National Institute of
BUILDING SCIENCES

Building Seismic Safety Council

Project 17 Workshop on Seismic Hazard Mapping

April 11, 2017, Burlingame, CA

PROCEEDINGS

An Authoritative Source of Innovative Solutions for the Built Environment

Project 17 Workshop on Seismic Hazard Mapping

April 11, 2017

Organized by

National Institute of Building Sciences Building Seismic Safety Council Project 17 Committee

Sponsored by

Federal Emergency Management Agency
in coordination with the
U.S. Geological Survey

National Institute of BUILDING SCIENCES

An Authoritative Source of Innovative Solutions for the Built Environment

Building Seismic Safety Council

Project 17

PROCEEDINGS OF THE PROJECT 17 WORKSHOP ON SEISMIC HAZARD MAPPING

April 11, 2017

The workshop proceedings are prepared by the Building Seismic Safety Council (BSSC) of National Institute of Building Sciences (Institute) for Federal Emergency Management Agency's National Earthquake Hazards Reduction Program (NEHRP) per FEMA contract HSFE60-D-15-0022 task order HSFE6016J0228.

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Table of Contents

PREFACE

The Project 17 Workshop on Seismic Hazard Mapping was organized and presented by the Project 17 Committee of BSSC at the Institute. The workshop was sponsored by the Federal Emergency Management Agency (FEMA)'s National Earthquake Hazards Reduction Program (NEHRP) in coordination with the US Geological Survey (USGS). The purpose of the workshop was to critic on some options to solve critical issues related to seismic design value maps, and seek input on important issues related to development of the next generation of seismic design value maps from structural engineers, building officials, and members of the earthquake community.

The workshop was established at the Project 17 Committee meeting held in Burlingame, CA on November 28, 2016. The BSSC announced the workshop to its members and member organizations in December, 2016, followed by release of a technical background paper in March, 2017.

The workshop was held on April 11, 2017 at Burlingame, CA with 62 participants. In the workshop's morning session, Project 17 Committee Chair, Ron Hamburger, presented an overview and history of the seismic design value maps, followed by a presentation on USGS national seismic hazard model by Nicolas Luco, and presentations on acceptable risk and seismic design categories by Robert Pekelnicky and Julie Furr, respectively, who are the corresponding P17 Work Group chairs on these two topics. In the afternoon session, the workshop attendees were divided into three discussion groups and asked to consider seven questions on the future direction of the seismic design value maps. Straw votes an each of the questions were conducted in a plenary session, and the results will be considered by the P17 committee to further refine its recommendations and develop formal proposals for the seismic design value maps.

These proceedings include the Project 17 Workshop participants list by discussion group, a recording of the discussion groups' straw votes, workshop announcement, technical background paper, and presentations.

WORKSHOP AGENDA

Conference Embassy A/B
Embassy Suites San Francisco Airport-Waterfront,
150 Anza Blvd., Burlingame, CA, 94010

April 11, 2016, 10:00am – 5:00pm

Agenda

10:00 am	Welcome, Introductions, Agenda Review	Jim Sealy
10:10 am	Project 17 Background, Purpose, and Workshop Goals	Ron Hamburger
10:50 am	Pending Updates to the USGS National Hazard Model	Nico Luco
11:05 am	Acceptable Risk Work Group Presentation	Robert Pekelnicky
11:50 am	Seismic Design Category Work Group Presentation	Julie Furr
12:15 am	CEUS Regional Seismic Hazard Mapping Workshop Update	Kevin Moore
12:30 am	Lunch	
1:30 pm	Breakout Group Discussion on Acceptable Risk	Hamburger/Pekelnicky
2:40 pm	Report on Group Discussions	
3:10 pm	Break	
3:20 pm	Breakout Group Discussion on Seismic Design Category	Hamburger/Furr
4:30 pm	Report on Group Discussions	
5:00 pm	Adjournment	

PARTICIPANTS AND DISCUSSION GROUPS

A total of 62 people attended the workshop. They were divided into three groups for the afternoon group discussion. The attendee list is presented here by group with each individual's name and organization.

Group 1 (23 Participants):

First Name	Last Name	Organization
Victor	Azzi	Rack Manufacturers Institute
James	Cagley	Cagley & Associates (BSSC Board)
Peter	Carrato	Bechtel Power Corporation
Charlie	Carter	AISC (BSSC Board)
C.B.	Crouse	URS Corporation
Susan	Dowty	ICC (BSSC Board)
John	Egan	SAGE Engineers
John	Gillengerten	Consultant
Ron	Hamburger	Simpson Gumpertz & Heger (P17 Chair)
Robert	Hanson	Federal Emergency Management Agency, National Earthquake Hazards Reduction Program (NEHRP)
John	Hooper*	Magnusson Klemencic Associates
Roy	Lobo	Structural Engineers Association of Central California
Steven	McCabe	National Institute of Standards and Technology
Kevin	Moore	NCSEA/Simpson Gumpertz & Heger
JR	Mujagic	Bekaert
Sanaz	Rezaeian	USGS
Rafael	Sabelli	Walter P. Moore
Siamak	Sattar	National Institute of Standards and Technology
Jon	Siu	City of Seattle, Washington
Greg	Soules*	Chicago Bridge and Iron Company
Mai	Tong	Federal Emergency Management Agency, National Earthquake Hazards Reduction Program (NEHRP)
Tom	Xia	Structural Engineers Association of Washington
Jiqiu (JQ)	Yuan	National Institute of Building Sciences, BSSC

* Group discussion moderator.

Group 2 (21 Participants):

First Name	**Last Name**	**Organization**
Robert	Anderson	Alfred E. Alquist Seismic Safety Commission
James	Bela	Oregon Earthquake Awareness
Hussain	Bhatia	OSHPD - FDD – Structural Services Section
David	Bonneville*	Degenkolb Engineers (PUC Chair)
Philip	Caldwell	Schneider Electric
Kelly	Cobeen	Wiss, Janney, Elstner Associates
Dan	Dolan	Washington State University
Art	Frankel	USGS
Jennifer	Goupil	SEI of ASCE (BSSC Board)
John	Heintz	Applied Technology Council
Andrew	Herseth	Federal Emergency Management Agency, National Earthquake Hazards Reduction Program (NEHRP)
Sandy	Hohener	Degenkolb Engineers
William	Holmes*	Rutherford & Chekene
Charles	Kircher	Charles Kircher & Associates
Bret	Lizundia	RTC
James	Malley	Degenkolb Engineers
Khaled	Nahlawi	American Concrete Institute
David	Palmer	Stantec
Rob	Smith	Arup
Chris	Tokas	Office of Statewide Health Planning & Development (OSHPD)
Zia	Zafir	Kleinfelder

* Group discussion moderator.

Group 3 (18 Participants):

First Name	Last Name	Organization
Shawna	Ackerman	CEA (California Earthquake Authority)
Kevin	Aswegan	Magnusson Klemencic Associates
David	Bonowitz	
Jon-Paul	Cardin	American Iron & Steel Institute
Ngai-Chi	Chung	Berkshire Hathaway
Anne	Ellis	National Institute of Building Sciences Board of Directors
Ben	Enfield	City of Seattle Building Department
Julie	Furr*	CSA Engineering, Inc.
Jim	Harris	J.R. Harris
Nico	Luco	USGS
Janiele	Maffei	CEA (California Earthquake Authority)
Mike	Mahoney	Federal Emergency Management Agency, National Earthquake Hazards Reduction Program (NEHRP)
Bonnie	Manley	American Iron and Steel Institute
Robert	Pekelnicky*	Degenkolb Engineers
Philip	Schneider	National Instiute of Building Sciences, BSSC
Jimmy	Sealy	Jim Sealy Architect / Consultant (BSSC Board)
Larry	Stevig	State Farm
Fred	Turner	CA Seismic Safety Commission

* Group discussion moderator.

DISCUSSION GROUP STRAW VOTE RESULTS

In the afternoon group discussion, the attendees were asked for input on the following seven questions:

1. Is the community willing to accept a major change in the mapped values?
2. Is it desirable to eliminate the "deterministic caps" and place the entire country at the same risk level?
3. Uniform risk of collapse or uniform hazard?
4. If uniform risk of collapse is to be maintained, can this be done approximately, while maintaining uniform hazard?
5. If ground motions are reduced in the mid-south and east (because big earthquakes happen more often) is this acceptable?
6. Can SDCs be assigned "regionally" rather than on a site and building-specific basis?
7. Can SDCs be assigned independent of Risk Category?

