E APPENDIX E WORKING MEETINGS AND WORKSHOP

E.1 List of Working Meetings and Workshop

Appendix E provides the highlights for the working meetings and workshop. The five technical working meetings and workshop that were held as part of the EPRI (2004, 2006) GMM Review Project are listed below:

- Working Meeting 1 (Conference Call) March 8, 2012
- Working Meeting 2 April 26, 2012
- Working Meeting 3 May 24, 2012
- Working Meeting 4 June 27, 2012
- Working Meeting 5 August 14, 2012
- Workshop: Feedback October 17, 2012

----- Forwarded Message -----

From: Larry Salomone < ceus_ssc@yahoo.com >

To: Gabriel Toro <<u>toro@lettisci.com</u>>; Robin McGuire <<u>robinkmcguire@alum.mit.edu</u>>; "<u>mcc@vt.edu</u>" <<u>mcc@vt.edu</u>>; bob youngs <<u>bob.youngs@amec.com</u>>; walter arabasz <<u>arabasz@seis.utah.edu</u>>; "<u>richard.quittmeyer@rizzoassoc.com</u>" <<u>richard.quittmeyer@rizzoassoc.com</u>"; norman abrahamson

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<<u>naa2@pge.com</u>>; carl stepp <<u>cstepp@moment.net</u>>; Charles S Mueller <<u>cmueller@usgs.gov</u>>; Serkan Bozkurt <<u>bozkurt@lettisci.com</u>>; jeffrey kimball <<u>jeffreyk@dnfsb.gov</u>>; cliff munson

<<u>clifford.munson@nrc.gov</u>>; jon ake <<u>jon.ake@nrc.gov</u>>; jeff hamel <<u>jhamel@epri.com</u>>; robert kassawara <<u>rkassawa@epri.com</u>>

Sent: Friday, March 9, 2012 7:23 PM

Subject: EPRI (2004/2006) GMM Review Project: 3/8/12 Conference Call Highlights and Documentation (WM#!)

All,

Here are the following attachments providing documentation for the EPRI (2004, 2006) GMM Review Project conference call on March 8, 2012:

- Highlights and action items from the 3/8/12 conference call
- Revised Organization Chart
- Roles and Responsibilities of the project team to be included in the Project Plan (These descriptions will communicate expectations from each position in the organization chart)
- Draft Project Outline incorporating comments from the conference call.

If there are any questions or comments, please contact me.

Regards, Larry Salomone Project Manager (803) 645-3659

EPRI (2004, 2006) Ground Motion Model (GMM) Review Project Conference Call – March 8, 2012 Highlights

Introduction

A conference call was held on March 8, 2012 to start the EPRI (2004, 2006) GMM Review Project. The purpose of the conference call was to:

- Discuss project drivers and sponsor and stakeholder expectations for the project
- Review and update the conceptual plan and draft project outline provided to define the scope and project and tracking milestones
- Begin the development of a project plan that will review the EPRI (2004, 2006) GMPEs and will provide in 12 months a GMM that can be supported by the NRC for use prior to the development of the NGA-East GMM
- Discuss EPRI administrative forms and contracts for the EPRI (2004, 2006) Review Project Team

The agenda for the conference call included the following topics:

- Welcome
- Opening Remarks (Purposes for the Conference call, Project Drivers, Sponsor Expectations, Project Goals Project Organization and SSHAC Level 2 Assessment Process)
- Review of Conceptual Plan and Draft Project Outline
- Shear Wave Velocity Measurements at Recording Stations
- PPRP Expectations
- Development of Project Plan
- Contracts and
- Path Forward

Participants included: J. Hamel and R. Kassawara (EPRI Management), L. Salomone (Project Manager), R. McGuire and M. Chapman (TI Team), S. Bozkurt (Database Manager), W.Arabasz, R. Quittmeyer, N. Abrahamson (PPRP), C. Stepp, C. Mueller, (Senior Technical Advisors) and J. Kimball, C. Munson and J. Ake (Observers). The focus of the conference call was an open discussion to achieve the goals of the meeting. Highlights from the conference call are provided in the sections that follow.

Highlights

Welcome:

- J. Hamel welcomed the participants on the conference call, and explained the importance of the EPRI (2004, 2006) Review Project to industry providing its
- response to NTTF Recommendation 2.1 for seismic.

Opening Remarks:

• L. Salomone informed participants of the conference calls, interviews and a meeting at the offices of USGS in Golden CO with ground motion specialists to

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develop the conceptual plan and draft outline that were provided to conference call participants before the conference call.

- L. Salomone stated the purposes of the call (above). He explained there was a need to review the EPRI (2004, 2006) model before its use to calculate ground motion response spectra at existing nuclear power plant sites. It has been ten (10) years since the EPRI (2004) SSHAC Level 3 workshops were held in 2002 and eight (8) years since the sigma component of the model assessment beginning in 2005 and updated. It is very important to perform this review and update on schedule to meet the industry and NRC schedule requirements.
- L. Salomone explained the tools used to keep the project on track to meet the sponsor and regulator expectations and to keep the project team and sponsor abreast of project activities and progress
- L. Salomone stated that the objective of the Review Project is to evaluate whether the EPRI (2004, 2006) model requires modification/updating for application to address NTTF Recommendation 2.1 for seismic and, if so to update/modify the model using an approach that can be accepted by the NRC for proceeding with the program to calculate ground motion response spectra for existing nuclear power plant sites.
- L. Salomone explained the various roles and responsibilities of the project team shown in the organization chart that was provided before the conference call. See attachment that will be used for the project plan.

<u>Review of Conceptual Plan and Draft Project Outline and Shear Wave Velocity</u> <u>Measurements:</u>

- R. McGuire lead this discussion using a revised draft outline provided by G. Toro, TI Lead. For Task 2, "Compile Database," McGuire described a list of issues that need to be addressed during the project, such as Vs30 of recording sites, physical basis for clusters in EPRI-04 median models, importance of extrapolation methods for larger magnitudes and long distances needed for calculations of hazard.
- N. Abrahamson reviewed some of the findings from the NGA-East Project. Abrahamson indicated that proxies for Vs30 (e.g. topography) were not useful for NGA-East, that the reference rock velocity was being kept the same (3000 m/s but that category includes a reference rock velocity of 2800 m/s for consistency with past calculations), and he stressed the importance of obtaining shear wave velocity measurements and site conditions at selected recording stations.
- N. Abrahamson stated that G. Atkinson's work suggest that new GMPE clusters may be warranted.
- N. Abrahamson stated that new information may result in different sigma for small and large magnitude earthquakes.
- W. Arabasz stressed that the site description of recording stations should be expanded from Vs30 to include the geology in the vicinity of the recording stations and pictures of the recording station and local geologic structure.
- J. Kimball mentioned the importance of looking at spectral shape comparisons, not just spectral amplitudes at individual spectral frequencies.

- N. Abrahamson suggested looking at aftershocks for geometrical spreading. See IRIS database.
- M. Chapman provided a short briefing on what data is available from the Mineral Va earthquake. He said that mainshock data has already been included in the NGA-East Ground Motion database (approximately 300 recordings, according to N. Abrahamson). Unusual ground motions were recorded at Corban and Charlottesville, and larger-than-expected amplitudes were recorded at Reston. Chapman said that there is lack of data less than 150 km from the source. M. Chapman agreed to assemble readily available relevant data regarding aftershock data that may be helpful to the project.
- <u>N. Abrahamson said that in June 2012 the results of Walter Mooney's work on crustal structure may be available to the project.</u>
- R. McGuire asked the question about the value of assembling data from international sources. He stressed the importance of assessing the physical basis. Norm said that the project should examine what G. Toro has already assembled for the NGA-East Project. Norm said the international data may have limited use because metadata are not well documented for records.
- R. McGuire reviewed Task 3, "Review New Models" and described the sources of new data: a) contacting resource experts, b) having meetings with resource experts and c) prior publications. N. Abrahamson (N.A.) stated that parameters should be treated as a set. Do not do one parameter at a time. <u>He provided the following guidance for consideration: 1) geometrical spreading and stress drop, 2) kappa correction (N.A. can provide), 3) Sigma models (strong motion data correction) (NA can provide worldwide data) and 4) site correction. These 4 models will get us a long way toward updating EPRI-04-06 ground motions. N. A. said that the single-station sigma model may get us a long way toward updating the EPRI-06 sigma model, since some data are consistent worldwide.
 </u>
- C. Stepp recommended reviewing the D. Boore presentation at the Blue Castle meeting. N. Abrahamson took the action to ask D. Boore for his presentation. Norm will provide Boore's presentation to L. Salomone for distribution to the project team.
- R. McGuire described Task 4, "Modify EPRI-04-06 equations." He suggested that modifications to the existing 4 clusters might be made to account for revised magnitude and distance terms, or we could add another equation for a new model.
- There was agreement to avoid getting "bogged down" doing research e.g. on aftershock data from the Mineral VA earthquake. Simplify the EPRI (2004, 2006) model and stay focused on what is needed to meet the goals of the project. McGuire indicated that the EPRI-04 concept of general and non-general sources needs to be reviewed, as well as the situation when the wave travel path crosses from the mid-Continent to Gulf region. M. Chapman mentioned having separate attenuation relations for various locations (e.g. Mid-Continent and Gulf). M. Chapman suggested having separate attenuation relations for each region and a third for the travel path crossing regions developed using the Monte Carlo approach. Norm suggested keeping it simple by adding sigma to compensate for uncertainties in how Lg waves are affected when traveling from the mid-Continent to the Gulf region.

- R. McGuire reviewed Task 5, "Perform hazard at 7 sites." He explained that hazard would be calculated at the seven (7) CEUS SSC test sites to learn the potential effects of the EPRI (2004, 2006) model versus the updated model and to check the updated model for any significant issues.
- R. McGuire reviewed Task 6, "Documentation" and stated that the project activities and results will be documented in the final report.

PPRP Expectations:

- W. Arabasz stated pertinent sections from NUREG 2117. He stressed the importance of a systematic, structured approach to develop the new models.
- W. Arabasz referred to the approach described in the conceptual plan as a "quasi" SSHAC Level 3 assessment process because there is a TI Team and a PPRP and no workshops.
- C. Mueller confirmed the cooperation between the USGS National Seismic Hazard Mapping Project and the EPRI (2004, 2006) Review Project. He said there will be a ground motion workshop in October 2012 at a location to be determined.
- W. Arabasz stressed the "burden" and ownership of the final product is the TI Team's responsibility.
- W. Arabasz stated there should be complete and transparent documentation for decision points.
- W. Arabasz asked S. Bozkurt, Database Manager, to establish an FTP site for sharing among the project team project documentation.
- R. Quittmeyer agreed with W. Arabasz on the comments that he made, and Richard added that he would be watching that the center, body and range of technically defensible interpretations are represented from the evaluations.
- R. Quittmeyer recommended not trying to specify too much in the project plan, and stressed the importance of leaving options to prioritize what is most important.
- R. Quittmeyer suggested that the PPRP should have internal discussions
- N. Abrahamson informed the project team that he will have to serve as a Senior Technical Advisor instead of as a PPRP member because of his roll on the NGA-East Project. See revised organization chart. He also said that he would be the point of contact for data from the NGA-East Project. (Note: Y. Bozorgnia also agreed to be a point of contact). N. Abrahamson and L. Salomone agreed to talk further about the change. Norm will also suggest some younger professional who can assist, if needed.
- L. Salomone asked the participants to suggest a replacement for N. Abrahamson on the PPRP.

