RESULTS OF THE FEBRUARY 8, 2010
UTAH GROUND-SHAKING WORKING GROUP MEETING

Members:
Ivan Wong
Mark Petersen
Bill Stephenson
Walter Arabasz
Greg McDonald
Harold Magistrale
Kris Pankow
Jim Pechmann
Relu Berlacu
Kim Olsen
Daniel Roten
Robert Smith

Guests:
Steve Bowman
Michael Thorne
Jamie Farrell
Chris DuRoss
Morgan Moschetti
Jacobo Beilak
Ralph Archuleta
Mike Hylland
Christine Puskas
Anthony Crone
Bob Carey
Ashley Elliott
Charles Williamson

MEETING SUMMARY

The meeting was convened at 7:30 by Ivan Wong. Introductions of the attending members and guests were performed. Wong gave a brief overview of the purpose of the meeting, summarized the original objectives of the working group and reviewed last year's priorities. The following technical presentations were made:

Ivan Wong – Analysis of ANSS Data for Stress Drop and Kappa

The study evaluated critical factors controlling ground-shaking hazard along the Wasatch Front: stress drop, kappa, and crustal attenuation (Q[f]) using ANSS data.
Previous studies have suggested earthquake ground motions in extensional regimes may be lower than in California for the same magnitude and distance. The difference may be from lower stress drops of extensional versus compressional earthquakes (McGarr, 1984).

For earthquake hazard studies of the Wasatch Front:

- No systematic evaluation of earthquake stress drop has been performed;
- No studies have been performed to evaluate kappa; and
- Limited studies have been performed to estimate Q(f) (Brockman and Bollinger, 1992; Jeon and Herrmann, 2004)

The study analyzed available strong-motion and broadband data from ANSS stations in the central Wasatch Front region using a non-linear, least squares inversion of Fourier amplitude spectra (iterative process for best fit scheme developed by Silva)

- Analyzed ANSS data includes 17 events recorded between May 2001 and November 2007; M 3.0 to 4.2; 18 to 62 stations recording.
- Preliminary results indicate low stress drops of less than 25 bars, a Qo and eta of 103 and 0.69, respectively, and kappa values for soil and rock of 0.03 and 0.04 sec, respectively.
- Some of the inversions show poor comparisons between modeled results and observed spectra suggesting some of the seismic stations may have strong site effects. Further evaluation is to be performed.

Jim Pechmann – Sonic Log Analyses for the Wasatch Front CVM

The study evaluated sonic logs to compare with the Hill et al. (1990) model that used 2 sonic logs, 3 density logs, and one seismic reflection profile, all in the northern part of SLV.
This study looked at 24 sonic logs, 17 in Quaternary deposits, 7 in bedrock (3 outside the CVM area); depths ranging from 0.9 to 5.3 km (median ~2 km).
The study determined average Vp profiles above R1, between R1 and R2, and in bedrock for use in the CVM.

Conclusions:

- The sonic logs are generally consistent with Hill et al. basin model.
- Results confirm that the largest velocity contrast is at R2.
- Vp below R2 is typically ~1 km/s lower than the Hill et al. model.
- Mean bedrock Vp increases from ~3.0 km/s near surface to ~5.8 km/s at 5 km depth.
- Lateral variabilities of Vp in bedrock are comparable to that in basins.

Harold Magistrale – Update on Modifications to the WFCVM

WFCVM update (version 3c)

- Surface to R1: Vp from piecewise linear fits to geometric mean from sonic-log analysis or from modified mudline if Vs is from geotechnical data.
- R1 to R2: Vp from piecewise linear fits to geometric mean from sonic-log analysis or from Poisson's ratio if Vs is from geotech data.
- R2 to R3: Basement now at R3; Vp from Faust's relation
- Basement: Vp from sonic logs 0 to 4 km, from tomography below 5 km, and a weighted average of the two from 4 to 5 km; Vp/Vs gradient from 2.0 to 1.74 from 0 to 1 km; corrected bug "47,000 feet" to 47,000 meter"
- Compared simulated ground motions from versions 2e and 3c with actual ground motion recordings; some showed improved fit.

