEWGI, the current USGS 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?

Many of the issues selected for consideration at BRPEWGII are similar to those considered at BRPEWGI. Answers to these questions aren't simple or clear. Refining input into the NSHMs is an iterative process; the goal is to assure that each update includes improved data and information, which yields a better representation of seismic hazard at a national level.

## Update on Recurrence Models

The Working Group must decide which earthquake recurrence model(s) to use for the WGUEP process. Ivan reviewed the three recurrence models and their typical assigned weights traditionally used by the consulting industry when performing probabilistic seismic hazard analyses (PSHAs): $M_{max}$ (0.3), Characteristic (0.6), and Truncated Exponential (0.1). Ivan noted that based on work being conducted by Abrahamson and Hecker he expects that the truncated exponential model will soon be given no weight.

Ivan then reviewed the set of two recurrence models used by the USGS for the NSHMs, which differs from the set of models typically used by the consulting industry for PSHAs. The USGS refers to one of their models as a "Characteristic" model; however, it differs in significant ways from the traditional characteristic model of Youngs and Coppersmith and is more commonly called the "Maximum Magnitude" ($M_{max}$) model. The USGS NSHMs use both the $M_{max}$ and a "Gutenberg-Richter" (truncated exponential) model for faults, with weights of 2/3 and 1/3, respectively, for faults in the Intermountain West region. The USGS Gutenberg-Richter model is for M 6.5 and greater earthquakes only. This approach came about because of the mismatch of predicted and observed rates of moderate magnitude earthquakes in southern California. The USGS model places no moderate sized (M < 6.5) earthquakes on faults unless $M_{max}$ for the fault is less than 6.5. Smaller events are accommodated by a background zone with a relatively large $M_{max}$ of 7.0 (reduced near modeled faults).

A key question for the Working Group is should we adopt the traditional approach to recurrence models or use the USGS model? Implications of the model(s) selected include (1) do we think, or do we want the outside community to think, that the WFZ follows a truncated exponential model, and (2) do moderate magnitude earthquakes occur on or near faults at a greater rate than elsewhere? Ivan noted that the California Working Groups used the USGS model because background seismicity in California is a big player in the near term.

Further discussion on this topic was deferred to WGUEP Meeting #6 in November, 2011.

## Update on Final Wasatch Central Segment Recurrence Rates and COVs

Chris DuRoss presented the results of the Paleoseismology Subgroup's effort to (1) weight the segment rupture scenarios for the five central segments of the WFZ and for the West Valley fault zone (WVFZ), (2) sum the moment release per segment per scenario, (3) plot magnitude frequency distributions for the rupture scenarios, and (4) calculate coefficients of variation (COV) for the WFZ segments and the fault as a whole. See Chris' PowerPoint presentation at http://geology.utah.gov/ghp/workgroups/pdf/wguep/WGUEP-2011B_Presentations.pdf for supporting details:

(1) The Paleoseismology Subgroup's recommended WFZ rupture scenario weights as follows:

- Maximum rupture model (22 earthquakes) 50%
- Minimum rupture model (14 earthquakes) 5%
- Intermediate rupture model A (19 earthquakes) 10%
- Intermediate rupture model B (19 earthquakes) 10%
- Intermediate rupture model C (20 earthquakes) 15%
- Unsegmented earthquake model 10%

The recommended rupture scenario weights for the WVFZ and the adjacent Salt Lake City segment (SLCS) of the WFZ are as follows:

- WVFZ ruptures independently 50%
- WVFZ ruptures coseismically with SLCS (adds $M_0$) 45%
- WVFZ is non-seismogenic 5%

SLCS scenarios

- SLCS ruptures without WVFZ (SLCS only contributes $M_0$) 55%
- SLCS ruptures coseismically with WVFZ (both contribute $M_0$) 45%

(2) The Paleoseismology Subgroup used two seismic moment ($M_0$) calculations: (1) $M_0$ = rigidity (μ) * area (A; down-dip rupture length * surface rupture length [SRL]) * average net displacement (D) (Hanks and Kanamori, 1979), and (2) Log $M_0$ = 3/2 [$M_W$ (based on SRL)] + 16.05 (Hanks and Kanamori, 1979).