Contracts:

- J. Hamel said he was working on contracts following the conference call. He asked that anyone who has not submitted an EPRI 112 Form to provide them as soon as possible. He anticipated that contracts would be forthcoming within 1-3 weeks.
- J. Hamel said that contracts will have a start date of March 8, 2012, and if this is not possible with EPRI, he will advise participants.

Path Forward:

- L Salomone reviewed dates for all conference calls and working meetings on the project, to confirm availability of participants. Some dates changed from the project outline. See revised draft outline attached.
- L. Salomone will send out a notice for a conference call among the TI Team members on March 8, 2012. B. Youngs and G. Toro will be available for the conference call.
- L. Salomone will assist J. Hamel on the paperwork for the contracts.
- L. Salomone and the TI Team will begin the development of the Project Plan for review by the PPRP, Senior Technical Advisors, Sponsor and Observers.

EPRI(2004/2006)Review Project: Organization Chart



Recognized ground motion experts, as required



EPRI (2004, 2006) Review Project Position Description and Responsibilities

TI Team Members: The TI Team Members will have the primary responsibility for developing and documenting the technical basis for all project assessments and products. Additional duties will include, but not be limited to:

- Implementing the SSHAC Level 2 methodology throughout the project, including all key assessment steps of evaluation and integration;
- Working with the Project Manager to develop the Project Plan;
- Developing the Project Database;
- Conducting Working Meetings and other project meetings, as required;
- Participating in conference calls;
- Facilitating the requisite expert interactions;
- Communicating with the Project Manager and the PPRP and responding to PPRP communications, as required and
- Documenting all process and technical aspects of the study and decisions in a project report.

Database Manager: The database manager will have the primary responsibility to retrieving and compiling applicable data for use in developing the ground motion prediction equations (GMPEs). Additional duties will include, but not be limited to:

- Obtaining data sets from the USGS National Seismic Hazard Mapping Project and the NGA-East Project, as required
- Providing data sets in formats appropriate for use in the TI Team deliberations;
- Providing a FTP site for sharing project information among the project team;
- Participating in conference calls;
- Providing support for resolving copyright issues, working meetings and PPRP and Sponsor briefings, as required and
- Providing support and assistance for report preparation including but not be limited to support for preparing figures for the report.

PPRP Members: PPRP members will have the primary responsibility for reviewing the technical and process aspects of the project. Additional duties will include, but not be limited to:

- Attending working meetings and conference calls to observe the process and progress of the project;
- Providing feedback and written comments on, as a minimum, the project plan and the draft and final project report;
- Reviewing in depth the technical assessments made by the TI Team at key points during the study;
- Participating in the PPRP briefing to bring closure to the entire project review process;
- Providing verbal and written comments, as required, throughout the study to assist the TI Team in carrying out its assessments and

• Providing a written closure report to the Project Manager for inclusion in the final project report.

Senior Technical Advisors: Senior Technical Advisors will have the primary responsibility of providing their technical knowledge and experience on specific topics of discussion regarding ground motion to the TI Team and Project Manager throughout the study. Additional duties will include, but not be limited to:

- Providing insights, data and viewpoints at the request of the Project Manager and TI Team;
- Providing current data, models and methods to keep TI Team abreast of ground motion developments since the EPRI (2004) workshops in 2002;
- Providing a basis for assessing the technical bases and uncertainties with recent and ongoing ground motion-related studies in the technical community;
- Attending working meetings, participating in conference calls and attending the PPRP closure briefing at the end of the project and
- Reviewing and providing comments on the project report.

Project Manager: The Project Manager will have the primary responsibilities to serve as the point of contact between the project and the project sponsor and who will be responsible for ensuring adherence to scope, schedule, budgets and contractual requirements. The Project Manager will have the primary responsibility for the delivery of all technical products. Additional duties will include, but not be limited to:

- Working with the TI Lead to organize working meetings;
- Working with the EPRI Advanced Nuclear Technology Program Manager to communicate information to the project team regarding contractual requirements and establishing requirements for the project plan and report;
- Assisting the EPRI ANT Program Manager in establishing and maintaining budgets and schedules and preparing quarterly status reports
- Serving as the point of contact to keep the sponsor, PPRP, Senior Technical Advisors and Observers apprised of project activities and progress;
- Working with Norm Abrahamson, Yousef Bozorgnia and Charles Mueller to share information about the project and to obtain inputs from the NGA-East Project and the USGS National Seismic Hazards Mapping Project;
- Supporting PEER's and TI Team's efforts to obtain shear wave velocity measurements at 33 recording stations and
- Serving as the principal spokesperson to the outside community.

EPRI Advanced Nuclear Technology (ANT) Program Manager: The EPRI ANT Program Manager will have the primary responsibility to define the sponsor expectations, share the sponsor expectations with the Project Manager and keep EPRI members abreast of project activities and progress with the support of the Project Manager. Additional responsibilities will include, but not be limited to:

- Securing funding for the project and awarding a contract to obtain shear wave velocity measurements at 33 recording stations;
- Assuming responsibility for contract management and providing the fundamental interface for contracts;

- Working with the Database Manager to resolve copyright issues;
- Defining the level of transparency to use for products developed during the study;
- Providing support for the PPRP Closure Briefing in the offices of EPRI, Palo Alto CA;
- Establishing requirements for the project plan and report.

Observer: An observer will be given by the Project Manager the opportunity to provide their technical knowledge and experience on specific topics of discussion regarding ground motion to the TI Team and Project Manager throughout the study. An observer shall not be considered a member of the project team, but as an observer will be kept abreast of project activities, decisions and progress. An observer may attend project meetings at the option of the observer.

EPRI (2004, 2006) Review Project Draft Outline (3/8/12 with conference call comments)

Description	Project	Proposed Meetings	Tracking Milestones
Task 1. Write Dusiest Dis-	Milestone	or Conference Calls	Des & Des is a A Dise
Task I: write Project Plan	April 20, 2012	Coll Morch 8, 2012	Dratt Project Plan
• Execute Contract		March 13 2012;	PPRP Review Project
		(11 AM - PT) TI	Plan
		Team Conference	
		Call	
Task 2: Compile Current	July 31, 2012	WM #2: April 26,	Obtain NGA-East
Relevant Ground Motion	•	2012	Ground Motion
Database			Database
 Identify Subset of new 		WM #3: May 17,	
ground motion data		2012 (N.	Selection of approach for
from the NGA-East		Abrahamson will	incorporation of site
Project with site		call-in)	response (most likely
characterization		WM #4. Inmo 14 on	quarter wavelength); test
Information including		28 2012	approach as sile data
dete		20, 2012	become available
Extract ground motion			Development of
data with site			approach for
information			comparisons of data to
• Determine fit of EPRI			GMPEs and for
(2004, 2006) GMPEs			determining whether
with new ground			EPRI 2004-2006 are
motion NGA-East data			consistent with data.
			Approach should
			account for within-event
			importance of various
			magnitude-distance
			combinations
			Obtaining of complete
			NGA-East shear wave
			velocity data set
L.			
Task 3: Identify new CEUS	March 1 2012	WM #5 or	Canyas CMPE
GMPEs since EPRI (2004)	to August 1.	Conference Call:	developers and collect
workshops	2012	August 3. 2012	references
		g,	
			Electronic
			implementation of
			GMPEs
<u>Task 4:</u> Modify EPRI (2004,	September 30,	WM #6 or	A weighted set of ground
2006) GMPEs	2012	Conference Call:	motion relationships that
• Evaluate and assess		September 13, 2012	represent the median
weighting of GMPEs or			ground motion and its
updated EPRI (2004,			epistemic uncertainty
2006) GMPEs quantity-			
mg mean and epistemic and			A weighted set of models
aleatory uncertainty			for the aleatory
areatory uncertainty			variability about the
			median ground motion
			6
			Set of relationships

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			applicable to: CEUS excluding Gulf Coast
<u>Task 5:</u> Perform a hazard assessment at the 7 CEUS SSC Test sites	November 30, 2012	WM#7: Conference Call: October 25, 2012	Draft Comparison of Hazard Curves using old and updated EPRI (2004,2006) GMPEs at 3 test sites
<u>Task 6:</u> Write Report and Complete Documentation	February 28, 2013	PPRP Closure Briefing, Palo Alto CA: November 29, 2012	Draft Report for Review
Database Development and FTP Site Development			

----- Forwarded Message -----

From: Larry Salomone <<u>ceus_ssc@yahoo.com</u>>

To: Gabriel Toro <<u>toro@lettisci.com</u>>; Robin McGuire <<u>robinkmcguire@gmail.com</u>>; bob youngs <<u>bob.youngs@amec.com</u>>; Martin Chapman <<u>mcc@vt.edu</u>>; carl stepp <<u>cstepp@moment.net</u>>; Charles S Mueller <<u>cmueller@usgs.gov</u>>; jeffrey kimball <<u>jeffreyk@dnfsb.gov</u>>; walter arabasz <<u>arabasz@seis.utah.edu</u>>; Richard Quittmeyer <<u>richard.quittmeyer@rizzoassoc.com</u>>; Brian Chiou <<u>brian_chiou@comcast.net</u>>; bob whorton <<u>rwhorton@scana.com</u>>; jeff hamel <<u>jhamel@epri.com</u>>; cliff munson <<u>clifford.munson@nrc.gov</u>>; jon ake <<u>jon.ake@nrc.gov</u>>; Serkan Bozkurt <<u>bozkurt@lettisci.com</u>>; John Diehl <<u>jdiehl@geovision.com</u>>; Ken Stokoe <<u>k.stokoe@mail.utexas.edu</u>>; Robert A Williams <<u>rawilliams@usgs.gov</u>>; norman abrahamson <abrahamson@berkeley.edu>

Sent: Monday, April 30, 2012 4:23 PM

Subject: EPRI (2004, 2006) GMM Review Project: Working Meeting (WM) #2 Highlights

All,

I appreciate your taking time to participate in WM #2 held in the offices of EPRI on April 26, 2012 and helping us achieve the goals for the meeting. The goals of the meeting were:

- Review status of the Project Plan, provide overview of Project Plan including phases and decision points;
- Discuss NRC feedback on Project Plan, if available;
- Review Status of Task 2: Obtain Ground-Motion Database and Identify New CEUS Ground Motion Prediction Equations (GMPEs);
- Review Status and Schedule for Task 3: Obtain Shear Wave Velocity Measurements at Recording Stations;
- Discuss and Define Approach for Task 4: Test EPRI (2004, 2006) Ground Motion Model (GMM);
- Review Project Schedule, Table 7-1 in Project Plan, and Discuss Path Forward and
- Discuss any remaining administrative details for the EPRI (2004, 2006) Review Project Team

Attached are the Highlights for WM#2 for the EPRI (2004, 2006) GMM Review Project and the following additional documentation provided as handouts:

- Agenda
- Project Manager Presentation
- NRC Comments on Project Plan, Rev. 2 dated 4/14/12
- USGS Map showing alternate sites for shear wave velocity measurements at recording stations

We appreciate the NRC insights and perspective provided on the draft project plan in the attachment and during the meeting. We understand that the NRC staff were impressed with the very good discussion and the very clear answers to NRC comments provided during WM#2. We will now incorporate our responses to the NRC comments into a revised draft project plan, Rev.3 for NRC review.