In a follow-up plenary session, each discussion group was asked for a straw vote by a show-of-hands vote to ascertain preferences on each question. The votes with group comments are summarized here.

Q1: Is the community willing to accept a major change in the mapped values?			
Group Vote	Yes	No	Not Voting
Group 1	11 (only if the change can be justified)	5	6
Group 2	2	12	8
Group 3	8 (major change is acceptable with compelling reasons)	9	1

Q2: Is it desirable to eliminate the "deterministic caps" and place the entire country at the same risk level?			
Group Vote	Yes	No	Not Voting
Group 1	17 (eliminate caps)	1	5
Group 2	6 (eliminate caps)	10	5
Group 3	9 (see the need to eliminate, but the change could create additional problems)	3	6

Q3: Uniform risk of collapse or uniform hazard?			
Group Vote	Uniform Hazard	Uniform Risk	Not Voting
Group 1	14 (easy to understand and explain)	2	7
Group 2	2	12 (no change to the current approach)	7
Group 3	0	8	10

Q4: If uniform risk of collapse is to be maintained, can this be done approximately, while maintaining uniform hazard?			
Group Vote	Yes	No	Not Voting
Group 1	14	2	7
Group 2	3	10	8
Group 3	18	0	0

Q5: If ground motions are reduced in the mid-south and east (because big earthquakes happen more often) is this acceptable?			
Group Vote	Yes	No	Not Voting
Group 1	17 (but need to provide a rationale)	0	6
Group 2	2	12	7
Group 3	0	18	The Rest

Q6: Can SDCs be assigned “regionally” rather than on a site and building-specific basis?			
Group Vote	Yes	No	Not Voting
Group 1	8	6	9
Group 2	13	1	7
Group 3	8	3	7

Q7: Can SDCs be assigned independent of Risk Category?			
Group Vote	Yes	No	Not Voting
Group 1	8	7	8
Group 2	16	0	5
Group 3	18 (only that it is possible)		The Rest

PROJECT 17 WORKSHOP INVITATION ANNOUNCEMENT

By Ron Hamburger[1], SE, PE, SECB

[1] Senior Principal, Simpson Gumpertz & Heger, San Francisco, CA, main committee Chair of Project 17.

Since 1997, building code seismic design criteria have been set to avoid future U.S. urban disasters from foreseeable earthquake events. Originally, the maps set seismic design values for Maximum Considered Earthquake (MCE) shaking, having a 2,475 year return period (2% probability of exceedance in 50 years). The intent was that conforming structures would have minimal risk of collapse should such shaking occur. The 2,475-year hazard was selected to assure protection against repeats of large historic earthquakes, including the 1811-1812 New Madrid series, and the 1886 Charleston South Carolina earthquake. However, this return period resulted in very large ground motions at some sites in California, and Alaska, near faults that produce large magnitude events with return periods of a few hundreds of years. Consequently, the maps, through deterministic parameters, limited the probabilistic 2,475 year values by conservative estimates of ground motion resulting from characteristic large magnitude events on these major active faults.

In 2007, BSSC decided to revise the mapped hazard level from a 2,475 year uniform hazard, to a level of shaking that produced a notional 1% - 50 year collapse risk for structures having typical fragility, called Risk-targeted MCE shaking. This resulted in modest reductions of hazard in the eastern U.S, but had little effect in California and Alaska, where deterministic caps on the probabilistic motion remained in effect.

With continued research into seismic hazards, engineers and scientists developed successive updated models for source characterization and shaking intensity, resulting in changes in the mapped values from code edition to code edition. In 2014, as USGS (United States Geologic Survey) and BSSC (Building Seismic Safety Council) again collaborated in updating the maps for the 2015 *NEHRP Provisions* (FEMA P-1050), many engineers expressed concern with the shifting design values and the way this impacted building design. Engineers also complained about the complexity of hazards characterization and design in general. The ASCE 7 committee initially rejected the 2014 maps, then reconsidered and adopted them, as the basis for ASCE 7-16 and IBC-2018.

In response, the BSSC, under the sponsorship of FEMA (Federal Emergency Management Agency), with the USGS jointly engaged in a project (*Project 17*) to recommend a basis for development of next-generation seismic design value maps for future building codes. A key objective is to stabilize the mapped values and associated design requirements. *Project 17*, initiated in 2015, involved public outreach and identification of key issues. In 2016 the *Project 17* Committee established Work Groups (WG) and scopes of work to address four fundamental issues:

- Acceptable Risk WG: selection of an appropriate risk basis for the maps;
- Precision and Uncertainty WG: stabilizing the mapped values and associated design requirements over successive building code editions;

- Mult-Period Spectral Parameters WG: more properly representing site class effects, on soft sites where hazards are dominated by large magnitude earthquakes;
- Deterministic Maps WG: specification of the deterministic event on which seismic hazards are based at sites close to major active faults.

A fifth Work Group was added later in the year:

- Seismic Design Category WG: minimize the fluctuations that impact design requirements, specifically with the idea of decoupling SDC from mapped ground motions.

The *Project 17* Committee hopes to make recommendations on these issues to the BSSC Provisions Update Committee and USGS by the early 2018. On a preliminary basis, the Acceptable Risk WG has identified the potential to simplify the basis for mapped values by revising the Maximum Considered Earthquake shaking definition. In addition, the Seismic Design Category WG has postulated that designers are more concerned with stability in SDCs, and the associated design criteria, than relatively modest shifts in the mapped values of spectral acceleration parameters. Before proceeding further with recommendations, *Project 17* seeks input on a preferred path forward on these two issues from structural engineers, building officials, and members of the earthquake community.

To this end, *Project 17*, at its invitational workshop on April 11, 2017 plans to solicit input on:

- A preferred risk basis for the seismic design value maps
- A preferred approach to designation of Seismic Design Categories

Once this input is received, the *Project 17* Committee and it Work Groups will further refine its recommendations and develop formal proposals for consideration by the BSSC Provisions Update Committee, the ASCE 7 Standards Committee and the International Code Council.

Workshop participants will be provided with information on the choices currently considered and their likely impacts on the design process. This will include an informational webinar, early in 2017, followed by detailed written material. Workshop participants will have an opportunity to hear detailed presentations at the workshop and to provide feedback to the *Project 17* members on preferred approaches.

PROJECT 17 TECHNICAL BACKGROUND

by

Ron Hamburger[1], SE, PE, SECB, Robert Pekelnicky[2], SE, PE, and Julie Furr[3], SE, SECB

[1] Senior Principal, Simpson Gumpertz & Heger, San Francisco, CA, main committee Chair of Project 17.

[2] Principal, Degenkolb Engineers, San Francisco, CA, Acceptable Risk work group chair of Project 17.

[3] CSA Engineering, Inc., Lakeland, TN, is the Seismic Design Category work group chair of Project 17.

INTRODUCTION

The United States Geologic Survey (USGS), under funding provided through the National Earthquake Hazards Reduction Program (NEHRP), develops national seismic design value maps for adoption by the building codes. The USGS develops these maps in a cooperative manner with the Building Seismic Safety Council's (BSSC) Provisions Update Committee (PUC). On a periodic basis, the PUC, acting under funding provided by the Federal Emergency Management Agency (FEMA), develops the *NEHRP Recommended Seismic Provisions for New Buildings and Other Structures* (*NEHRP Provisions*) for publication by FEMA as a resource document for building codes and also as a standard for seismic design of new federally funded construction. Until 2009, the *NEHRP Provisions* comprised a complete set of provisions for determining seismic design criteria for buildings and other structures. The 2000 and 2003 editions of the *International Building Code* adopted the *NEHRP Provisions* directly into Chapter 16 of the code, together with modifications to the materials standards, adopted in Chapters 17 through 22 of the code. At the same time, the ASCE 7 Committee adopted the *NEHRP Provisions* with some modification, into the *ASCE 7 Standard*. In 2006, the International Code Council (ICC) decided to refer to industry standards for most technical structural engineering criteria. Instead of transcribing the *NEHRP Provisions* in their entirety, ICC transcribed only that portion of the provisions associated with determining design ground motion parameters, together with the associated maps, and referred to the *ASCE 7 Standard*, which was adopted by reference for the balance of the seismic design criteria. In 2009, the PUC also began adopting the *ASCE 7 Standard* as the basic seismic design requirements, but made substantive recommendations for modification and improvement of the standard based on recent research and improvements in knowledge. In this manner, the PUC process and the *NEHRP Provisions* have become a technology resource and proving ground for new requirements adopted into the ASCE *Standard* and the *International Building Code*. The development of seismic design value maps is a significant part of this process.