- Displacement conclusions
  - D was calculated using a simple method (average of observed displacements per rupture) and an analytical method following Chang and Smith (2002) and Biasi and Weldon (2009) (half-ellipse displacement profile). For the WFZ, the analytical half ellipse was scaled using the observed displacements rather than an SRL-D regression (see Biasi and Weldon, 2009).
  - The subgroup reported very similar results in using the simple versus analytical methods of calculating D. However, the WFZ per-event displacements are consistently large (average of 2.8 m in each rupture model), bringing into question site bias (small displacements under-sampled) and/or underestimated SRLs. These large displacements contribute to significant discrepancies in $M_W$ and $M_0$ when based on D versus SRL or area.

- $M_0$ conclusions
  - Using $M_0$ (μAD), the five rupture scenarios have similar amounts of moment release (summed per segment and for the WFZ). Consistent results were obtained using both the observed and modeled average displacements. Because of the available WFZ displacement data, it is not likely that $M_0$ (μAD) underestimates moment release for larger ruptures (displacements are not significantly larger in multi-segment ruptures, and we're probably not missing the largest displacements). However, it is possible that $M_0$ (μAD) overestimates $M_0$ for smaller (single-segment) ruptures (longer SRLs than mapped, site bias?).
  - $M_0$ (μAD) consistently yields more moment release (per earthquake, segment, and rupture model) than $M_0$ based $M_W$(SRL). Given the large WFZ displacements, $M_0$(μAD) better portrays moment release than $M_0$(SRL) (more $M_0$ released in single- and multi-segment ruptures than indicated by $M_0$(SRL) regression)

(3) The Paleoseismology Subgroup calculated $M_W$ using the following regressions:

- $M_W$
  - $M_W$ (SRL) = 1.16* LOG(SRL)+5.08 (W&C94–all-fault-types); range based on SRL uncertainty
  - $M_W$ (A) = 4.07+0.98*LOG(DDW*SRL) (W&C94–all-fault-types); range based on DDW and SRL uncertainties
  - $M_W$ (AD–HH&W99) (in progress…)
  - $M_W$ (AD–W&C94): $M_W$ (AD[net]) = 0.82*(LOG(AD[net]))+6.93 (all-fault-types)
  - $M_W$ ($M_0$) = (2/3)*(LOG($M_0$)) - 10.7 (H&K79)

- Mean $M_W$
    - $M_W$ (SRL) – 0.25 wt
    - $M_W$ (A) – 0.25 wt
    - $M_W$ (AD–W&C94) – 0.25 wt
    - $M_W$ ($M_0$) – 0.25 wt