If there are any questions or comments, please contact me. Regards, Larry Salomone Project Manager

Proposed Agenda EPRI (2004, 2006) GMM Review Project Working Meeting #2

Electric Power Research Institute 3420 Hillview Avenue Palo Alto, CA 94304 Conference Room B1045

8:30AM to 4:00PM (PDT) 11:30 AM to 7:00 PM (EDT)

April 26, 2012

GOALS OF THE MEETING: The goals of the meeting are:

- Review status of the Project Plan, provide overview of Project Plan including phases and decision points;
- Discuss NRC feedback on Project Plan, if available;
- Review Status of Task 2: Obtain Ground-Motion Database and Identify New CEUS Ground Motion Prediction Equations (GMPEs);
- Review Status and Schedule for Task 3: Obtain Shear Wave Velocity Measurements at Recording Stations;
- Discuss and Define Approach for Task 4: Test EPRI (2004, 2006) Ground Motion Model (GMM);
- Review Project Schedule, Table 7-1 in Project Plan, and Discuss Path Forward and
- Discuss any remaining administrative details for the EPRI (2004, 2006) Review Project Team

APPROACH: The focus of the meeting will be a roundtable discussion to achieve the goals of the meeting. We will have a call-in number for those invited participants who cannot attend in person. The call-in number is 1-877-625-7420; pass code is 3096. The leads in blue are invited to participate. If they have conflicts to attend in-person and have limited time to participate, I would appreciate your calling-in at the time noted in the agenda for those topics indicated.

The approach to review the EPRI (2004, 2006) GMPEs and develop GMPEs in 12 months will be discussed. There will be a targeted discussion for the tasks identified in the objectives. The results of the meeting will be incorporated into the project plan that will be provided to the Electric Power Research Institute (EPRI) for publication as an EPRI Technical Update Report. The published project plan will also reflect Nuclear Regulatory Commission (NRC) feedback received on or before April 30, 2012.

Time (PDT)	Торіс	Lead
8:30 - 8:35 AM	Welcome	J.Hamel/L. Salomone
8:35 – 9:30 AM	 Opening Remarks: Purposes for the Meeting Project Status and Overview NRC Feedback, if available 	L.Salomone/C. Munson, if available
9:30 – 10:30 AM	 Task 2: Status of NGA-East GM Database: Summary of Database Efforts for securing official access Data being added by C. Cramer Status of QA by PEER Schedule for obtaining and (if necessary) reformatting database Discussion of additional GM data that may be added 	G. Toro/C. Mueller/M. Chapman/N. Abrahamson or Y. Bozorgnia, if available
10:30 - 10:45AM	Break	
10:45 – 11:30AM	 I ask 2 (continued): Literature Review Plan for review: assignments Plan for documentation Plan for storage/distributi on and handling of copyright issues 	G. 10ro/S.Bozkurt
11:30 – 12:30PM	Lunch	
12:30 – 1:00PM	Task 3: Shear Wave	L. Salomone/ C. Mueller/J.

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	Velocity Measurements at	Diehl, if
	Recording Stations:	available/R.Williams, if
	• Data to be obtained	available
	Locations	
	• Schedule	
	USGS work	
1:00 – 2:30 PM	Task 4: Discussion of	G. Toro/All
	Approach for Quantitative	
	Comparisons:	
	Approach for site	
	response	
	calculations	
	(including	
	uncertainty)	
	• Issues that must be	
	considered	
	Proposed Approach	
	for Comparisons to	
	Other Models	
	Decision Point 2	
	Criteria	
2:30 – 2:45 PM	Break	
2:45-3:15 PM	Observer, including PPRP,	All
	Feedback	
3:15 – 3:20 PM	Contracts	J. Hamel
3:20 - 4:00 PM	Schedule/Path Forward	L. Salomone/G.Toro
4:00 PM	Adjourn	



EPEI ELECTRIC POWER RESEARCH INSTITUTE

EPRI (2004,2006) Ground Motion Model (GMM) Review Project

Working Meeting #2 April 26, 2012

Lawrence Salomone Project Manager



Background:

- The EPRI (2004, 2006) Ground Motion Model (GMM) Review Project will provide industry information necessary specifically for an informed response to the NRC Request for Information (RFI) to Title 10 of the Code of Federal Regulation 50.54(f) Recommendation 2.1 of the Near-Term Task Force (NTTF) Review of Insights from the Fukushima Dai-Ichi Accident dated March 12, 2012.
- The project will provide information for developing site-specific ground motion response spectra (GMRS) for existing nuclear power plant sites.
- The industry position is to review and, if necessary, update the EPRI (2004, 2006) <u>GMM</u>: This position is prudent in light of guidance in NUREG-2117 (2012), input from ground motion experts and seismologists contacted from October 2011 to March 2012 and new data, models and methods that have become available since the SSHAC Level 3 EPRI (2004) workshops were held in 2002.

Purposes:

- Review and Update, if appropriate, the EPRI (2004, 2006) GMM for the specific limited need of calculating GMRS for existing nuclear power plant sites in response to the NRC RFI of the NTTF recommendation for seismic using an approach that can be accepted by the NRC
- Increase the accuracy of input to compute ground motion response spectra (GMRS) required in NTTF Recommendation 2.1 for seismic





INDUSTRY DUE DILIGENCE

Contact Type	Date	<u>Participants</u>
Conference Call	November 8, 2011	G. Atkinson, J. Bailess, J. Hamel, R. Kassawara, K. Keithline, J. Marrone, S. McDuffie, R. McGuire, M. Petersen, L. Salomone, J.C. Stepp, G. Toro, B. Youngs,
Interviews	October 26, 2011	N. Abrahamson
	November 2, 2011	M. McCann
	November 3, 2011	W. Silva
Meeting	November 30, 2011	A. Frankel, C. Goulet, R. McGuire, M. Moschetti, C. Mueller, M. Petersen, S. Rezaeian, L. Salomone, J.C. Stepp, G. Toro,
Conference Call –Project "Kickoff" Call	March 8, 2012	N. Abrahamson, J. Ake, W. Arabasz, S. Bozkurt, M. Chapman, J. Hamel, R. Kassawara, J. Kimball, R. McGuire, C. Mueller, C. Munson, R. Quittmeyer, L. Salomone, J.C. Stepp,

HIGHLIGHTS FROM DUE DILIGENCE CONTACTS

• EPRI (2004) GMM workshops in 2002; sigma component updated beginning in 2005;

- New CENA Ground Motion Database available;
- New Ground Motion Prediction Equations (GMPEs) available since 2002
 (see Project Plan for list)
- New significant earthquakes since 2002 (e.g., 2011 M 5.8 Mineral VA earthquake; 2010 M 5.0 Val des Bois Quebec; 2008 M 5.3 Mt. Carmel IL.)
- One hybrid GMPE in EPRI (2004, 2006) GMM has unphysical behavior at long distances
- Should take into account that some GMPEs do better in certain magnitude distance ranges;
- Modification of existing four (4) clusters may be necessary to account for revised magnitude and distance terms;
- Calculation of sigma should take into account the site-conversion to reduce scatter; new information may result in different sigma for small and large magnitude earthquakes;
- Ground motion parameters should be treated as a set: a) geometrical spreading and stress drop, b) kappa correction, c) sigma models and d) site correction.



Project Plan: FLOW CHART



Project Plan: Flow Chart (continued)





Decision Point Criteria

- <u>Decision Point 1</u>: The criterion to be applied at Decision Point 1 is whether this Project Plan is endorsed by the Project Team, PPRP, and Sponsor, after considering feedback by the NRC.
- **Decision Point 2:** The criteria for Decision Point 2 are:
 - Is the EPRI (2004, 2006) GMM consistent with all models, results, or data in the literature that are Technically Defensible, in the judgment of the TI Team? Consistency is defined in terms of ground-motion amplitudes, not in the sense of individual parameters or functional forms. Comparisons of ground-motion data to GMPEs developed since 2002 will help answer this question.
 - Do the comparisons of the EPRI (2004, 2006) GMM to the data, taking into account the considerations listed above, indicate any significant deviation? Deviations may be either in the form of a significant bias for a particular magnitude-distance range or in the form of uncertainties that are too broad or too narrow, given the data and their limitations.



Decision Point Criteria (continued)

- Decision Point 3: The criterion for Decision Point 3 is: In the judgment of the TI Team--with feedback from the PPRP and NRC--does the EPRI (2013) GMM represent the center, body, and range of the Technically Defensible Interpretations (TDI) for ground motions in the CEUS, taking into account the existing data, models, and methods? This criterion will be applied for all frequency-magnitude-distance combinations of interest for CEUS hazard calculations, but those combinations of marginal interest will be given reduced weight in the decision.
- If the Decision Point 3 criterion is met, recommend the EPRI (2013) GMM for use to calculate GMRS at existing nuclear power plant sites.