The PUC and USGS act cooperatively to develop the maps. The PUC sets the basic criteria for map development, including specification of the level of hazard, or risk, that the maps should portray as well as the specific parameters to be mapped and the design procedures that convert these parameters into seismic design requirements. The USGS then, with input from the earth science community, applies the latest seismic hazard models, uses the basis set by the PUC to develop the maps. Following review and balloting by the PUC, a second ballot by BSSC Member Organizations (MOs) representing the broader seismic community, and BSSC Board of Direction approval, the maps are adopted into the *NEHRP Provisions*, and subsequently are adopted by the *ASCE 7* standard and the *International Building Code*.

The present maps have under gone an evolutionary process over the last 20 years, with major innovations introduced approximately every 10 years, and more moderate updates conducted during the interim years. The first major step in this process occurred in the mid-1990s, when FEMA, BSSC and USGS engaged in a collaborative process known as Project '97. Major accomplishments of this effort included:

- Adoption of a seismic design basis for ordinary structures that sought avoidance of collapse for major foreseeable earthquake events, termed Maximum Considered Earthquake (MCE) shaking.

- Targeting MCE shaking with a 2,475 year return period (2% chance of exceedance in 50 years) except in regions proximate to major active faults where MCE intensities were limited by a deterministic event taken as 150% of the median motion computed for a characteristic earthquake on any of these proximate faults.

- Development of design procedures deriving design forces from a standard acceleration response spectrum keyed to parameters, S_{DS} and S_{D1} derived from mapped parameters S_S and S_1 and site class coefficients F_a and F_v.

- Development of the concept of Seismic Design Categories (SDCs) to regulate the level of seismic design required for a structure, depending on the intensity of design ground motions, and the structure's occupancy/use, and therefore acceptable risk.

The PUC adopted the Project '97 recommendations into the 1997 edition of *the NEHRP Provisions* which formed the basis for *ASCE 7-98*, *ASCE 7-02* and the *2000 International Building Code* and *2003 International Building Code*. The USGS updated its seismic hazard model to incorporate new information on the activity of certain seismic sources and published a new series of maps referenced by the *2003 NEHRP Provisions*, *ASCE 7-05*, and the 2006 and 2009 editions of the *International Building Code*. This resulted in some substantive changes to the mapped values. In some regions mapped values increased, and in others, the values decreased. Changes to mapped values were generally within +/-10% but still, were sufficient to change the required Seismic Design Categories for some structures in some regions. Since Seismic Design Categories are key to seismic regulation, this resulted in shifting requirements both for design and construction in the affected areas.

In 2005, FEMA, BSSC and USGS jointly executed a new effort termed Project '07 to review the basis of the maps developed under Project '97 in light of updated research and approximately 10 years of experience in use of the maps. At that time the Pacific Earthquake Engineering Research Center (PEER) was completing its Next-Generation Attenuation (NGA) project and had developed a series of new ground motion prediction equations (GMPEs) to estimate the likely intensity of shaking resulting from earthquakes of given magnitude and characteristics on sites having different subsurface conditions. The earth science community advised USGS that the next set of maps should use these NGA equations and so, Project ’07 focused on the implications of using NGA for map development. At the same time, Project ’07 attempted to deal with complaints by engineers in the central and eastern U.S. that the maps required excessively conservative design in those regions of the country. Project ’07 recommended the following modifications to the mapping process:

- Convert from mapped ground motion parameters having a 2,475 year return period (2% chance of exceedance in 50 years) to ground motion parameters producing a 1% in 50 year collapse risk for structures having a standard fragility represented by a 10% chance of collapse given MCE motions and dispersion of 0.9, later reduced to 0.6.

- Represent “maximum direction” motions, rather than geomean motions, as had been done in past cycles.

- In areas close to major active faults, rather than capping probabilistic motions with 150% of the median motion resulting from characteristic earthquakes, cap probabilistic motions with true 84th percentile motions resulting from characteristic earthquakes, as represented by the PEER NGA GMPEs.

The PUC adopted these recommendations in its 2009 *NEHRP Provisions* and the resulting maps were adopted into *ASCE 7-10* and the 2012 and 2015 editions of the *International Building Code*. As with prior updates to the maps, mapped values changed, in some cases substantially. Generally, design values in the eastern and central U.S. decreased while those in the western U.S. increased somewhat. Changes were typically on the order of +/-20%. As in the past, as design values changed, the required assignment of buildings to Seismic Design Categories changed in some communities.

In 2014, USGS again updated the seismic design value maps to incorporate updated scientific opinion as to the magnitudes and recurrence rates on various faults. Of note, at the time of this map update, the earth science community had completed an update to their hazard model for California (known as Uniform California Earthquake Rupture Forecast or UCERF3), which dropped the concept of characteristic earthquake ruptures for faults in favor of multi-segment models in which multiple fault segments could participate in a rupture sequence at varying levels of probability. BSSC and USGS elected, as a temporary measure, to retain the prior definitions of characteristic earthquakes for the 2014 maps, though other aspects of the UCERF3 model were adopted for the 2014 maps. The 2015 *NEHRP Provisions* adopted these maps as has *ASCE 7-16* and the 2018 edition of the *International Building Code.* As with prior updates to the maps, design values changed, typically within +/-10%, as did Seismic Design Category assignments for typical structures in some regions.

As part of the 2020 *Provisions* update process, FEMA has again conceived and funded a joint USGS-BSSC project, Project 17, to evaluate the basis for developing the seismic design value maps for publication in the *2020 NEHRP Provisions*, *ASCE 7-22* and the 2024 edition of the *International Building Code*. Major project goals include:

- Correct the representation of spectral shape for soft soil sites with motions dominated by large magnitude earthquakes (this issue was identified during the latter phases of the 2015 *Provisions* Update Cycle, and addressed with a “patch” requiring a site-specific study for many buildings).

- Coordinate with updated earth science characterization of fault segmentation and magnitude-recurrence relationships, particularly as applies to designating deterministic ground motion limits.

- Re-evaluate the risk basis for the maps considering provision of acceptable levels of protection for construction; enhancing understanding and application by the profession; and if appropriate, simplification of the process.

- Attempt to stabilize the mapped values of motion over time to minimize changes to practice and enhance practice and enforcement.

The Project 17 workshop to be held in conjunction with the BSSC Annual Meeting will provide users the ability to provide input to the Committee on the latter two issues. This paper provides important background information for users.

BASIS FOR DESIGN VALUE MAPS

Prior to 1997 U.S. building codes identified seismic risk through the use of broad regional seismic zones based mostly on historic earthquake activity, representing, sequentially, regions of negligible, moderate, high and very high seismic risk.. Seismic design criteria contained in the codes were targeted at zones of high and very high seismic risk with arbitrary reductions made to design force levels, design procedures, and required seismic detailing in zones of lower risk. The requirements specified by these codes have generally been found to provide adequate earthquake protection, though some revisions have been made to the requirements over the years. No one knows if the measures required in lower seismic zones were effective, because, 1) many communities in lower seismic zones had not enforced the code requirements and 2) there had not been many significant earthquakes in these regions to allow evaluation of effectiveness.

Since 1997 USGS has developed the maps using probabilistic seismic hazard analysis. This process starts with identification of a catalog of seismic sources that can produce significant magnitude earthquakes. Some of these sources are discrete faults, others are complex networks of interconnected fault segments, and still others are broad areal zones in which earthquakes are known to occur, but in which discrete faults have not yet been identified. In addition to identification of each of these sources, and their locations, the catalog includes magnitude-recurrence relationships that identify how often earthquakes of different magnitudes are likely to occur on each source. These determinations are made by evaluating the historic record of earthquakes on these faults, evidence of pre-historic events, and by theoretical models that predict the amount of strain accumulation in the earth’s crust, and the earth’s need to relieve these strains through seismic and aseismic events. Different researchers and scientists have differing opinions on the locations, connectivity and magnitude/recurrence relationships for these various sources, and these opinions evolve over time as new research is performed. When developing an edition of the seismic design value maps, the USGS attempts to develop and implement a consensus opinion on catalog components. This consensus opinion changes from cycle to cycle as more research and knowledge becomes available and additional study is performed.