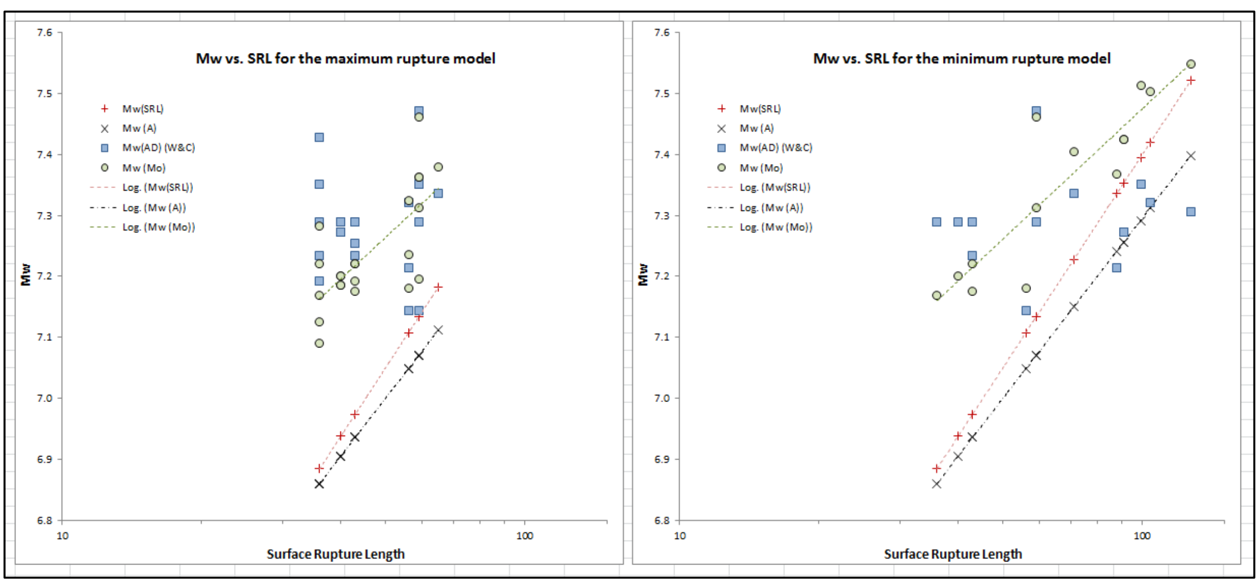
Moment Magnitude

- Maximum model
    - $M_W$ (SRL): <u>7.0 ± 0.2</u>
    - (6.9 ± 0.2 – 7.1 ± 0.2)
    - $M_W$ (A): <u>7.0 ± 0.2</u>
    - (6.7 ± 0.2 – 7.2 ± 0.2)
    - $M_W$ (AD): 7.3 ± 0.2
    - $M_W$ ($M_0$-mAD): 7.2 ± 0.2
    - Mean $M_W$: 7.1 ± 0.2

- Minimum model
    - $M_W$ (SRL): <u>7.2 ± 0.4</u>
    - $M_W$ (A): <u>7.1 ± 0.3</u>
    - $M_W$ (AD): 7.3 ± 0.1
    - $M_W$ ($M_0$-mAD): 7.4 ± 0.3
    - Mean $M_W$: 7.2 ± 0.3

$M_w$ vs. SRL

- The subgroup reported significant discrepancies in $M_W$ when based on D versus SRL or area.




<u>Maximum model</u>
$M_W$ (D or $M_0$) consistently greater than $M_W$ (SRL or A)

<u>Minimum model</u>
$M_W$ (D or $M_0$) generally greater than $M_W$ (SRL or A)

$M_W$ Frequency

- $M_W$ frequencies reported were based on the number of occurrences of earthquakes of a particular SRL divided by the total elapsed time (7.1-ka max constraint for W5 to present). For example, in the max model a 43-km-SRL earthquake occurs 4 times in 7.1 years. See Chris' PowerPoint presentation at http://geology.utah.gov/ghp/workgroups/pdf/wguep/WGUEP-2011B_Presentations.pdf for the $M_w$-frequency plots.

- The Working Group discussed the displacement data and apparent discrepancy between $M_0$ and $M_W$ when based on µAD and $M_W$(SRL). Note that this topic will receive further discussion at the BRPEWGII meeting.

(4) COV

1. Determine earthquake times per segment (one out of 10,000 scenarios). Using the Brigham City model, simulation1 has the following earthquake times:
   - E4: 5615
   - E3: 4355
   - E2: 3500
   - E1: 2225
2. Compute recurrence intervals (RIs):
   - E4-E3: 1260
   - E3-E2: 855
   - E2-E1: 1275
3. Calculate COV = standard deviation of RIs (238 yr) divided by their mean (1130 yr):
   - COV = 238/1130 = 0.21
4. Repeat, and then compile and plot earthquake times, RIs, and COVs

COV results per segment:

- Brigham City 0.3 ± 0.4 (2s)
- Weber and Salt Lake City 0.5 ± 0.3 (WS) 0.5 ± 0.2 (SLCS)
- Provo 0.6 ± 0.3
- Nephi 0.7 ± 0.5 (E4-E1), 0.2 ± 0.4 (E3-E1)

Considerable discussion followed regarding the correct procedure for calculating COVs for each rupture model and for the WFZ as a whole. Mark suggested following the lead of the California Working Groups and adopting a COV of 0.5±0.2. The consensus of the Working Group was to attempt to calculate a single composite COV for the WFZ. Chris indicated that he would consult with Jim and Nico on the best way to make the calculations.

**Update on West Valley Fault Zone and Coseismic Rupture**

Mike Hylland reviewed the most recent results from the WVFZ Baileys Lake paleoseismic trenching study, and the resulting implications for weighting WVFZ rupture activity. The numerical age data available at this time allow OxCal modeling of only the most recent paleoearthquake. The results of OSL analyses (in progress) are needed before the timing of the earlier earthquakes can be modeled.

Preliminary Results

Baileys Lake site shows evidence of at least four large earthquakes.

Earthquake timing:

- P4 – Warping event around the time of the Bonneville highstand (~18 ka)
- P3 – Surface faulting during lake regression from the Provo shoreline, possibly during the period of very low lake level prior to the Gilbert transgression (~12 ka)
- P2 – Surface faulting sometime after the Gilbert lake cycle (early Holocene)
- P1 – Surface faulting during the mid-Holocene (5.6 ± 0.8 ka)

Vertical displacement:

- Average per-event vertical displacement ~0.5 m

Modeled timing of P1 is in very good agreement with timing of SLCS event E2 at the Penrose Drive site.

Current thoughts on weighting WVFZ activity (WGUEP Paleoseismology Subgroup):

- 0.50 independent (currently 0.25 in the NSHMs)
- 0.45 dependent (coseismic with SLCS, adds moment to SLCS earthquake)
- 0.05 non-seismogenic (space-accommodation structure)

Mike discussed three historical earthquakes that may provide analogs for WVFZ fault activity as it relates to the SLCS of the WFZ. The three earthquakes were Devils Canyon, Idaho (M 5.8 and an antithetic M 5.0 aftershock; 1984), Irpinia, Italy (M 6.9; 1980), and Hansel Valley, Utah (M 6.6; 1934). Summary information for each of these earthquakes is contained in Mike's PowerPoint presentation at http://geology.utah.gov/ghp/workgroups/pdf/wguep/WGUEP-2011B_Presentations.pdf.

**Update on "Other" Faults**

Bill Lund provided an update (no PowerPoint) on the effort to recompute vertical slip rates and $M_{max}$ using available paleoseismic data for the "Other" faults in the WGUEP study area. Bill stated that he is well underway with the project, and has consistently used 50±15 degrees for fault dips and 15±2 kilometers for seismogenic depth in his calculations. Bill noted that well documented displacement data are rare for the "Other" faults, and consequently he has a low level of confidence in most $M_{max}$ values determined using displacement data. In nearly every instance where displacement data are available, it is unknown if the data represent average or maximum values, and it is most likely that they represent neither. Dave Schwartz suggested that the WGUEP follow the California Working Groups' practice of using only $M_{max}$ values determined using SRL or Area. This elicited considerable discussion, since values of $M_{max}$ determined using SRL and Area are consistently lower than $M_{max}$ values obtained from displacement data.