Greg McDonald – WFCVM discussion

- The latest version (v3c) supercedes previous versions; no value in making earlier versions available.
- UGS will host web site having CVM and associated data downloadable.
- A "readme" file will be available with CVM bundle detailing updates to current version.
- No immediate plans for CVM update. Other factors (e.g., Q, kappa) are likely more important for refining ground motion models.
- Salt Lake Valley portion of the CVM is fairly good; other Wasatch Front basins/backvalleys need refinement; there is not much existing data and what there is has already been incorporated into the CVM; the gravity data used in the regional model (Mabey) needs to be reviewed, possibly reprocessed.

Presentation/Discussion of Different Wasatch Front Ground Motion Models

Morgan Moschetti – USGS Plans for Analysis of the CVM

Current USGS efforts in calculating Wasatch Front ground motions include:

- Modeling ground motions for the current CVM (version 3c).
- Evaluation of the CVM for improvements to the regional Vs model.
- Linear, kinematic modeling with Hercules finite-element code developed by Carnegie Mellon University.
- Validation runs using Lehi and Magna events up to 0.5 Hz on desktop computers

Future modeling efforts include:

- Perform validation runs on USGS or Teragrid clusters for Lehi and Magna events to ~2 Hz.
- Develop scenario earthquake on Salt Lake segment of the Wasatch fault for comparison with other groups models.
- Evaluate effects of slip history and fault geometry on ground motions.

Modifying regional Vs model:

- Presently there is no regional-scale crustal Vs model for the region.

Dispersion maps from ambient seismic noise

- Ambient noise tomography; maps in 6-40 s period band
- Develop earthquake surface wave tomography maps to 100 s
- Combine inversion for Vs structure – regional model

- Current resolution ~50 km with improvements from incorporating local data. Combine existing USArray data with shorter inter-station pair measurements in the Wasatch Front region.
- Invert dispersion maps for 3-D Vs structure; maps from ambient seismic noise can incorporate some stratigraphic velocity structure and reduce velocity trade offs.

Jacobo Bielak – 3D Nonlinear Earthquake Ground Motion Simulation in the Salt Lake Basin Using the Wasatch Front CVM

Objectives of Future Work:

- Examine how earthquake ground motions along Wasatch Front are affected by nonlinear soil behavior in conjunction with other factors (e.g., depth, edge effects, focusing) using Hercules; limited to low frequencies (<1.5-2 Hz)
- Assess the impacts on ground motions as soil becomes progressively nonlinear - under what conditions and to what extent - using elastoplatic constitutive laws
- Incorporate geostatic stresses and extend model to more realistic constitutive relations.
- Evaluate sites in Salt Lake Valley in generalized silt/clay and sand/gravel geologic settings
- The Volvi EuroSeisTest verification exercise is useful as an example; compared elastic and elastoplastic response to horizontal displacement for sites in elongate, basin setting comparable to Wasatch Front basins.

Ralph Archuleta – Ground Motions in Salt Lake Basin from Dynamic Modeling of a M7 Earthquake on the Wasatch Fault

Modeled earthquake on the Salt Lake segment; simple, linear trace,150 deg strike, 50 deg dip (west),. 30 km trace x 18 km downdip, 50 m grid
Six stations used for ground motion results
Vs ranged from 85 to 3661 m/s
Dynamic finite-element model incorporates slip-weakening friction law
Basic parameters include:

- minimum Vs - 500 m/s
- maximum frequency - 1 Hz.
- initial normal stress - 36 MPa
- $\mu 0$ – 0.55; μd – 0.448; μs – 0.66; S – 1.1
- stress drop - 30 bars over 0.25 m
- tmax – 30 s
- hypocentral depth - 11.5 km

Summary:

- There is a strong concentration of energy near the crack tip with peak horizontal velocities >3m/s
- Hanging wall, sediments have strongest effect on ground motions
- Basin effects lead to longer duration ground shaking with amplitudes ~0.2-0.5 m/s far from the fault

Kim Olsen/Daniel Roten – 3D Nonlinear Broadband Ground Motion Predictions for M7 Earthquakes on the Salt Lake City Segment of the Wasatch Fault using Dynamic Source Models

Re-validation of CVM: some improvement in wavefit at some stations (notably Northern SL basin) but in general, little to no improvement was observed.