The second major component of seismic hazard analysis are the GMPEs. GMPEs are complex relationships that enable the estimate of spectral acceleration and other ground motion parameters at a particular site as a function of fault type, magnitude, direction of rupture, distance from site, soil conditions at the site, and other factors. Geotechnical engineers and earth scientists develop these relationships by performing regression analysis on data sets of past ground motion recordings from events of known magnitude, distance and other parameters. Once input of the necessary parameters is conducted, GMPEs provide estimates of the probable (mean) value of the ground motion parameter, as well as uncertainties expressed in the form of logarithmic standard deviations. Just as with the earthquake source catalog, a number of different researchers and engineers have developed GMPEs that they believe represent the best predictors of probable ground motion from future earthquakes. When the USGS develops an edition of the maps, they seek to build consensus as to the appropriate group of GMPEs to be used, often adopting a weighted average of several GMPEs Over the past 20 years, researchers at PEER, working with USGS and other interested government bodies, have developed a series of new GMPEs through the Center's NGA projects.

Once the USGS has adopted an earthquake source model and suite of GMPEs to be used, it goes about performing probabilistic seismic hazard analyses to determine the values of mapped ground motion parameters on a 2km by 2km grid across the United States, assuming that each site has a single reference type of soil condition present. Procedurally, for a given point on the grid, and for each earthquake source in the catalog, the GMPEs are applied to determine the probability of incurring different values of the ground motion parameter at that site, for different magnitude earthquakes on each source. Then, these probabilities are summed over all earthquake sources, to produce a probabilistic seismic hazard curve for that site, for that ground motion parameter. Figure 1 below is a representative seismic hazard curve for a site near Kansas City, MO, plotting the probability of exceedance for spectral acceleration at 0.2 seconds ($S_{0.2}$) and spectral acceleration at 1 second (S_1) on a reference site condition. For a 2,475 year return period (0.0004 annual frequency of exceedance) this curve shows values of 0.11g for $S_{0.2}$ and 0.06g for S_1.

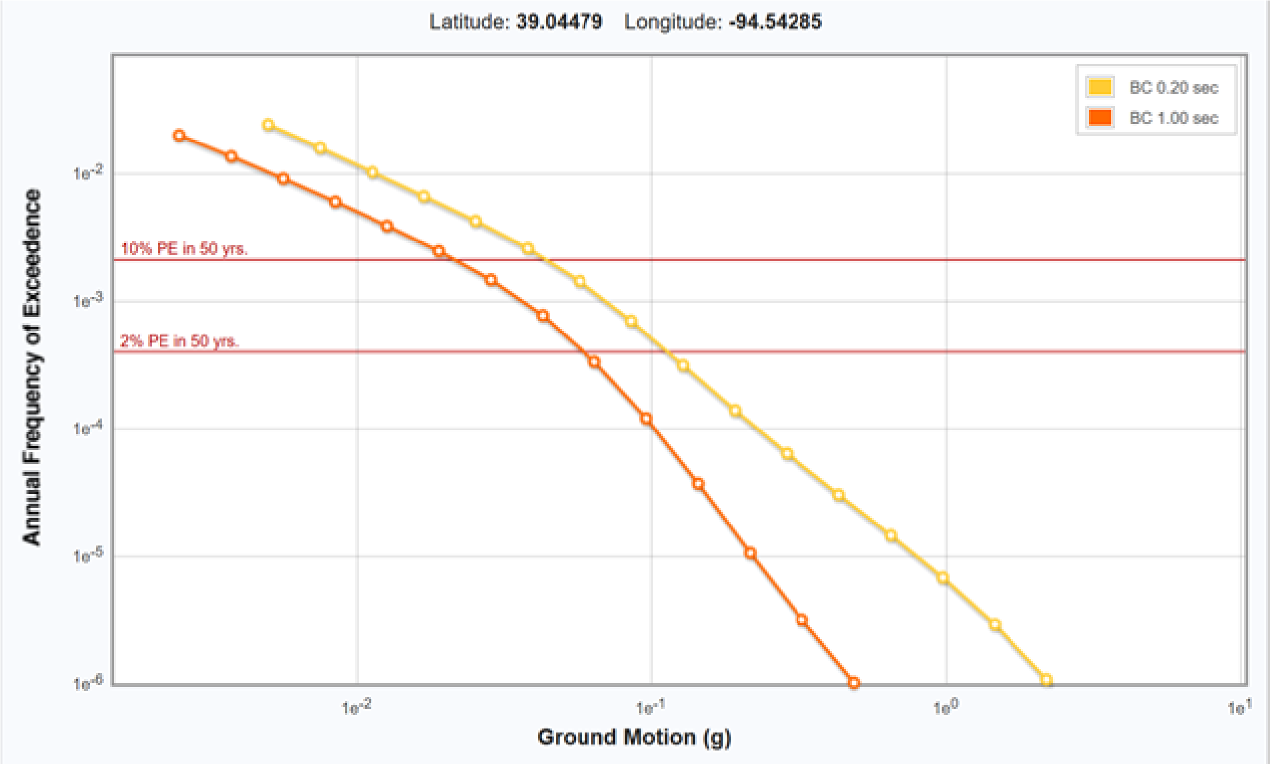

Figure 1 – Representative seismic hazard curves for $S_{0.2}$ and S_1 for a site near Kansas City, MO

A byproduct of this process are the so-called deaggregation plots, such as that shown in Figure 2 for $S_{0.2}$ for this same site at a 2,475 year return period. Each of the bars in this figure represents the contribution to the hazard from earthquakes of different magnitudes on different sources. This figure shows that at 2,475 years, the $S_{0.2}$ has a significant contribution from very large magnitude events (M7.5-8) located approximately 500 kilometers away (in this case the New Madrid zone); somewhat less, but significant contribution from small magnitude earthquake (M4-M5) located within 50 kilometers of the site; and some contribution from moderate magnitude (M5-6) earthquakes located within 200 kilometers off the site. Thus, for most sites, the hazard values shown on the maps are not directly related to any specific magnitude earthquake on any particular fault, but rather are the composite of a number of different size events on many possible sources.