Chris DuRoss recommended that "Other" faults with a minimum of three displacement observations from three independent sites be treated as type A faults in the ranking system devised by Susan Olig and Dave Schwartz for calculating $M_{max}$ (see discussion in WGUEP Meeting #4 summary at http://geology.utah.gov/ghp/workgroups/pdf/wguep/WGUEP-2011A_Presentations.pdf). In all other cases, he recommended treating the "Other" faults as type C faults and using SRL and Area to calculate $M_{max}$. The Working Group seemed to concur with this suggestion. Bill will continue to calculate $M_{max}$ using SRL, Area, and displacement where available, and will devise a system to rank the quality of the displacement data and the reliability of the $M_{max}$ values obtained from them. However, given the quantity and quality of the displacement data, most displacement-based $M_{max}$ values for the "Other" faults should be considered poorly constrained estimates at best.

Bill stated that based on comments made by Lucy Piety, U.S. Bureau of Reclamation (USBR), at the 2011 Utah Quaternary Fault Parameters Working Group meeting in February, he recommends restoring the Joes Valley faults to the WGUEP "Other Fault" database. The USBR is not yet convinced that the Joes Valley faults are nonseismogenic, and they intend to conduct additional studies of those faults in the future.

**Path Forward on Use of Geodetic Data**

Jim Pechmann reviewed Christine Puskas' comparison of geodetic, historical earthquake, and geologic moment rates across the Wasatch Front (see WGUEP Meeting #4 Summary at http://geology.utah.gov/ghp/workgroups/pdf/wguep/WGUEP-2011A_Presentations.pdf). Jim noted that Christine's comparison showed that geodetic moment was generally an order of magnitude greater than geologic moment. Based on similar comparisons that Jim and others have done in the past, Jim was concerned that the difference was too high. A close review of Christine's calculations showed that she had used an incorrect rigidity constant ($3x10^{11}$ PA = $3x10^{12}$ dynes/cm$^2$ instead of $3x10^{11}$ dynes/cm$^2$) for her calculations, which resulted in the order of magnitude discrepancy. Jim also noted that the three boxes (north, central, south) spanning the Wasatch Front within which Christine computed geologic moment did not correspond with WFZ segment boundaries, making calculation of the geologic moment released within the boxes difficult. Additionally, the boxes are large and contain other active faults that may contribute geologic moment not included in Christine's calculations. Jim attempted to reproduce Christine's calculations of geologic moment rates using Kostrov's equation, the Wells and Coppersmith (1994) M(SRL) relation, and paleoearthquake models for the five central segments of the Wasatch fault only (following Christine). Jim counted only the moment release rates from the sections of the Wasatch fault within Christine's boxes, which is necessary when applying Kostrov's equation to the crustal volumes represented by these boxes. Jim's calculated geologic moment rates were on average 2.6 times lower than those that Christine reported. (Based on correspondence with Christine following the meeting, Jim identified two errors in the methodology that Christine used to determine her geologic moment rates.)

Based on his review, Jim concluded that for Christine's northern and central boxes, geodetic moment is a factor of two to three times (depending on the rupture model used) greater than geologic moment. For the southern box, geodetic moment is a factor of five to ten times greater than geologic moment. The reasons for these discrepancies remain unclear, but may be due in part to missed contributions to geologic moment rates from faults not included in the analysis.

In the ensuing discussion regarding how to incorporate the geodetic data in the WGUEP process, it was noted that the geodetic data could provide an estimate of extension in a volume of crust across a region (Wasatch Front), and therefore provide a check on geologic rates. Areas with large discrepancies could be targeted for additional study to resolve significant differences. However, the geodetic data alone is not sufficient to enable geodetic extension to be partitioned among individual faults. Walter stated that the Geodetic Data Subgroup should write a commentary on the utility/application of geodetic data to the WGUEP process to diffuse possible reviewer criticism.

Discussion ensued regarding a path forward that involved using a block model and/or Kostrov's equation (which are essentially equivalent) to calculate average strain or extension rates for the entire WGUEP Wasatch Front block. Mark Petersen indicated that he could average the GPS strain rate across the Wasatch Front and compare it to the geologic strain rate to look for discrepancies between the two. Ivan stated that he would send the geologic model to Mark so he could calculate geologic moment rates.