Project Manager Proposed Topics for Discussion

- Project Objectives
- Role of PPRP in Working Meetings as Resource Experts or Observers
- SSHAC Study Level
- Decision Point Criteria
- Task 2: Process- Obtain New Ground Motion Database and Identify New GMPEs
- Task 3: Shear Wave Velocity Measurements (EPRI and USGS)
 - Alternate Sites
- Task 4: Quantifying the uncertainty in site amplification factor
- Task 6: USGS Workshop Details
 - When
 - Where
 - Duration
 - Other Details
 - Questions for Resource and Proponent Experts
- Schedule: Target Dates



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Recording Stations:

Locations for Shear Wave Velocity Measurements

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Work Plan and Schedule Showing Target Dates

• PHASE 1

- Task 1: Project Plan (April 2012)
 - Decision Point 1 April 2012
- Task 2: Obtain GM Database and Identify New GMPEs (July 2012)
- Task 3: Obtain Shear Wave Velocity Measurements (July 2012)
- Task 4: Test EPRI (2004, 2006) GMM (July 2012)
 - Decision Point 2 July 2012



Work Plan and Schedule (continued)

• PHASE 2

- Task 5: Update the EPRI (2004, 2006) GMM (Sept. 2012)
- Task 6: Interaction with Technical Community at USGS Workshop (2012)
- Task 7: Calculate Seismic Hazard at Seven (7) Test Sites (November 2012)
- Task 8: Finalize EPRI (2013) GMM (Nov. 2012)
 - Decision Point 3 November 2012
- Tasks 9-11: Document Project in Report (January – March 2013)
- Task 12: Issue EPRI (2004, 2006) GMM Review Project (April 2013)





Other Industry Milestones

- Begin GMRS Calculations (April 2013)
- Complete GMRS Calculations (September 2013)





WHAT'S NEXT

- Incorporate NRC comments into Project Plan
- Obtain Technical Editor review of Project Plan and incorporate comments
- Publish EPRI (2004, 2006) GMM Review Project Plan as EPRI Technical Update
- Obtain NGA-East Ground Motion Database from NGA-East Project
- Identify Ground Motion Prediction Equations (GMPEs) developed after 2002
- Mobilize contractors for shear wave velocity measurements at recording stations



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NRC Comments on EPRI (2004, 2006) Ground Motion Model Review Project – Project Plan

- 1. The criteria for determining the continued viability of the EPRI (2004, 2006) GMM is not adequately described and justified. At one point in the Project Plan (PP) it states that the EPRI (2004, 2006) GMM will be tested "against the consensus state of knowledge." The staff considers that this type of criterion is too vague and qualitative. In addition, throughout the PP the criteria for determining the "consistency" of EPRI (2004, 2006) includes a comparison to more recently developed individual GMM for the CEUS. The staff does not consider this to be a fair comparison to determine continued viability of the existing EPRI GMM. The EPRI (2004, 2006) GMM is an amalgamation of several GMMs that were individually weighted within four clusters, which were then also weighted to form the final GMM. Among the thirteen GMMs used to develop EPRI (2004, 2006) is not a valid criterion to determine continued viability. The only situation where this type of comparison would be warranted is if several or most of the newer GMMs showed a similar trend that differed significantly from the EPRI (2004, 2006) GMM.
- Given that the recordings in the CEUS are very limited in number (particularly in regard to the magnitude and distance bins of interest), and that they generally come from equipment that does not capture high frequency or horizontal motions, explain how current EPRI (2004, 2006) and newer CEUS GMMs will be evaluated to determine an update is necessary and if they should be included in the update.
- 3. The scope of the update, should it be necessary, appears to be considerable in that several new GMMs will be replacing older CEUS GMMs and the grouping of the GMMs into clusters may differ significantly from EPRI (2004, 2006). As such, it is challenging to see how one can justify calling this an update rather than a Level 2 replacement since fundamental elements of the model are being changed. In other cases there is a discussion of considering kappa and other similar technical aspects that underpin the GMPE models. However, in this case it is unclear how one could use this information given that the focus of the project is simply comparing the GMM outputs rather than their technical underpinnings. Considering that this update may be more of a replacement, justify the use of SSHAC Level 2.
- 4. In a number of places (page 3-2, 4-3, 4-6, 4-7) the upcoming USGS workshop is discussed and it is implied or stated that the USGS and EPRI are coordinating on the USGS workshop. For example, on page 3-2 it states "The PM and TI Team plan to work closely with the USGS to develop objectives and an agenda for the workshop, specifically identifying those proponents who will be requested to present targeted technical discussions for workshop participants." On page 4-7, the project plan states "Task 8: Finalize EPRI (2013) Ground Motion Model (GMM): In light of the feedback received in the Workshop with the USGS and using the final database and input from the PPRP, Senior Technical Advisors, Observers and NRC, the TI Team will finalize the

ground motion model as part of this task..." The words "the Workshop with the USGS" give the strong impression that it is a joint workshop. The USGS do not appear on the organization chart (Figure 5-1) and their involvement in this SSHAC Level 2 project is not clearly described. In addition, it is not clear from our conversations with USGS that they are on board with the coordination that is described in the PP. It also appears that USGS feedback from the workshop will be used as a basis for Decision Point 3. Please describe how this informal input would fit into the SSHAC process. In addition, please clarify the coordination and role that the USGS will play in this update.

- 5. The PP states that an updated EPRI (2013) GMM would be used until the "NGA-East GMPEs are available." The staff concurs with this decision but believes that the PP would benefit from a paragraph that more clearly describes the relationship between the proposed update of EPRI (2004, 2006) and NGA-East. This paragraph should include the limitations of the proposed update with respect to the more comprehensive NGA-East project. This discussion should clarify and emphasize that the GMMs to be developed by the NGA-East project will be considered the appropriate models to use for future characterization of seismic hazards for the CEUS once they become available.
- 6. The PP states that the "project is necessary to evaluate regulatory risk and to make the decision on whether the EPRI (2004, 2006) GMM is appropriate …" Please clarify what is meant by "regulatory risk."
- 7. Decision Point 3 is not clearly described in the PP. What will be the criteria for determining if the updated EPRI GMM is to be used in place of EPRI (2004, 2006)? It appears from the PP that this decision would be based, in part, on feedback from the USGS Ground Motion Workshop? Decision Point 3 is not adequately described in the work plan (Section 4) of the PP. How do Tasks 7 and 8 factor into Decision Point 3? Explain the criteria for making adjustments to the weights after Task 7.
- Page 1-1 of the PP states that "industry's position is that industry will review, and if necessary, update the EPRI (2004, 2006) GMM before calculating the ground motion response spectra at existing nuclear power plant sites." Consider rephrasing this sentence to emphasize that ground motion modeling experts through the SSHAC process will determine if it is necessary to update EPRI (2004, 2006).
- 9. The PP states that advances in the WUS with respect to modeling sigma will be used in a similar fashion for the proposed update of EPRI (2004, 2006). The plan should describe the technical basis that will be used to justify the application of WUS sigma values in the CEUS. The team should also consider if additional epistemic uncertainty in sigma needs to be added to account for the potential differences between the WUS and CEUS.
- 10. Page 1-2 of the PP states that "ground motion parameters should be treated as a set: a) geometrical spreading and stress drop; (b) kappa correction; c) sigma models and d) site
correction." This sentence is not particularly clear, but if the intent is to suggest that correlations between parameters need to be considered, then the staff agrees. While this type of approach is one of the technical cornerstones of the NGA-East project, please explain how this would be implemented for the proposed update of EPRI (2004, 2006). The proposed update will use existing CEUS GMMs that have already incorporated some assumptions regarding parameters and correlations into their respective models.

- 11. Page 4-2 of the PP states, with respect to the 2011 Mineral, VA earthquake, that "the most important strong motion data were collected at the North Anna power plant site. The recorded mainshock data will provide important information on the source spectrum, and may give some new insight and constraint on magnitude fault-area relations and stress-drop." The strong motion recordings at the North Anna power plant site are instructure motions and recorded on an SMA-3 with no pre-event memory. Please describe how these in-structure motions will be used for the proposed update of EPRI (2004, 2006). In addition, there are only a few strong-motion records from this event recorded at distance ranges of most interest. The other closest (~55 km) records were recorded near large buildings and need to be carefully evaluated for applicability.
- 12. The PP does not discuss the weighting criteria for the individual GMMs to be used for the proposed update. Will weighting be based only on comparison to the NGA-East dataset or on additional criteria? Page 4-5 of the PP lists additional considerations but does not state how each of these considerations will be used to determine the weighs. The development of at least a draft framework for the weighting criteria should be done at the beginning of the project. This will inform the activities of the project.
- 13. The PP indicates that S-wave velocity measurements will be made at a number of stations by a specialty contractor (GeoVision?) and the USGS. Staff assumes the measurements will be a non-invasive technique such as SASW. The PP should specify the technique and the target depths of interest.



http://anf.ucsd.edu/spevents/2011/235/b/

Red triangle symbols are active stations at the time of the August 23, 2011, earthquake in the USArray



EPRI (2004, 2006) GMM Review Project: Working Meeting #3 Highlights (Prepared by G. Toro, TI Lead, and L. Salomone, PM, 5/31/12)

Introduction

Working Meeting (WM) #3 for the EPRI (2004, 2006) Ground Motion Model (GMM) Review Project was held at the offices of Lettis Consultants International (LCI), Walnut Creek, CA on May 24, 2012. The goals of WM #3 were the following:

- Review status of the Project Plan and PPRP and NRC Project Plan feedback
- Review Status of Task 2: Obtain Ground-Motion Database and Identify New CEUS Ground Motion Prediction Equations (GMPEs);
- Review Status and Schedule for Task 3: Obtain Shear Wave Velocity Measurements at Recording Stations;
- Discuss EPRI (2004, 2006) GMM and its Development
- Discuss Approach for Task 4: Test EPRI (2004, 2006) Ground Motion Model (GMM);
- Review Project Schedule, Table 7-1 in Project Plan, and Discuss Path Forward

The format of the meeting was a roundtable discussion to achieve the goals listed above. There was a call-in number and webinar technology for those invited participants who could not attend in person. Participants in the meeting (in person or via telephone and webinar) included: Walter Arabasz, Brian Chiou, and Bob Whorton (PPRP); Jon Ake (NRC Observer) and Cliff Munson (NRC Observer); Chuck Mueller (USGS, Project Senior Technical Advisor); Rob Williams (USGS Shear Wave Velocity Measurement Coordinator); Jeff Hamel (EPRI); Carl Stepp (Project Senior Technical Advisor); Norm Abrahamson (Observer and NGA-East Project Liaison); Linda Al Atik (Resource Expert); Serkan Bozkurt (GIS, Web & Database Support); Martin Chapman and Robin McGuire (TI Team); Gabriel Toro (TI Team Lead); and Larry Salomone (PM). WM#3 Presentations are included as attachments.

Highlights

- 1. L. Salomone presented the project status and highlights from the Project Plan:
 - a. Context for the EPRI (2004, 2006) GMM Review Project
 - b) Work Plan and Schedule showing Target Dates
 - c) Path Forward in the Short-Term

Participants agreed that the criteria for Decision Point 1 was met and that the Project Manager should send the Project Plan to EPRI for publication as an EPRI Technical Update after addressing editorial comments by Walter Arabasz received on May 24, 2012. Additional comments included : Walter Arabasz, PPRP Chairman, confirmed that the project plan should be published, and he asked that the highlights include the presentations. Also, J. Ake added that Decision Point 2 looks good.