M7 scenario earthquakes:

- Four rupture models obtained from simulation of spontaneous rupture on a planar, vertical fault with depth-dependent normal stress for a 50-degree dip
- Planar rupture models were projected onto 3-D model of Wasatch fault that incorporates tear fault connecting East Bench to Warm Springs section
- Modeled six scenario earthquakes with different hypocenters for frequencies up to 1 Hz, using a minimum shear-velocity of 200 m/s.
- Produced average maps of 2s-SAs (spectral accelerations) and 1s-SAs, compared to next-generation attenuation models (NGA) and results of Solomon et al. (2004)
- Generated broadband (0-10 Hz) synthetics on a 200m grid for each rupture model
- Performed fully-nonlinear 1-D simulations along three profiles across the Salt Lake basin.
- Reference strain needed for these nonlinear simulations was derived from plasticity index using empirical relationship modified for Bonneville clays (Bay and Sasanakul, 2005); plasticity index was assigned to each site using Quaternary site response units
- Comparisons of broadband and nonlinear peak ground acceleration and 5 Hz spectral accelerations to NGA predictions

Conclusions:

- Ground motion tends to be larger on low-velocity sediments on the hanging wall side of the fault than on outcropping rock on the footwall side
- High low-frequency ground motions near fault stepovers (Holladay, East bench-Warm Springs) for some scenarios, which are due to a Love wave in the case of the Holladay stepover
- Strong along-strike and along-dip directivity effects
- Compared to Solomon et al. (2004), simulations predict larger ground motion on the hanging wall side, but lower values on the footwall side
- Simulated 2s-SAs agree well with NGA predictions, while simulated 1s-SAs exceed NGA by up to 75%. Maximum SAs are reached at ~2km from fault trace.

- PGAs derived from broadband synthetic seismograms are exceeding those predicted by NGA models by more than one standard deviation at near-fault locations on the hanging wall side
- Synthetic ground motions obtained from fully nonlinear 1-D simulations exhibit PGAs and SAs that are generally consistent with NGA models, even when taking into account the uncertainty in the nonlinear soil parameters

Ivan Wong – Modeling Near-Surface Effects

Discussed formation of a sub-working group to evaluate site-amplification factors pending results of study of non-linear effects (Beilak)
Objectives:

- Determine a suite of amplification factors to model site response effects for urban hazard maps using both geotechnical and empirical approaches
- Need to involve geotechnical engineering community (e.g., Bartlett, Bay)

Mark Petersen – USGS Perspective; Comparison of Models/Differences; Applicability for Urban Hazard Maps, Direction of Modeling; Priorities for Future Research

Ultimate goal is to make urban hazard maps that are meaningful for all users (e.g., city planners, developers)
Important to stress UGSWG is behind and supports hazard maps
Optimal products:

- Based on 3-D simulations and empirical ground motion models
- Broadband 10-0.1 Hz (0.1-10 s)
- Probabilistic and scenario (**M** 7) maps of Salt Lake County urban hazard

Initially focus on Salt Lake segment of Wasatch fault; later incorporate other faults (e.g., Great Salt Lake faults)

Need to coordinate and facilitate interaction between modeling groups; perhaps via internet connection; physically meet yearly.
Need a test case to compare different models; linear as baseline then nonlinear; some models have been vetted/validated to some extent

Test model for validation/verification; short and long periods

- Prescribe Lehi or Magna event (verification)
- Use WFCVM v3c
- Prescribe damping model, slip history, and frequency (0.1-1 Hz)
- Prescribe mesh resolution (output grid spacing and format) and minimum Vs

General methodology

- Finite-fault geometry (Salt Lake segment used in Roten et al. model)

– Allow for variable slip functions (supershear, etc)

Groups need database of 17 largest events **M** 2-4 compiled by URS/Wong
Submit group proposal (long-period modelers) for funding through co-op agreement
Need to establish time when groups will be ready to meet and compare results (possibly March 2011)
Make progress toward dynamic modeling on complex (segmented) fault
Discuss high-frequency stochastic methods
Phase 3 – use results to estimate ground motions from other faults, add uncertainty from phases 1 and 2, calculate hazard for urban hazard maps

The meeting adjourned at 12:00 pm.