## Inputs for Forecast and Moment Balancing

Patricia Thomas reported that URS Corporation has acquired the computer code used for California WG02, and that she plans to follow a procedure similar to WG02 for WGUEP. Patricia discussed the steps required to implement the WG02 code: See Patricia's PowerPoint presentation at http://geology.utah.gov/ghp/workgroups/pdf/wguep/WGUEP-2011B_Presentations.pdf for supporting details:

1. Define fault segment attributes
2. Define rupture sources and rates
3. Define background seismicity
4. Define probability model parameters
5. Probability calculations

And summarized the various inputs required for the model:

1. Geometry
    - Segment endpoints
    - Seismogenic thickness
    - Dip
2. Long term segment slip rate?
3. Regional moment rate constraint?
4. Mean characteristic magnitude models
5. Average displacement for rupture sources
6. Magnitude probability density models
7. Fault rupture models (rupture sources, scenarios, weights)
8. Background seismicity parameters

9. Probability models and weights
10. Probability model parameters
    - Time since last event, COV

### Update on Consensus Wasatch Front Earthquake Catalog

Walter Arabasz and Jim Pechmann updated the Working Group on efforts to compile a consensus Wasatch Front earthquake catalog.

Collaboration with the USGS:

- Discussions started with Chuck Mueller in January 2011.
- Working Group teleconference (Wong, Arabasz, Pechmann, Mueller, Petersen) on May 17, 2011.
- USGS/NSHM catalog through 2010 for "extended Utah region" (36.0°−43.5° N, 108°−115° W) delivered by Chuck Mueller to Arabasz and Pechmann on June 6, 2011.

Walter compared the University of Utah Seismograph Stations (UUSS) and National Seismic Hazard Maps (NSHM) earthquake catalogs for the WGUEP region and noted the discrepancy between the two catalogs in the number of independent main shocks (declustered using different methods) in the $4.0 \leq M < 4.5$ and $5.0 \leq M < 5.5$ bins.

| Magnitude Range | UUSS Catalog | NSHM Catalog |
|---|---|---|
| $4.0 \leq M < 4.5$ | 45 | 34 |
| $4.5 \leq M < 5.0$ | 5 | 4 |
| $5.0 \leq M < 5.5$ | 10 | 21 |
| $5.5 \leq M < 6.0$ | 4 | 4 |
| $6.0 \leq M < 6.5$ | 3 | 3 |
| $6.5 \leq M < 7.0$ | 1 | 1 |
| Total Number | 68 | 67 |

*Comparison of UUSS and NSHM catalogs for the WGUEP region (1880 through 2010; independent main shocks $M \geq 4.0$, non-tectonic events removed).*

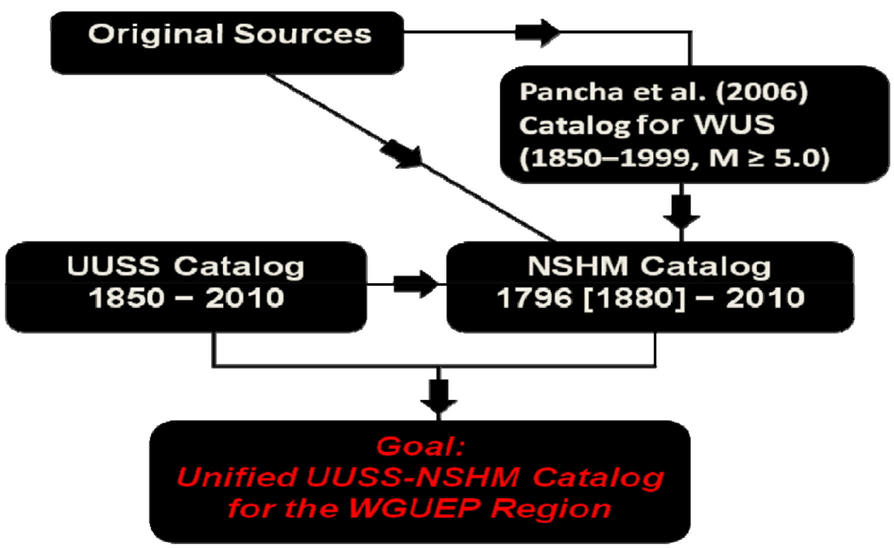
After accounting for time- and magnitude-dependent variations in catalog completeness, a similar discrepancy between the two catalogs was noted in the number of $4.67 \leq M < 5.33$ independent main shocks.