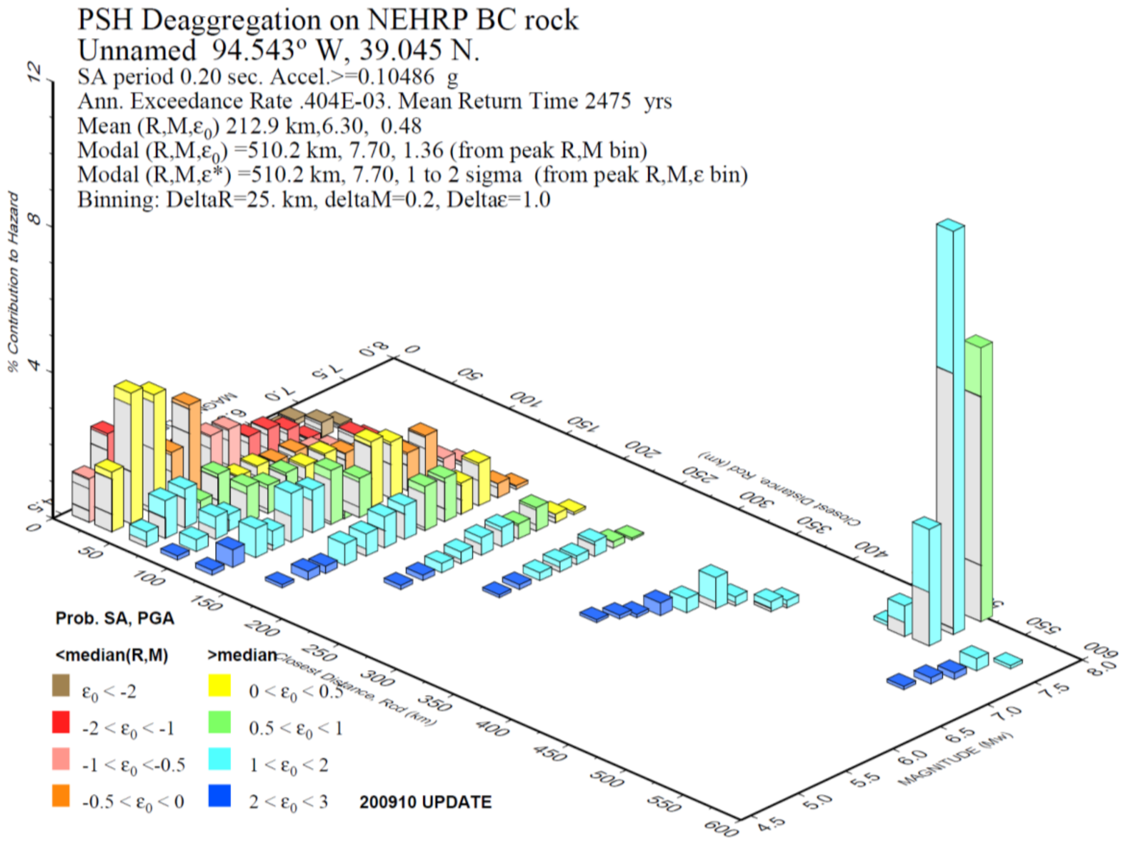

Figure 2 – Hazard deaggregation plot for 0.2 second spectral acceleration

After USGS conducts this analysis for each site on the 2km by 2km grid, it produces the maps by creating contours through sites with similar values of each of the spectral parameters. This is performed by interpolating the values between points on the grid. The USGS can produce maps of this type for any return period (annual frequency of exceedance) selected by the PUC.

This process was first conducted in the mid-1990s under Project 97. Project 97's charter was to produce ground motion maps and a companion design procedure that would protect the U.S. from experiencing a major urban earthquake disaster in a foreseeable major earthquake event. Specifically, Project 97 sought to avoid disasters of the type that had affected the towns of Spitak and Leninikan in Armenia in 1988. A moderate magnitude M6.9 earthquake, on a known fault, caused more than 50,000 fatalities, destroying the towns in the process. In Spitak, in particular, nearly every building collapsed. Project 97 adopted as a goal, preventing, or at least minimizing the risk of collapse, of structures in such foreseeable events.

In addition to the well-known and highly active faults systems along the Pacific Coast, Project '97 also wanted to assure that the new maps would provide protection against potential earthquakes along the New Madrid Fault zone in the mid-South, the Wasatch Fault zone in the Salt Lake region, and the fault zone that produced the 1886 Charleston South Carolina earthquake. The project team also recognized the potential occurrence of smaller magnitude events distributed across the U.S., much like the smaller magnitude events depicted in Figure 2. At the time, USGS was producing trial maps with return periods of 475 years, 975 years and 2,475 years corresponding to 10%, 5% and 2% probabilities of exceedance in 50 years, respectively. Since return periods for large magnitude events on the New Madrid and other faults systems of concern in the eastern and central U.S. and the intermountain region was thought at that time to be on the order of 1,200 years or so, only the 2,475 year map was capable of capturing the occurrence of these events. Therefore, 2,475 years was selected as the return period for definition of Maximum Considered Earthquake shaking throughout much of the U.S. Other return periods could have been adopted. The 2,475 year selection was made because it corresponded with an interval already being mapped and was thought to capture the appropriate potential events (i.e. Charleston, New Madrid and Wasatch). This was a major break with past practice in that building codes of the era targeted 475-year shaking as the design event, and 975 year shaking as an Upper Bound Earthquake, representing the worst shaking that should ever be considered in design of buildings. Some industries, notably the nuclear power and hydroelectric industries did consider much less probable events because the consequence of nuclear accident or failure of a major dam are perceived as intolerable.

Examination of the 2,475-year maps, however, indicated much higher ground motions in portions of Coastal California than had previously been considered and, in some cases, values that engineers deemed impractical for use in design. California engineers believed, based on recent experience, e.g. the 1989 Loma Prieta and 1994 Northridge earthquakes, that significantly larger design forces than presently used were not necessary to provide adequate protection of the public. They argued that in coastal California, like Los Angeles, and San Francisco, earthquakes were likely to occur on known, active faults that had maximum magnitude events (termed characteristic) on the order of one time every few hundred years and that design for motions having a 2,475 year return period was unjustified. Instead, these engineers argued that in regions where the hazard is dominated by well-known, highly active faults, Maximum Considered Earthquake shaking should be limited to a conservative estimate (initially 150%) of the ground motion obtained from the GMPEs for the characteristic earthquakes on these faults.

Thus, Project 97 adopted the model for determination of MCE spectral parameters illustrated in Figure 3. The figure represents a plot of an MCE spectral acceleration parameter with distance from a major active fault, like the San Andreas in California. The horizontal dashed line represents 150% of the ground motion specified by the 1997 UBC for Zone 4, without near fault factors. The UBC motions were amplified by 150% to represent the margin Project 97 members believed existed in design of building for UBC Zone 4 motion. That is, the Project 97 panel believed that buildings designed to the 1997 UBC Zone 4 criteria should be capable of resisting 150% of the design ground motions without significant risk of collapse. This margin of 1.5 was later carried forward into the factor used to convert MCE motion parameters to design values.

Also shown in the figure are exponential plots representing the value of the spectral parameter at a 2,475 year return period, and as calculated deterministically for a characteristic magnitude event on the nearby dominant fault, factored by 1.5. Where the probabilistic motion was less than the 1997 UBC motions, the probabilistic motion would be used. Where the probabilistic motion exceeded the 1997 UBC motion, the larger of the 1997 UBC motions or the deterministic motions computed for the characteristic magnitude would be used. The heavy multi-segment line in the figure represents the definition of MCE as adopted, and contained in *ASCE 7-98*, *ASCE 7-02*, *ASCE 7-05,* the 1997, 2000 and 2003 *NEHRP Provisions,* and the 2000 through 2009 editions of the *International Building Code*.

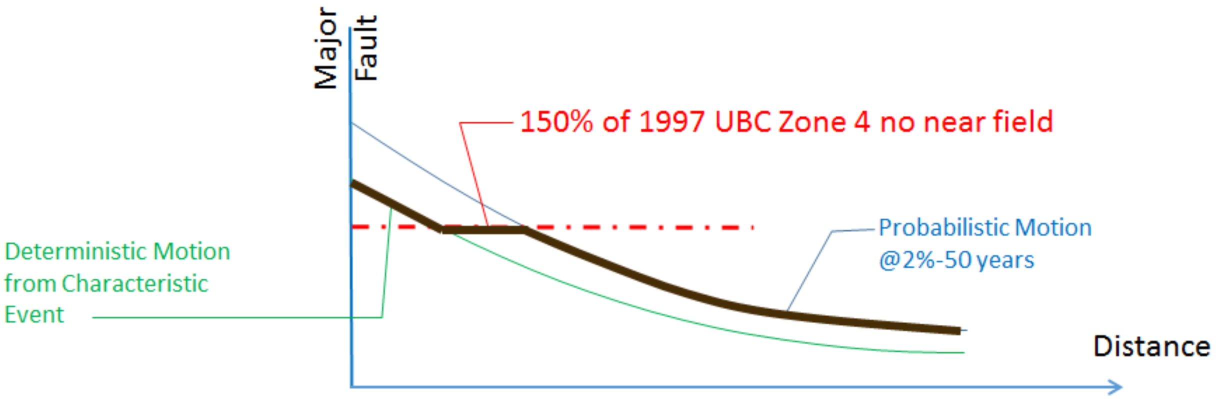

Figure 3- Project 97 definition of MCE shaking

In 2005, FEMA sponsored Project ’07 to take a fresh look at the basis for the seismic design value maps as part of the 2009 *Provisions* update process. One key issue considered by Project ’07 included the reluctance of cities in some parts of the mid-south to adopt the seismic maps and design requirements published in the *International Building Code*. Another was the emergence of the first-generation PEER NGA GMPE’s and the USGS’ decision to adopt these. This appeared problematic because the PEER NGA GMPEs suggested that ground motions resulting from large magnitude earthquakes, such as those that dominate hazard in the western U.S., were significantly lower than had been previously thought. Implementation of these GMPEs meant that design forces in places like coastal California would be significantly reduced. Ground motions in the central and eastern U.S. would not have been affected because the PEER NGAs at that time addressed only the western U.S. Adoption of these new GMPEs without changing the rules by which the maps were generated would have resulted in substantially reduced ground motions in California, and other portions of the Western U.S., while ground motions in portions of the central and eastern U.S. remained at previous levels. As some engineers and building officials in the central and eastern U.S. were already calling into question why places like Memphis were supposed to design for similar motions to sites in San Francisco, a reduction of the motions in California was politically ill-advised.