- 2. G. Toro summarized the status of Task 2 and related issues.
 - a. NGA-East Ground-Motion Data
 - i. Number of available records much larger than in 2004, but much of the new data comes from distances > 500 km.
 - ii. It would be very useful to have access to NGA-East raw and processed time histories, so that we can check any record that looks unusual in terms of residuals or spectral shape.
 - iii. There may be ~ 43 stations for which NGA-East has Vs30. Toro proposed that recordings from most of these stations should be considered in Tasks 4 and 5 (stations on deep soil will be excluded because removal of siteresponse effects is more difficult). It would be very useful to have access to all the data that NGA-East project collected about these stations (entire Vs profile, unit weights, soil types, etc.).
 - iv. L. Salomone took the action to obtain the NGA-East data needs identified in Items ii and iii. Y. Bozorgnia agreed to provide the requested information on May 30, 2012.
 - v. G. Toro summarized status of NGA-East QC of database, based on conversations with Goulet and Cramer: in progress; no show-stoppers; time histories will change; may tweak filters; spectral acceleration data OK; QC will not be completed soon. No more database updates from Cramer are anticipated.
 - b. GMPEs and Other Relevant Publications Since 2004 (all work to be completed prior to June WM)
 - i. W. Arabasz recommended that the process of contacting the Informed Technical Community (ITC) be structured, systematic and be documented thoroughly. Discussions that took place prior to project initiation are documented in the Project Plan; Other inputs must be obtained much earlier than the Task 6 Workshop for the project to be able to act on them. The TI Team will review technical papers identified from the literature and documented in the project plan on or before June 27, 2012. G. Toro provided a form for the TI Team to document its review of each technical paper. The following plan was developed to expand the Project's contact with the larger

technical community (Note some variations will be necessary to accommodate special situations.):

- a) TI Team Member will make an initial contact with Resource or Proponent Expert to set up a time for a telephone conversation and indicate the scope of questions.
- b) TI Team Member will call Resource or Proponent Expert. Interview will begin with specific questions (G. Toro will prepare a template), and will follow up with appropriate questions depending on the Expert's background and interests.
 - a. J. Ake suggested that Proponents be asked if their GMPEs have been superseded, and if so, which GMPEs supersede them.
- c) TI Team Member will prepare a summary of the conversation and send it to Expert to verify that the summary is accurate and complete.
- d) G. Toro will provide the form to document the expert interviews to the TI Team
- e) TI Team will complete interviews on or before June 27, 2012.
- f) In addition, the possibility of inviting some Resource or Proponent Experts to WM7 was mentioned for consideration,, but no final decision was made.
- ii. Names of additional Resource or Proponent Expert to be contacted included Silva, Somerville
- iii. Assignment of experts to TI Team members is:
 - a) Abrahamson (Toro)
 - b) Atkinson (Toro)
 - c) Boore (Toro)
 - d) Boatwright (McGuire)
 - e) Campbell (McGuire)
 - f) Cramer (Toro)
 - g) Herrmann (Chapman)
 - h) Pezesch (Toro)
 - i) Silva (McGuire)
 - j) Somerville (Youngs)
- iv. Additional papers to review (papers on sigma are less urgent)
 - a) Atkinson and Wald SRL 2007 (DYF)
 - b) Papers on kappa (see Linda's presentation, Van Houtte, Scherbaum, etc.)

- c) Papers on Val de Bois (Atkinson) and Mt. Carmel earthquakes (Herrmann, Leo Ramirez)
- d) Papers on single-station sigma (Gregor+Abrahamson, Al Atik, Rodriguez-Marek, Atkinson, Anderson [2-3 years ago])
- e) Paper by Chapman and Goodbee (BSSA, to appear) on geometrical spreading
- 3. M. Chapman summarized initial observations from VA aftershocks.
 - a. Most stations along a NNW-oriented profile; a few at other azimuths
 - b. Good S/N ratio for M 2.0-2.5 up to ~ 45 km
 - c. Profile data show less scatter
 - d. Mainshock and aftershock are shallow, which is typical for the region. May contain more surface-wave effects as a result of shallow depth.
 - e. Larger aftershock (Aug. 25) occurred before most temporary instruments were in place. Magnitude was 3.9 according to Herrmann (appears as 4.5 in database; verify)
 - f. Nine (9) portable stations are still deployed (USGS (3), Lehigh (6); sent to IRIS in real time)
 - g. M. Chapman will complete lessons learned from review of the Mineral VA recordings on or before the end of July 2012.
 - h. Data will constitute a separate dataset and none will be integrated into NGA-East flat file)
 - i. Process all data
 - ii. Investigate frequency-dependence of slope (geometric effects; take anelastic attenuation into account)
 - Other earthquakes of interest: OK, AK, and TX recent quakes show much lower Q (Martin's NGA-East presentation; Herrmann's recent email regarding OK earthquake)
- 4. Update on Task 3: Site investigations (R. Williams, L. Salomone)
 - a. R. Kayem completed shear wave velocity measurements at 14 sites (green in map)
 Processed profiles are expected to be available for distribution to the EPRI (2004, 2006) GMM Review Project at the end of July 2012.
 - b. R. Kayem will measure shear wave velocity at an additional 10-12 recording stations in June 2012.
 - c. GeoVision and UTA (Stokoe) will obtain shear wave velocity measurements at approximately 33 recording stations. Geo Vision performed the planning work to obtain geologic maps, aerial photographs and clearance for access. TI Team

reviewed and made changes to the list of recording stations to maximize effectiveness of the shear wave velocity measurements to address the needs of this GMM study.

- d. L. Salomone provided the status report for this field program to obtain shear wave velocity measurements. L. Salomone also provided the status in an email to R.
 Williams of the USGS on May 24, 2012.
- e. Stokoe completed shear wave velocity measurements at 11 recording stations
- f. GeoVision mobilized to the field on May 23, 2012. The target date to receive the GeoVision-Stokoe shear wave velocity profiles is on or before the end of July 2012.
- 5. Summary of EPRI (2004) study
 - a. G. Toro presented a summary of the study. This led to some interesting discussions, as follows:
 - J. Ake: Agrees that EPRI (2004, 2006) needs to be re-assessed. However, be cautious of "Replacement" vs. "Revision" in new NUREG-2117 SSHAC Guidance. Revision would mean re-evaluating with same EPRI (2004, 2006) GMM structure while updating with new data, models and methods. Replacement requires SSHAC Level III.
 - W. Arabasz: This caution may be too much of a constraint for this project. This is the first time the community is going through the process of revising a SSHAC study as per NUREG-2117 Guidelines, so it may be advisable to provide some latitude in how these un-tested guidelines are followed.
 - iii. C. Stepp: If a revised EPRI (2004, 2006) GMM is necessary, the approach used to develop the revised GMM should provide a high level of assurance that risk results do not need to be redone when NGA-East GMPEs are available.
 - iv. McGuire: EPRI (2004) within-cluster weighting scheme may give excessive weights to groups of GMPEs that differ slightly from each other.
 - v. All: Weights to clusters and/or models may have to be frequency-magnitudedistance dependent; otherwise some large misfits may occur
 - vi. N. Abrahamson: Suggests that the concept of clusters be abandoned and individual GMPEs be judged by TI Team's confidence that GMPE is a good extrapolator to the M-R range of interest
- 6. Kappa Presentation by L. Al Atik
 - a. Works with kappa_1: kappa slope associated with distances of 5-25 km (includes some anelastic effects, as well as kappa_0). Will call it kappa for brevity.
 - b. Host kappa determined from GMPES \rightarrow Sa \rightarrow Fourier spectra \rightarrow slope in 5-20 Hz \rightarrow kappa. There is also an empirical approach.

- c. Target kappa: determined from recordings as in PEGASOS 2 or from Vs30
- d. Apply kappa effect in frequency domain, and then convert to Sa using RVT.
- e. <u>Important Finding and Conclusion</u>: kappa corrections in traditional method (calculated on the basis of Sa ratios) over-estimate the effect of kappa. As a result, high frequencies in EPRI (2004) hybrid GMPEs may be too high. EPRI (2004) overestimates ground motions in high frequency range.
- 7. EPRI (2006) sigma model: Presentation by N. Abrahamson
 - a. EPRI (2006) used preliminary NGA1 sigmas
 - b. Checked whether there are CEUS-WUS differences in sigma
 - i. examined differences in within-event (phi) using simulations: found none
 - ii. examined differences in between-event (tau) using teleseismic source durations: found none
 - c. Checked for larger sigmas at short distances (due to depth): found no effect in NGA database
 - d. Other issue: hard rock sigmas from West may not be representative of CEUS sigmas
 - e. Use new 2008 NGA sigma models
 - i. AS08, CY08: magnitude-dependent
 - ii. BA08, CB08: magnitude-independent
 - f. Alternative: use SRSS of sigma_ss (single station; stable from region to region) and CEUS phi_s2s (station-to-station term)
 - g. Some of these results show a strong magnitude dependence (which may be caused by bad metadata) and which may distort the deaggregation.
- 8. Proposed Approach to Task 4: G. Toro
 - a. Key issues:
 - i. Site-response correction: Use ¼ wavelength approach: needs profile, kappa, Fourier amplitude of record; will compute uncertainty for typical sites
 - ii. Cluster weights: may need to be re-evaluated to consider models that have been superseded, new models, different perspectives regarding assessment of weights (see EPRI (2004) summary above)
 - iii. Assignment of weights to data according to their significance in M-R space, within-event correlation, uncertainty in correction, etc.
 - b. Alternative approaches for Task 4
 - i. Repeat EPRI (2004) approach with new data and models: uses accepted procedure
 - ii. Bayesian updating using EPRI (2004) clusters (with their medians and sigma_mu's) as a starting point: more rigorous

- iii. Simple (ad-hoc) comparison of residuals (selected as approach for Task 4)
- c. Decision Point 2 Open Issues:
 - i. Need to translate from ground-motion to hazard space (use CEUS-SSC deaggregation results and typical hazard-curve slopes)
 - ii. Apply CEUS-SSC Sect. 9-4 criteria? Adjust for risk-benefit considerations (generic vs. site-specific)?
 - iii. How to apply at different frequencies?
- 9. Comments from Participants
 - a. J. Ake
 - i. Comments provided as a resource expert and Observer
 - ii. Do not use EPRI (2004, 2006) process "blindly".
 - iii. Critical issues captured by last couple of slides in G. Toro presentation
 - iv. Be aware of "Revision" vs. "Replacement" issue
 - v. Bayesian approach: creative, less ad-hoc; needs to be carefully thought-out, and there needs to be substantial documentation because it is new in this context
 - vi. Interesting problem; look at different frequencies; EPRI (2004, 2006) would be expected to fail for certain frequencies
 - vii. Spectral shape is important for fragility
 - b. B. Whorton: Participation in WM#3 was very helpful; will follow project closely from now on.
 - c. C. Stepp
 - i. Concerned about Bayesian: new direction that will require quite a bit of thought ;may cause a hurdle
 - ii. Ad-hoc comparison chosen by TI Team while discussing Stepp's comments
 - d. W. Arabasz
 - i. Project Plan still not totally clear about how TI Team will contact broader technical community in a structured, systematic way. Need to engage ITC and document the process
 - ii. Project Plan is good enough after editorial corrections to publish.
 - iii. "Revision" vs. "Replacement" represents new ground; discuss methodology changes with NRC at an early stage to avoid late surprises
 - iv. Establish date for workshop
 - e. B. Chiou
 - i. Sees project as a technical advance
 - ii. Concerned about regulatory constraints (i.e., "Revision" vs. "Replacement"); would like to see more flexibility