| Magnitude Range | Completeness Period | Years | UUSS Catalog | NSHM Catalog |
|---|---|---|---|---|
| 4.00 ≤ M < 4.67 | July 1962−Dec 2010 | 48.5 | 17 | 16 |
| 4.67 ≤ M < 5.33 | Jan 1950−Dec 2010 | 61.0 | 7 | 17 |
| 5.33 ≤ M < 6.00 | Jan 1938−Dec 2010 | 73.0 | 1 | 1 |
| 6.00 ≤ M < 6.67 | Jan 1900−Dec 2010 | 111.0 | 3 | 3 |

*Comparison of independent main shocks (M ≥ 4.0) in the UUSS and NSHM catalogs for the WGUEP Region — accounting for completeness periods.*

The latter discrepancy between the two catalogs is likely due to the importation of events into the NSHM catalog from the Pancha and others (2006) catalog for the western United States (1850−1999) for M ≥ 4.8.

Walter presented the following diagram outlining the path forward to achieving a unified UUSS–NSHM earthquake catalog, and noted the effort required to create such a catalog represents a nontrivial task in terms of time and effort. Walter hopes that with some help, a consensus catalog can be complete by the end of the year.




## Spatial Smoothing Versus Uniform Source Zone(s)

This discussion centered on whether the WGUEP wants to include a uniform background zone, in additional to Gaussian smoothing to account for non-stationarity in the historical record. That is, should we allow for the possibility that background earthquakes in the Wasatch Front region could occur in locations that have not occurred in the historical record. Both approaches could be weighted as was done for the Salt Lake Valley microzonation maps that were developed by Wong and others. The USGS uses uniform background zones in the western U.S. to provide a hazard floor in areas of low seismicity. No decision was made. A less significant issue is what kernel size to use in the smoothing. The USGS uses 50 km in most of the western U.S., including Utah, in contrast to the Salt Lake Valley microzonation maps where 15 km was used. An adaptive kernel approach could also be used in which this issue would be addressed.

### $M_{max}$ for Background Earthquakes

The discussion centered on what $M_{max}$ should be considered for the background earthquake. Previous studies in the Wasatch Front have generally used M 6.5 +/- 0.25. The USGS uses a $M_{max}$ of M 7.0 which seems too high. The answer to the question depends on the minimum $M_{max}$ for faults that would be observed at the surface after repeated events. The prevailing thinking was that M 6.5 was too low. Hence, Ivan suggested a preliminary $M_{max}$ of M 6.75 +/- 0.25. Further discussion is needed here.

## TASK LIST

1. Recurrence Model Subgroup (Ivan, Walter, and Jim) develop a set of strawman recurrence models and weights for the Working Group's consideration. This will be done after the BRPEWGII. Also determine the $M_{max}$ distribution for background earthquakes.

2. Validate comparison of geodetic, historical earthquake, and geologic moment rates and provide a recommendation on how to incorporate GPS horizontal extension data in the WGUEP probability forecast (Jim and Mark).

3. Revise historical earthquake catalog – Seismology Subgroup (Walter, Ivan, Jim, Mark).

4. Calculate COV for WFZ segments and the fault as a whole (Chris, Nico, Jim).

5. Recompute vertical slip rates and $M_{max}$, and devise a reliability indicator for the displacement data in the WGUEP "Other" faults database (Bill).