At that time, the Applied Technology Council had just completed development of the FEMA P695 methodology, intended to provide a rational method for validating design procedures, *R* factors and related criteria for new structural systems. The *FEMA P695* methodology put forward the concept that buildings with sufficient earthquake resistance should have not greater than a notional 10% chance of collapse, when subjected to MCE shaking. The Project ’07 group was familiar with this methodology and thought that one way to address the apparent disparity between design criteria in California and the mid-south would be to move to a “uniform risk” basis for the maps, as opposed to the “uniform hazard” basis then underlying the maps. In theory, because earthquakes are more likely to occur in the western U.S. than in the eastern U.S., if buildings in the two locations were designed for the same criteria, i.e. ground motions having the same probability of exceedance, the buildings in the west would have higher risk of collapse than buildings in the east, simply because they were more likely to experience a damaging earthquake. By going to a uniform risk basis, the design motions in the east could be decreased somewhat, while those in the west were increased to produce similar risk of collapse in both regions.

Thus, the concept of uniform risk maps, referenced by *ASCE 7-10* and adopted in the 2012, 2015 and 2018 *International Building Codes* was developed. The risk of collapse of a building is computed as the product of the probability of experiencing a given level of ground shaking intensity and the probability that the building will collapse if it experiences such motion, integrated over all possible levels of ground motion. FEMA P695 suggested that buildings conforming to the code would have not greater than a 10% probability of collapse given the occurrence of MCE shaking. Using this statistic, and an assumed uncertainty associated with the collapse probability, on average, it could be shown that the structures designed using MCE motions having a 2,475 year return period would have approximately a 1% chance of experiencing earthquake collapse over a 50 year period; some such buildings having as much as 0.75% collapse risk and others 1.5% collapse risk. Project 17 decided to massage the definition of MCE motions such that all buildings having the assumed fragility (probability of collapse given a level of ground motion) would have exactly 1% risk of collapse in 50 years, producing “uniform risk.” The resulting motions were termed Risk-targeted MCE motions denoted as MCE_R.

To construct the new Uniform Risk maps, USGS starts by computing the 2,475 year ground motion, just as it did before, and the hazard curves for shaking at 0.2 seconds and 1.0 seconds. USGS then assumes that structures designed for such ground motion will have a 10% probability of collapse, if they experience 2,475 year shaking, as suggested by *FEMA P695*, and that the dispersion representing the uncertainty in collapse probability at a given level of shaking, has a value of 0.6. Using these collapse fragility parameters, and the hazard curves, the USGS computes the probability of collapse for the “typical” structure. If this collapse risk is exactly 1% in 50 years, the USGS uses the 2,475 year motion as $\mathrm{MCE_R}$. However, if the computed collapse risk is higher than 1% in 50 years, the USGS will iteratively increase the return period for $\mathrm{MCE_R}$ motion and repeat the risk calculation until they determine that the collapse risk is indeed 1%. If the originally computed collapse risk was lower than 1% in 50 years, the USGS will iteratively reduce the return period for the $\mathrm{MCE_R}$ motion until they determine a collapse risk of 1%. The resulting contours of $\mathrm{MCE_R}$ motions presented on these maps do not have a defined return period or probability of exceedance. In some locations, the return period approximates 1,700 years, while in others, it approximate 2,700 years. This has the effect of reducing motions slightly in some portions of the central and southeast U.S., while increasing them slightly in portions of the Western U.S. Typically, changes are on the order of 20% or less.

The conversion to uniform risk maps did not eliminate the unreasonably large ground motions predicted in portions of California, for instance, sites in Los Angeles and San Francisco. Therefore, Project ’07 retained the concept of deterministic limits on the probabilistically computed motions, as illustrated in Figure 4 below. Similar to Figure 3, motion is taken as probabilistically determined risk-targeted motion unless this exceeds the 1997 UBC zone 4 motion. Where this exceeds the 1997 UBC Zone 4 motion, the $\mathrm{MCE_R}$ is taken as the greater of the 1997 UBC motion or motion determined as having a 16% chance of exceedance (84th percentile) given the occurrence of a characteristic earthquake on a nearby active fault. There is no risk adjustment for sites located close to such major active faults.

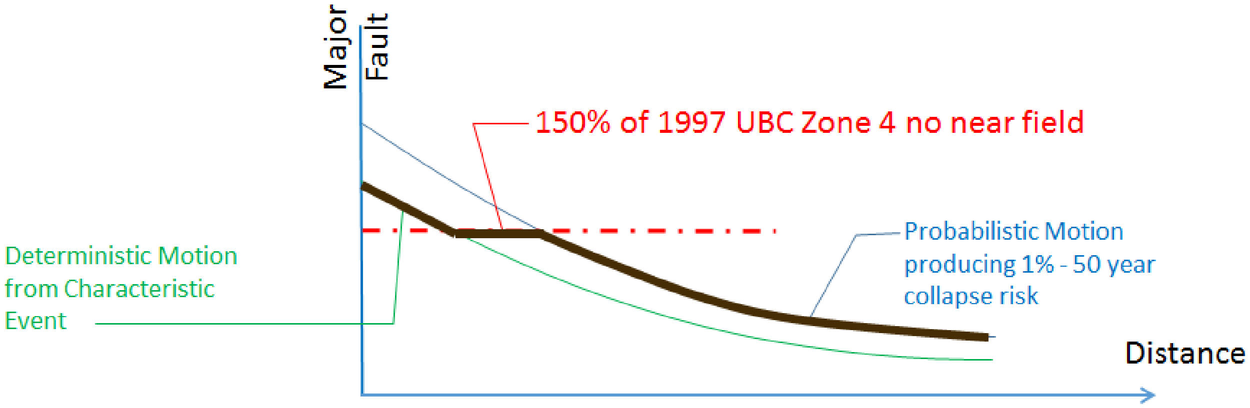

Figure 4 – Project ’07 Uniform risk basis for MCE$_R$ maps

The “uniform-risk” maps therefore, are not really uniform risk. For most of the U.S., they provide building design with a notional 1% in 50 year collapse risk. At sites located within a few kilometers of major active faults, the collapse risk can be much higher, on the order of 2% to 3% in 50 years.

Although commentary to the NEHRP *Provisions* and *ASCE 7* suggest that typical structures designed to the building code have as much as a 10% chance of collapse given that they experience MCE (or MCE$_R$) motions, many engineers, including those who developed the FEMA P695 methodology, believe that the actual collapse risk for buildings is substantially lower than this, and may be on the order of 2% or so. This is based mostly on the observation of damage statistics in recent U.S. earthquakes, and on the knowledge that the FEMA P695 methodology computes collapse risk using conservative criteria. Thus the actual collapse risk for buildings designed to the *ASCE 7-10* requirements might be on the order of 0.2% in 50 years, and for those near major active faults in California, on the order of 0.5% in 50 years.

STABILITY OF MAPPED VALUES

With successive editions of the *ASCE 7 Standard* and the *International Building Code*, engineers have noted specified ground motions in regions that go up, then down, then back up again. These oscillations, although scientifically logical, create a lack of confidence in the basis for design ground motions. More significantly, in regions close to Seismic Design Category boundaries, these oscillations result in shifting design and construction requirements as structures move from SDC B to C or C to D and back again with successive editions of the maps. Design and construction requirements can vary significantly between SDCs, favoring different structural systems, and radically affecting the cost of construction. This oscillation creates considerable problems in practice, and code adoption and enforcement as both designers and public officials work to justify the new provisions, and contractors struggle to build as required by the code and individual designs.

There are many reasons for the constantly changing values and their effect on design practice. The most significant of these is that seismology is a field of intense ongoing research into the location, length and activity rate of faults and other seismic sources, as well as development of new GMPEs. The USGS is under mandate to produce updated seismic design value maps for each successive edition of the *NEHRP Provisions* and *ASCE 7 Standard*. When producing the next generation maps, USGS is under considerable pressure to incorporate recently completed research findings.