- f. R. McGuire Plot GMM data with site corrections: assess old model and new ground motion prediction equations
- g. L. Salomone Stay focused on the division between Task 4 (Phase 1) and Task 5 (Phase 2) as appropriate. Keep Decision Point 2 simple and focused and be mindful of losing focus on pursuing research.
- h. C. Mueller- USGS is fully engaged at this time conducting five (5) workshops for the USGS National Seismic Hazard Mapping Project.
- 10. Action Items:
 - a. Toro:
 - i. Confirm magnitude of 8/25/2011 VA aftershock. 4.5? 3.9?
 - ii. Prepare template for questions to Proponent and Resource Expert interviews
 - b. Salomone
 - i. Confirm workshop dates with Mark Petersen.
 - ii. Coordinate with Yousef Bozorgnia to obtain NGA East data (raw and processed time histories, fourier spectra, profile data for stations with known Vs30.
 - iii. Finalize project plan including feedback from W. Arabasz received on May 24, 2012.
 - iv. Distribute supporting documentation to the project team, as required
 - c. Chapman
 - i. Complete Assessment of VA aftershock data on or before the end of July 2012.
 - d. TI Team: Task 2 literature reviews and contacts with Experts (due June 27: WM4)
- 11. Attachments:
- Agenda
- PM (L.Salomone) Presentation
- TI Team Chairman (G. Toro) Presentations (3)
- Task 2 List of Papers for Review
- Task 2 Literature Review Form
- TI Team Member (M. Chapman) Presentation (Word File)
- Resource Expert (L. Al Atik) Presentation
- Resource Expert and Observer (N. Abrahamson) Presentation

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Proposed Agenda EPRI (2004, 2006) GMM Review Project Working Meeting #3

Lettis Consultants International 1981 N. Broadway, Suite 330 Walnut Creek, CA 94596 Main Conference Room

8:30AM to 4:00PM (PDT) 11:30 AM to 7:00 PM (EDT)

May 24, 2012

GOALS OF THE MEETING

- Review status of the Project Plan and PPRP and NRC Project Plan feedback
- Review Status of Task 2: Obtain Ground-Motion Database and Identify New CEUS Ground Motion Prediction Equations (GMPEs);
- Review Status and Schedule for Task 3: Obtain Shear Wave Velocity Measurements at Recording Stations;
- Discuss EPRI (2004, 2006) GMM and its Development
- Discuss Approach for Task 4: Test EPRI (2004, 2006) Ground Motion Model (GMM);
- Review Project Schedule, Table 7-1 in Project Plan, and Discuss Path Forward

APPROACH: The focus of the meeting will be a roundtable discussion to achieve the goals of the meeting. I ask that the leads shown in the agenda be prepared to brief the participants on their topics. If you are not attending in person, I would appreciate your calling-in at the time noted in the agenda for your topics. It will be a roundtable discussion. Therefore, slides are desirable, but they can be considered optional.

We will provide a call-in number and instructions to participate in the webinar for those invited participants who cannot attend in person. For those in government facilities, the government firewall may require government participants to view the webinar outside the government facility. Please call Serkan Bozkurt at 1-510-364-9199 for any questions regarding the webinar instructions.

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Proposed Agenda

Time (PDT)	Торіс	Lead
8:30-9:15	Welcome, Opening Remarks and Project Plan Highlights	L. Salomone
9:15-10:15	Status of Task 2: NGA-East Database and new GMPEs	G. Toro, All
10:15-10:30	Break	
10:30-11:30	Data from Mineral VA aftershocks, discussion on how to use these data in project	M. Chapman, All
11:30-12:00	Update on Task 3	L. Salomone/R.
	Project Shear Wave Velocity Measurements	Williams
	USGS Shear Wave Velocity Measurements	
12:00-1:00	Lunch	
1:00-1:30	Approaches for the estimation of kappa and for kappa	N. Abrahamson/L.
	adjustments to GMPEs	Al Atik
1:30-2:00	Overview of EPRI (2004, 2006) model and its development	G. Toro/ N.
	• EPRI (2004) (G. Toro)	Abrahamson
	• EPRI (2006) Sigma Refinement (N. Abrahamson)	
2:00-3:00	Proposed Approach for Task 4: Test EPRI (2004, 2006) Ground Motion Model (GMM)	G. Toro, All
3:00-3:30	PPRP and NRC Feedback	W. Arabasz; C.
		Munson
3:30-4:00	General discussion	All
	 USGS National Seismic Hazard Mapping Project Update (C. Mueller) 	
	• Planning for Upcoming Tasks (G. Toro)	
	• Path Forward (L.Salomone)	
4:00	Adjourn	

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EPEI ELECTRIC POWER RESEARCH INSTITUTE

EPRI (2004,2006) Ground Motion Model (GMM) Review Project Status and Highlights from Project Plan

Working Meeting #3 May 24, 2012

Lawrence Salomone Project Manager

CONTEXT OF THE STUDY

- Chapter 6 of NUREG-2117 (2012) notes that the end action of updating an existing hazard study is either to *replace (completely set aside), revise (modify),* or *refine (incorporate site-specific into)* the existing study.
- The CEUS SSC Project (new earthquake source model) *replaced* the EPRI-SOG (1986) source model.
- The NGA-East Project, now in progress, will *replace* the EPRI (2004, 2006) Ground Motion Model (GMM).
- The EPRI (2004, 2006) GMM Review Project will review and revise, if appropriate, using new data, models and methods, the EPRI (2004, 2006) GMM to calculate ground motion response spectra (GMRS) by September 2013.
- The NGA-East GMM will be considered the appropriate model for future characterization of CEUS seismic hazards once the NGA-East GMM becomes available.







Background:

- The EPRI (2004, 2006) Ground Motion Model (GMM) Review Project will provide industry information necessary specifically for an informed response to the NRC Request for Information (RFI) to Title 10 of the Code of Federal Regulation 50.54(f) Recommendation 2.1 of the Near-Term Task Force (NTTF) Review of Insights from the Fukushima Dai-Ichi Accident dated March 12, 2012.
- The project will provide information for developing site-specific ground motion response spectra (GMRS) for existing nuclear power plant sites and other seismic regulatory issues pending completion of the NGA-East Ground Motion Model.
- <u>The industry position is to review and, if necessary, update the EPRI (2004, 2006)</u> <u>GMM:</u> This position is prudent in light of guidance in NUREG-2117 (2012), input from ground motion experts and seismologists contacted from October 2011 to March 2012 and new data, models and methods that have become available since the SSHAC Level 3 EPRI (2004) workshops were held in 2002.

Purposes:

- Review and Update, if appropriate, the EPRI (2004, 2006) GMM for the need of calculating GMRS for existing nuclear power plant sites in response to the NRC RFI of the NTTF recommendation for seismic using an approach that can be accepted by the NRC
- Increase the accuracy of input to compute ground motion response spectra (GMRS) required in NTTF Recommendation 2.1 for seismic





INDUSTRY DUE DILIGENCE

Contact Type	Date	Participants
Conference Call	November 8, 2011	G. Atkinson, J. Bailess, J. Hamel, R. Kassawara, K. Keithline, J. Marrone, S. McDuffie, R. McGuire, M. Petersen, L. Salomone, J.C. Stepp, G. Toro, B. Youngs,
Interviews	October 26, 2011	N. Abrahamson
	November 2, 2011	M. McCann
	November 3, 2011	W. Silva
Meeting	November 30, 2011	A. Frankel, C. Goulet, R. McGuire, M. Moschetti, C. Mueller, M. Petersen, S. Rezaeian, L. Salomone, J.C. Stepp, G. Toro,
Conference Call –Project "Kickoff" Call	March 8, 2012	N. Abrahamson, J. Ake, W. Arabasz, S. Bozkurt, M. Chapman, J. Hamel, R. Kassawara, J. Kimball, R. McGuire, C. Mueller, C. Munson, R. Quittmeyer, L. Salomone, J.C. Stepp,

HIGHLIGHTS FROM DUE DILIGENCE CONTACTS

 EPRI (2004) GMM workshops in 2002; sigma component updated beginning in 2005;

100 A.

- New CENA Ground Motion Database available;
- New Ground Motion Prediction Equations (GMPEs) available since 2002
 - Atkinson, 2004a, 2004, 2008; Atkinson and Boore, 2006, 2011; Atkinson and Kraeva, 2010; Atkinson and Morrison, 2009; Atkinson et al, 2007, 2011; Boatwright and Seekins, 2011; Boore et al, 2010; Boore, 2012; Campbell, 2004, 2009; Pezesch et al, 2011; Sonley and Atkinson, 2006; Tavakoli and Pezesch, 2005; Zandich and Pezesch, 2010.
- New significant earthquakes since 2002 (e.g.,2011 M 5.8 Mineral VA earthquake; 2011 M 5.6 Sparks OK; 2010 M 5.0 Val des Bois Quebec; 2008 M 5.3 Mt. Carmel IL.)
- One hybrid GMPE in EPRI (2004, 2006) GMM has unphysical behavior at long distances
- Should take into account that some GMPEs do better in certain magnitude distance ranges;
- Modification of existing four (4) clusters may be necessary to account for new information, new models, and new data;
- Calculation of sigma should take into account large datasets from other regions and new insights on sigma; new information may result in different sigma for small and large magnitude earthquakes;
- Correlations between ground motion parameters need to be considered.