6. Address Gaussian smoothing versus uniform background zone (Ivan, Mark).

7. Make trial probability calculation by November meeting (Ivan and Patricia).

Additionally, a number of issues need to be addressed regarding implementing the WGCEP code (Patricia, Susan, Ivan).

## REFERENCES

Presenters did not provide complete citations for the references (see citations above) given in their presentations and reported in these minutes.

## NEXT MEETING

The next WGUEP meeting is scheduled for November 16–18, 2011, at the Utah Department of Natural Resources Building (1594 West North Temple, Salt Lake City, Utah).

## ATTACHMENT 1

### Members
### Working Group on Utah Earthquake Probabilities

Walter Arabasz, UUSS
Tony Crone, USGS
Chris DuRoss, UGS
Nico Luco, USGS (participated via phone)
Bill Lund, UGS, Coordinator
Susan Olig, URS Corporation
James Pechmann, UUSS
Steve Personius, USGS
Mark Petersen, USGS
Dave Schwartz, USGS
Bob Smith, UUGG*
Ivan Wong, URS Corporation, Chair
*Absent

Others presenting or assisting the Working Group

Steve Bowman, UGS Liaison to WGUEP
Mike Hylland, UGS
Patricia Thomas, URS Corporation

## AGENDA

## WORKING GROUP ON UTAH EARTHQUAKE PROBABILITIES
## MEETING #5
## Tuesday & Wednesday, 28 & 29 June 2011
## Utah Department of Natural Resources Building, Room 2000 (2nd floor)
## 1594 West North Temple, Salt Lake City

**28 June 2011**

| | | |
|---|---|---|
| 7:30 – 8:00 | Continental Breakfast | |
| 8:00 – 8:15 | Welcome | Bill |
| 8:15 – 8:30 | Overview of Agenda | Ivan |
| 8:30 – 9:00 | WGUEP Products and Issue of Consistency with USGS Maps | Ivan |
| 9:00 – 10:00 | BRPEWG Workshop Issues | Mark/Tony |
| 10:00 – 10:15 | Break | |
| 10:15 – 10:45 | Update on Recurrence Models | Ivan |
| 10:45 – 11:45 | Update on Final Wasatch Central Segment Recurrence Rates and COVs | Chris |
| 11:45 – 12:45 | Lunch | |
| 12:45 – 1:45 | Inputs for Forecast and Moment Balancing | Patricia |
| 1:45 – 2:15 | Update on West Valley Fault Zone and Coseismic Rupture | Mike |
| 2:15 – 2:45 | Update on Other Faults | Bill |
| 2:45 – 3:00 | Break | |
| 3:00 – 4:30 | Path Forward on Use of Geodetic Data | Mark/Ivan |
| 4:30 – 5:00 | Wrap-up Discussion | All |

**29 June 2011**

| | | |
|---|---|---|
| 7:30 – 8:00 | Continental Breakfast | |
| 8:00 – 8:30 | Update on Consensus Wasatch Front Earthquake Catalog | Walt/Jim |
| 8:30 – 9:15 | Spatial Smoothing Versus Uniform Source Zone(s) | Ivan |
| 9:15 – 10:00 | $M_{max}$ for Background Earthquakes | Ivan |
| 10:00 – 10:15 | Break | |
| 10:15 – 12:00 | Open Discussion | |
| 12:00 – 12:30 | Lunch | |
| 12:30 – 3:00 | Open Discussion and Schedule | |
| 3:00 | Adjourn | |

WGUEP Members

Ivan Wong, URS (Chair)
Bill Lund, UGS (Coordinator)
Walter Arabasz, UUSS
Tony Crone, USGS
Chris DuRoss, UGS
Nico Luco, USGS
Susan Olig, URS
Jim Pechmann, UUSS
Mark Petersen, USGS
Steve Personius, USGS
David Schwartz, USGS
Bob Smith, UUGG

Other Participants

Patricia Thomas, URS
Steve Bowman, UGS
Mike Hylland, UGS