All incorporated research impacts the computed ground motion values. Sometimes, however, the research is not sufficiently complete or vetted, and rushed too quickly into the design value maps. As an example, the PEER NGA ground motions suggested that substantial reductions in ground motions would occur in areas of the western U.S. where hazard is dominated by large magnitude events. However, a few years later researchers discovered other factors that tended to counter some of these reductions. As a result, ground motions went down, then back up, as each successive generation of research was put into practice.

Change to values in the maps also occurs when the BSSC changes the rules governing map development. Major change occurred in 1997 and 2007, and is again being proposed under Project 17, which will impact structures designed after 2024.

CONSIDERATIONS OF ACCEPTABLE RISK

Project 17 is considering revision of the risk basis for the maps illustrated in Figures 5 and 6. Because earth scientists no longer support the concept of a characteristic earthquake on a fault, there is a need to revisit the model illustrated in Figure 5. Alternatives being considered include:

1. Do not make any modification from the current approach of defining the MCE_R based on a 1% in 50 year risk of collapse with a deterministic cap of the mean plus one standard deviation from the maximum event on a characteristic fault, continuing to use the pre-2014 definitions of characteristic events.

2. Retain the current notional 1%-50 year collapse risk, and re-define the deterministic event as one having a defined probability of occurrence, possibly on the order of 5% in 50 years (975 year return period).

3. Increase the current notional 1%-50 year collapse risk such that ground motions in regions currently computed on a deterministic basis (mostly coastal California) remain at levels traditionally used for design, and significantly reduce design values throughout much of the rest of the U.S. Under this approach the notional collapse risk might be adjusted to 1.5% in 50 years (3% in 100 years) or 2% in 50 years. The USGS would continue to integrate hazard against a nominal structural fragility in order to derive the maps. Deterministic limits would be eliminated.

4. Return to a uniform hazard, rather than uniform collapse risk model for the maps, but select a return period other than 2,475 years for the uniform hazard, such that again, ground motions in zones currently controlled by deterministic limits would remain at historic design levels. Potential choices for the uniform hazard period include 975 years and 1,500 years though other return periods could be selected. Deterministic zones would be eliminated.

Detailed discussion of these options will be conducted at the workshop and input from the attendees solicited. As background data, Figure 5 below shows the notional collapse risk for structures designed to the present maps. As can be seen the notional collapse risk is 1% throughout much of the U.S. and 5% or higher in some sites along the San Andreas fault zone in California. The reason for this increase in risk is due to the deterministic caps governing the MCE_R in those locations. Figure 6 presents the return period of ground motions portrayed on the 2018 IBC maps. Values range from approximately 200 years in portions of California to more than 3,000 years in isolated locations of the midwest.

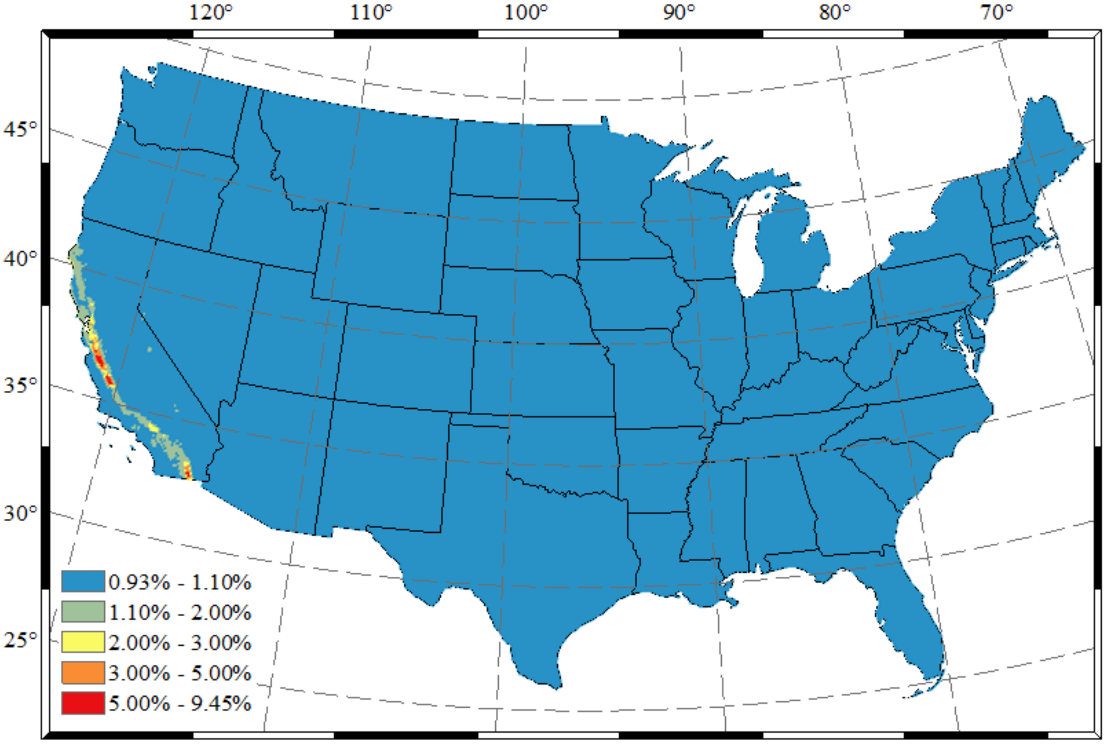

Figure 5 – Geographic distribution of notional collapse risk, 2018 IBC S_s map

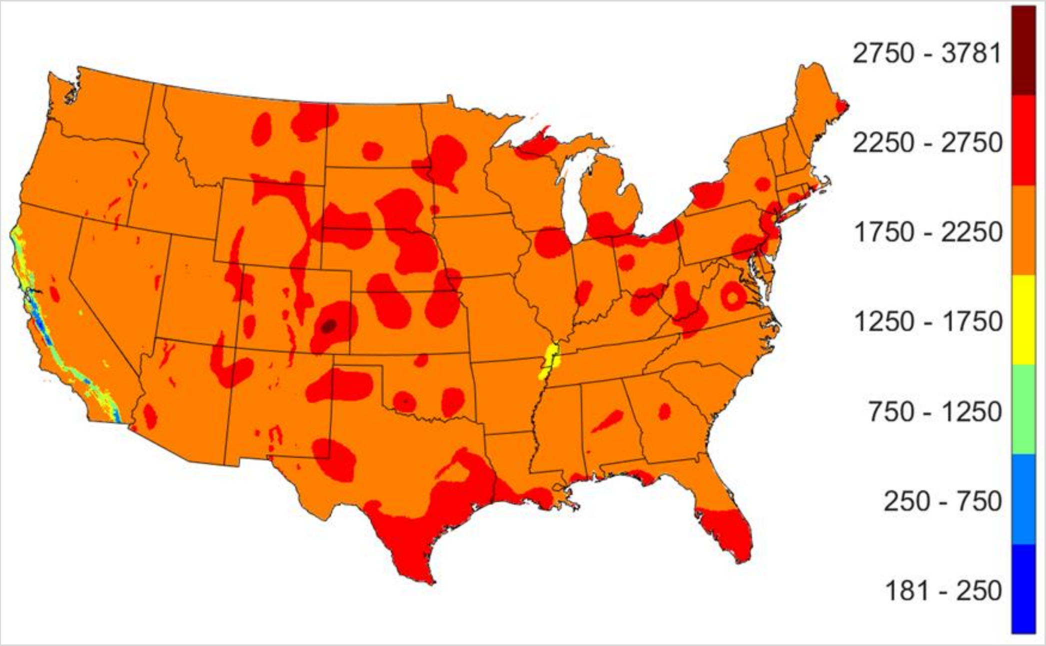

Figure 6 – Return period for S_s, 2018 IBC Maps

Figure 7 shows the distribution of notional risk of collapse for structures that would be attained if a uniform hazard with a 975 year return period (5% - 50 year exceedance probability) were selected. As can be seen this would approximate 2% in 50 years for most structures. Figure 8 presents the ratio between the values that would be obtained under 975 year maps to the present specified design ground motion values based on 2018 IBC maps. In most parts of the country, the ground motion parameters would be reduced because and the risk of collapse would increase. However, in portions of California that are currently based on the deterministic cap ground motion parameters would increase somewhat. Table 1 presents a summary of this data for a number of important cities in the U.S.