NGA-EAST DATABASE

- Data and metadata from earthquakes in CENA including some recent earthquakes:
 - M4 and greater with any records within 1000km
 - M2.5 to M4 with five or more recordings within 100km
- Number of records is nearly 28,000
- Each record has a flag indicating its quality
- Includes notable earthquakes not in EPRI (2004) study:
 - 2008 M5.3 Mt. Carmel, IL
 - 2010 M5.0 Val des Bois, Quebec
 - 2011 M5.8 Mineral Va earthquake (about 300 recordings) and one M4.5 aftershock
 - 2011 M5.6 Sparks Oklahoma
- Eighty Percent (80%) of the records are from earthquakes that occurred since 2004



MAGNITUDE-DISTANCE PLOT – NGA-EAST



Recording Stations:

Locations for Shear Wave Velocity Measurements

Proposed Recording Stations for Shear Wave Velocity Measurements



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Project Plan: FLOW CHART



Project Plan: Flow Chart (continued)



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TASK 4: Test EPRI (2004, 2006) Ground Motion Model

- 1. Initial Steps
 - Evaluate new GMPEs and other relevant publications
 - Correct ground-motion data with site condition information to reference rock (2,800 m/s) & estimate uncertainty in correction
- 2. Assign new models to EPRI (2004) clusters, add new clusters, if necessary, and assess new cluster weights
- 3. Use corrected data to calculate weights to models in each cluster, and calculate new cluster medians
- 4. Calculate new medians and epistemic uncertainties for use in Decision Point 2



TASK 5: Revise EPRI (2004, 2006) Ground Motion Model

- 1. Evaluate within-cluster epistemic uncertainty
 - model-to-model differences
 - parametric uncertainty (take correlations into account)
- 2. Consistency check against corrected data (and adjust, if necessary)
- 3. Develop parametric GMPEs for PSHA (for Midcontinent and Gulf, 9 frequencies)
- 4. Consider modifying EPRI (2006) model for sigma following EPRI (2006) approach
 - Consider new publications on sigma
 - Consider new data from other regions

Decision Point Criteria

- <u>Decision Point 1</u>: The criterion to be applied at Decision Point 1 is whether this Project Plan is endorsed by the Project Team, PPRP, and Sponsor, after considering feedback by the NRC.
- **Decision Point 2:** The criteria for Decision Point 2 are:
 - Are there significant changes in hazard due to changes in the amplitude and epistemic uncertainty of ground motions relative to the EPRI (2004, 2006) GMM, as a result of considering new data, models and methods?
 - The criterion will be applied for all frequency-magnitude-distance combinations of interest for CEUS hazard calculations, but those combinations of marginal interest will be given reduced weight in the decision.
 - Section 9.4 of CEUS SSC Report (2012) provides guidance on what differences in hazard are considered significant. This guidance, suitably modified so it accounts for the differences between site-specific and generic issues, may be useful in applying these criteria.





Decision Point Criteria (continued)

- <u>Decision Point 3:</u> The criterion for Decision Point 3 is: In the judgment of the TI Team--with feedback from the PPRP, NRC, and Workshop Resource and Proponent Experts --does the EPRI (2013) GMM represent the center, body, and range of the Technically Defensible Interpretations (TDI) for ground motions in the CEUS, taking into account the existing data, models, and methods?
- This criterion will be applied for all frequency-magnitude-distance combinations of interest for CEUS hazard calculations, but those combinations of marginal interest will be given reduced weight in the decision.
- If the Decision Point 3 criterion is met, recommend the EPRI (2013) GMM for use to calculate GMRS at existing nuclear power plant sites.



Work Plan and Schedule Showing Target Dates

• PHASE 1

- Task 1: Project Plan (April 2012)
 - Decision Point 1 May 2012
- Task 2: Obtain GM Database and Identify New GMPEs (July 2012)
- Task 3: Obtain Shear Wave Velocity Measurements (July 2012)
- Task 4: Test EPRI (2004, 2006) GMM (August 2012)
 Decision Point 2 August 2012



Work Plan and Schedule (continued)

• PHASE 2

- Task 5: Update the EPRI (2004, 2006) GMM (October 2012)
- Task 6: Interaction with Technical Community at USGS Workshop (October 2012)
- Task 7: Calculate Seismic Hazard at Seven (7) Test Sites (December 2012)
- Task 8: Finalize EPRI (2013) GMM (February 2013)
 - Decision Point 3 February 2013
- Tasks 9-11: Document Project in Report (January – March 2013)
- Task 12: Issue EPRI (2004, 2006) GMM Review Project (April 2013)



Important Industry Milestone

Complete GMRS Calculations (September 2013)

See.



Status and What's Next in Short-Term

- Incorporate NRC comments into Project Plan (Completed May 7, 2012)
- Working Meetings:
 - Working Meeting #1 (Conference Call) (Completed March 8, 2012)
 - Working Meeting #2 (Completed April 26, 2012)
 - Working Meeting #3 (May 24, 2012)
 - Working Meeting #4 (June 27, 2012)
- Publish EPRI (2004, 2006) GMM Review Project Plan as EPRI Technical Update (May 2012)
- Begin Shear Wave Velocity Measurements at Recording Stations (May 2012)
- Obtain NGA-East Ground Motion Database (Version 2.2) from NGA-East Project (Completed)
- Identify Ground Motion Prediction Equations (GMPEs) developed after 2002 (In progress)

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Status of Task 2: NGA-East Database and Compilations of New GMPEs

EPRI (2004, 2006) GMM Review Project Working Meeting #3 LCI, Walnut Creek 5/25/2012

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Topics

- NGA-East Database
 - What data we have to work with
 - Issues
- GMPEs and Other Publications since EPRI (2004)
 - Initial list of publications
 - Review Form
 - Assignments & Tracking milestones
- General discussion of Task 2

NGA-East Database

- Flat File: Excel File containing everything one needs to compare to GMPEs, fit models, etc.
 - Fields: event, magnitude, lat, lon, station, lat, lon, Vs30 (if known), distance, component, data quality, all spectral accelerations within "good" frequency band (as is component)
- Event Table: more info. For each earthquake: Depth, Strike, Dip, Rake, etc.
- Station-Component Table: Info in flat file + geological description & geol. data source

NGA-East Database (2)

- NGA-East Selection Criteria:
 - M4 and greater with any recordings within 1000km
 - M2.5 to M4 with five or more recordings within 100km
- Number of records is nearly 28,000
- Each record has a flag indicating its quality
- Notable earthquakes not in EPRI (2004) study:
 - 2008 M5.3 Mt. Carmel, IL (9-1500 km)
 - 2010 M5.0 Val des Bois, Quebec (45-2500 km)
 - 2011 M5.8 Mineral VA mainshock (48-2600 km; about 300 recordings)
 - 2011 M4.5 8/25 Mineral VA M4.5 aftershock (9-990 km)
 - 2011 M5.6 Sparks Oklahoma (40-2000 km)
- Eighty Percent (80%) of the records are from earthquakes that occurred since 2004



EPRI (2004):







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NGA-East Data

		Distance (km)						
		<10	10-20	20-50	50-100	100-200	200-500	500-1000
Magnitude	3-3.99	10	22	54	53	142	541	713
	4-4.99	17	12	54	93	195	1093	1849
	5-5.99	2	1	10	22	34	227	377
	>=6	2	1	1	0	0	0	0

Notes: good quality records only, H only, 2H counted as one record (preliminary values)

Quality of Recordings

- Quality Designation
- A: good
- Others: clipped, noisy, radiation pattern node, etc.

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Example of Possible problem: CBN record from Mineral VA Mainshock ("A" quality)





Ideally, would like to have time histories from NGA-East database to check records showing unusual residuals or spectral shapes





Ideally, would like to have the profiles that were used to derive VS30 in NGA-East database (db has Vs30, depth, and investigation method)

Status of NGA-East db QA

- Re-examining (and re-processing?) all records
- Issues
 - Minor tweaking of bandpass filters
 - Need to redefine time windowing of records (some are very long)
- No significant changes in spectral accelerations are anticipated (OK to use NGA-East database)

Source: C. Goulet (PEER), personal communications

GMPEs and Other Relevan Publications Since 2004

- Identified 18 publications containing GMPEs and other relevant studies relevant to amplitude
 - Assigned to TI Team members for review (Part of Task 4; need to agree on a schedule; "Tracking Milstones")
- There are also ~4 publications regarding sigma (lower priority; sigma will be considered in Task 5)



To do (task 2)

- Contact key investigators and collect additional references/insights (May 2012)
 - Abrahamson (also as proxy for NGA-East)
 - Atkinson
 - Boore
 - Boatwright
 - Campbell
 - Cramer
 - Herrmann
 - Pezesch



Question to All:

- Any additions to list of papers?
- Any addition to list of people to contact?



Citation	Short summary (~1-2 paragraphs)	Key Model Assumptions	Data Used	Assessment of Technical Value for this Project
	short summary (1 2 paragraphsy			
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Questions?

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Summary of EPRI (2004) Study

EPRI (2004, 2006) GMM Review Project Working Meeting #3 LCI, Walnut Creek 5/25/2012

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Regionalization Followed EPRI (1993)









Identified 13 Existing

Model & Grouped into Clusters

- 1 Single Corner Stochastic
- Double Corner Stochastic
- 3 Hybrid
- 4 Finite source / Greens Function

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Cluster	Model Type	Models
а а а а а Шана и анысти. В	a 1,18 i a 11 i a 10 12 i 1131- 0 22 ^{998 ¹⁰ 7}	
1	Single Corner	Hwang and Huo (1997)
	Stochastic	Silva et al (2002) - SC-CS
el _{um} el cita evera i	ist taking in the state of the	Silva et al (2002) - SC-CS-Sat
		Silva et al (2002) - SC-VS
		Toro et al (1997)
		Frankel et al (1996)
2	Double Corner	Atkinson and Boore (1995)
	Stochastic	Silva et al (2002) DC
	2 2	Silva et al (2002) DC - Sat
3	Hybrid	Abrahamon & Silva (2002)
		Atkinson (2001) & Sadigh et al (1997)
8 a a 1		Campbell (2003)
4	Finite Source	Somerville et al. (2001)
1 .	/Greens Function	



EUS Data Used for Model Evaluations

No.	Date	Earthquake	M
1	3/1/1925	Charlevoix, Quebec, CAN	6.4
2	11/1/1935	Timiskaming, CAN	6.2
3	9/5/1944	Cornwall (CAN) - Massena, NY	5.8
4	3/25/1976	New Madrid, MO	4.6
5	1/19/1982	Franklin Falls, NH	4.3
6	3/31/1982	New Brunswick (A13)	4.0
7	10/7/1983	Goodnow, NY	5.0
8	11/9/1985	Nahani, CAN (F1)	4.6
9	12/23/1985	Nahani, CAN	6.7
10	12/25/1985	Nahani, CAN (A1)	5.0
11	1/31/1986	Painesville, OH	4.8
12	7/12/1986.*	St. Marys, OH	'4.5
13	11/23/1988	Saguenay, CAN (F1)	4.2
14	11/25/1988	Saguenay, CAN	5.8
15	4/27/1989	New Madrid, MO	4.7
16	9/26/1990	Cape Girardeau	4.7
17	10/19/1990	Mount-Laurier Quebec, CAN	4.5
18	5/4/1991	New Madrid, MO	4.4
19	1/1/2000	Temiscamingue Region, Quebec, CAN	4.7
20	4/20/2002	Au Sable Forks, NY	5.0







Model Type	Models	Weights
a a a a a a a a a		
Single Corner	Hwang & Huo (1997)	0.037
Stochastic	Silva et al (2002) - SC-CS	0.192
	Silva et al (2002) - SC-CS-Sat	0.148
ana	Silva et al (2002) - SC-VS	0.560
	Toro et al (1997)	0.029
a dia dia dia 1975 Dia dia ben'ny ¹⁹ 4	Frankel et al (1996)	0.034
Double Corner	Atkinson & Boore (1995)	0.714
Stochastic	Silva et al (2002) DC	0.154
	Silva et al (2002) DC - Sat	0.132
Hybrid	Abrahamon & Silva (2002)	0.336
2	Atkinson (2001) & Sadigh et al (1997)	0.363
	Campbell (2003)	0.301
Finite Source /Greens Function	Somerville et al. (2001)	1.0
	Model Type Single Corner Stochastic Double Corner Stochastic Hybrid Finite Source /Greens Function	Model TypeModelsSingle Corner StochasticHwang & Huo (1997)Silva et al (2002) - SC-CS Silva et al (2002) - SC-CS-Sat Silva et al (2002) - SC-VS Toro et al (1997)Double Corner StochasticAtkinson & Boore (1995)Double Corner StochasticSilva et al (2002) DC Silva et al (2002) DC - SatHybridAbrahamon & Silva (2002) Atkinson (2001) & Sadigh et al (1997) Campbell (2003)Finite Source /Greens FunctionSomerville et al. (2001)

Charactereization of Eac



cluster

Using GMPEs and their weights

- Median model
- Epistemic uncertainty
 - Model to model
 - Parametric (computed separately)

Discretization of epistemic uncertainty→3 branches



Cluster Evaluation

- Consistency of the cluster median with CEUS ground motion data
- Strength of the seismological principles used in the model development
- Degree to which modeling of epistemic uncertainty was considered in developing individual ground motion models



Consistency with CEUS Data

(Weights inversely proportional to variance)

Cluster	Relative Weight
Single Corner Stochastic	0.3639
Double Corner Stochastic	0.5869
Hybrid	0.0135
Finite Source /Greens Function	0.0357





	Importance		
	0.25	0.75	
Cluster	Consistency with data	Seismological Principles/	Composite Weight
		Uncertainty	
1	0.3639	0.245	0.275
2	0.5869	0.221	0.312
3	0.0135	0.257	0.196
4	0.0357	0.277	0.217

Logic Tree





Figure 3-7 Logic Tree Illustrating the CEUS Ground Motion |



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Questions?

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Plans for Task 4: Testing of EPRI (2004, 2006) Model

EPRI (2004, 2006) GMM Review Project Working Meeting #3 LCI, Walnut Creek 5/25/2012

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Topics

- Proposed approach for incorporation of new models and data
 - Key issues
 - Alternative approach
- Decision Point 2
 - Discussion of criteria

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Task 4: Need to Answer Questions:

- How would we go through EPRI 2004 exercise if we had the publications and data that we have now, in addition to what TI team had in 2003-2004
 - a. Is there anything in new model formulations that causes us to re-think the definition of clusters and weight to clusters?
 - b. Is there anything in new data that causes us to re-think the calculated values of the cluster medians and within-cluster epistemic uncertainty?

→Net effect of a and b; is it significant?

Task 4: Approach parallel to EPRI (2004)

- 1. Initial Steps
 - Evaluate new GMPEs and other relevant publications
 - Correct ground-motion data with site condition information to reference rock (2,800 m/s) & estimate uncertainty in correction*
- 2. Assign new models to EPRI (2004) clusters, add new clusters if necessary, and assess new cluster weights**
- 3. Use corrected data to calculate weights to models in each cluster, and calculate new cluster medians***
- 4. Calculate new medians and epistemic uncertainties for use in Decision Point 2

* ** ***Details on next slides



Correction for Site Effects

- Approach: Quarter-wavelength (Joyner & Boore)
- Required inputs:
 - Vs profile (not just Vs30; may need generic profile shapes to extend profile)
 - Kappa: used estimates based on Vs (Van Houtte? Others?)
- Need to quantify uncertainty due to:
 - Imperfect knowledge of site profile
 - Approach for site-response calculation

Problem: approach works with FA, not with Sa (need NGA-East FA or need to do IRVT for each record)



****** Cluster Weights

- EPRI (2004):
 - Consistency with "seismological principles" & treatment of epistemic uncertainty
 - consistency with data (weak effect)
- Alternative Approach:
 - Use TI Team's confidence that the GMPEs within a cluster constitute robust tools to extrapolate the existing data to the magnitude-distance range of engineering interest. Suggested by Norm; being considered by the NGA-East project.
 - consistency with data
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** Issues to Consider in Step 3

- Within-earthquake correlation (done by EPRI (2004)
- Uncertainty in site response (our converted rock data contain measurement error because correction not exact)
- Give different weights to data in different magnitudedistance ranges (distant or low-magnitude data tell us less about the model behavior in the M-R range of interest*)
 - Related issue: extrapolated GMPEs usually overestimate low-M motions
- Mathematical details of approach for comparisons (EPRI vs Scherbaum)
- How to weight comparisons at different frequencies
 *M-R range of interest is frequency-dependent



Table 3-5Ground Motion Attenuation Model Weights in Each Cluster

Cluster No.	Model Type	Models	Weights ¹
1	Spectral, Single Corner	Hwang & Huo (1997)	0.037
		Silva et al. (2002) – SC-CS	
		Silva et al. (2002) – SC-CS-S	0.148
		Silva et al. (2002) - SC-VS1	0.560
		Toro et al. (1997)	0.029
		Frankel et al. (1996)	0.034
2	Spectral, Double Corner	Atkinson & Boore (1995)	0.714
		Silva et al. (2002) DC	0.154
		Silva et al. (2002) DC-S	0.132
3	Hybrid	Abrahamson & Silva (2002)	0.336
		Atkinson (2001) & Sadigh et al. (1997)	0.363
		Campbel/ (2003)	0.301
4	Finite Source/Greens Function	Somerville et al. (2001) ¹	1.0

'The model weights have been rounded to three decimal places.

Alternative: Bayesian Approact

- 1. Prior Distribution: EPRI (2004) clusters (including cluster weights and within-cluster epistemic uncertainty
- 2. Subjectively Modified Prior: EPRI (2004) clusters and clusters built using new models (new weights)
- 3. Bayesian update: Multiply prior from step 2 by likelihood function constructed from **new** ground motion data added since EPRI (2004).

Advantage: shows the effects of new models and new data separately and in a very transparent manner.

Disadvantages/Problems of Bayesian

- How to re-distribute weights (step 2) to old and new clusters has a subjective element (unavoidable in both approaches)
- How to estimate within-cluster uncertainty for new clusters? (Possible approach is to obtain an initial estimate based on the uncertainty in the EPRI (2004) clusters, present this estimate to the GMPE authors, and then adjust it based on their feedback.
- Data being used twice (for new models, for likelihood)

Other Issues

- Should weights be frequency-dependent?
 - Weights to models within cluster
 - Weights to clusters

Book-keeping difficulties if frequency-dependent

- If data show that a model or cluster is clearly deficient for a certain frequency-M-R range but good in other ranges, is it permissible to modify it?
 - Old "Weight on models vs. weight on values" issue
 - SSHAC GM elicitation consistent with "weight on values"
 - Many on-going SSHAC Level 3 moving in same direction

Quotes re. "Models vs. Values" Issue

"Civilization advances by extending the number of important operations which we can perform without thinking about them."

Alfred North Whitehead





Issues (cont'd)

Which data to use?

- Initial plan: use data from stations for which we have Task-3 or recent USGS measurements
- Use additional data?
 - Stations for which NGA-East has Vs30 (>43 stations; exclude deep soils)
 - Some stations for which indirect methods may work decently (e.g., Silva-Thmphson-Magistrale NGA East work)







Decision Point 2

- <u>Criterion</u>:
 - Do the changes in median ground-motion amplitude and epistemic uncertainty introduce significant changes in hazard?
 - Criterion is in terms of hazard, needs to consider typical slope of hazard curves
 - Criterion will be applied for all frequency-magnitude-distance combinations of interest for CEUS hazard calculations.
 - Section 9.4 of CEUS SSC Report (2012) provides guidance on what differences in hazard are considered significant.
 - Guidance applies to site-specific issues; how to modify for a generic issue?



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CEUS-SSC Sect. 9-4*

"...If an alternative assumption or parameter is used in a seismic hazard study, and it potentially changes the calculated mean hazard by less than $\pm 25\%$ ($\pm 35\%$) for ground motions corresponding to 1E-4 (1E-6) annual frequency of exceedance, then that potential change is less than the best (highest) level of precision with which we can calculate mean seismic hazard..."

*slight paraphrase



CEUS-SSC Sect. 9.4 (same paragraph)

"... Note that regulators addressing the impacts of potential changes in seismic hazard on seismic design motions or on seismic risk-related decisions may (appropriately) require action even if potential changes are less than the guidelines given above."

Issues

- Translate criterion from site-specific to generic
- What if differences are large at one frequency and small at others?

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Issues (2):

- Criterion is in term of hazards
- Can be translated to GM space if hazard is dominated by one "scenario"
 - Consider slope of hazard curves
 - Can include effect of sigma_mu
 - Easy to implement for HF; more complicated for LF and for sites where Charleston or NM are important at HF



Questions?

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Citation	Reference	Assigned		
		to		
Atkinson,	Atkinson, Gail M. 2004a. "Empirical Attenuation of Ground- Motion Spectral Amplitudes in Southeastern Canada and the			
2004a				
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EPRI (2004, 2006) Review Project - Proposed Review Form

Reviews by _____

Citation	Short summary (~1-2 paragraphs)	Key Model Assumptions	Data Used	Assessment of Technical Value for this Project
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Map showing locations of aftershock deployment. Blue stations are the AIDA profile stations (IRIS-Virginia Tech-Cornell), Black triangles are XY network (Virginia Tech), Black squares are YC network (IRIS). Red star shows location of one of about 30 well-recorded events on the AIDA profile.

1



Time (seconds)

2

Vertical component (acceleration) recordings of the 16:54, Sept. 5, 2011 UTC aftershock recorded by the AIDA profiles stations



Acceleration recorded at AIDA profile station 3120 at 3.8 km from the epicenter of the 16:54, Sept. 5, 2011 UTC aftershock. (Right) Acceleration recorded at station 3510, 42.6 km from the epicenter.



(Left) Fourier amplitude spectra of the S wave and pre-P wave noise at AIDA profile station 3120. (Right) station 3510. Note the large signal/noise ratio at the more distant station. Also note the well-resolved source corner frequency at approximately 8 Hz.

3







Acceleration filtered in 8-16 Hz band (geom. mean, horizontal). Black AIDA profile stations, red XY stations, Green YC stations.

4-8 Hz, gm h1h2



Acceleration filtered in 8-16 Hz band (geom. mean, horizontal). Black AIDA profile stations, red XY stations, Green YC stations.

2-4hz gm h1 h2



Acceleration filtered in 2-4 Hz band (geom. mean, horizontal). Black AIDA profile stations, red XY stations, Green YC stations.