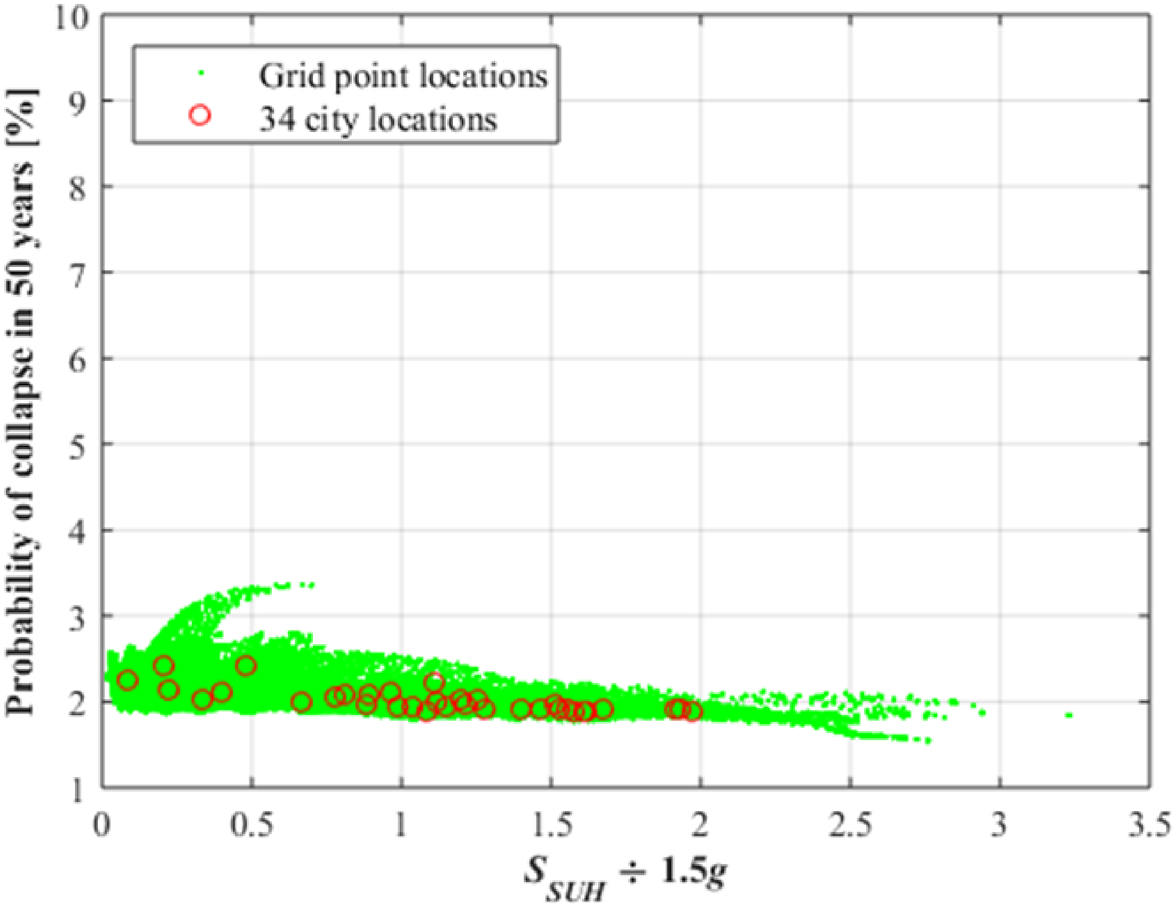

Figure 7 – Distribution of notional collapse risk, 975-year shaking

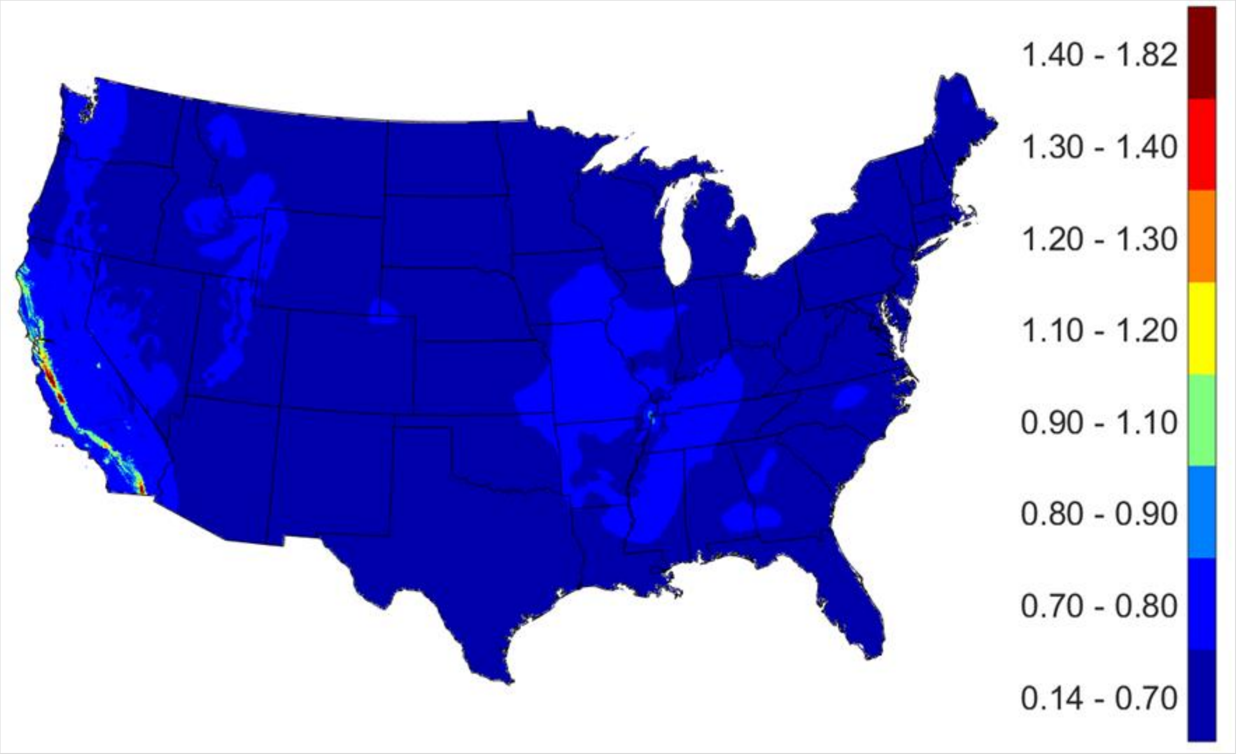

Figure 8 – Ratio of design values (S_s) 975-year motion to 2018 IBC maps

Table 1: Ground Motion Parameter Changes based on 975 Year Shaking.

Region	City (Site Location)	Uniform-Hazard, 975 Years			
		S_S (g)	Change	Risk	RP (yrs)
Southern California	Los Angeles	1.50	-24%	1.9%	975
	Long Beach	1.23	-27%	2.0%	975
	Irvine	0.92	-26%	2.1%	975
	Riverside	1.23	-18%	2.0%	975
	San Bernardino	2.05	-12%	1.9%	975
	San Diego	1.11	-30%	2.0%	975
	Santa Barbara	1.59	-25%	1.9%	975
	Ventura	1.52	-25%	1.9%	975
Northern California	Oakland	1.79	-5%	1.9%	975
	Concord	2.03	-9%	1.9%	975
	Sacramento	0.42	-25%	2.1%	975
	San Francisco	1.40	-7%	1.9%	975
	San Jose	1.72	15%	2.0%	975

	Santa Cruz	1.25	-22%	1.9%	975
	Vallejo	1.68	12%	1.9%	975
	Santa Rosa	2.01	-17%	1.9%	975
Pac. NW	Seattle	1.06	-24%	1.9%	975
	Portland	0.63	-29%	2.0%	975
Other WUS	Salt Lake City	1.05	-32%	2.0%	975
	Denver	0.13	-38%	2.3%	974
	Reno	1.14	-22%	1.9%	975
	Las Vegas	0.37	-43%	2.4%	975
CEUS	St. Louis	0.32	-31%	2.0%	975
	Atlanta	0.13	-30%	2.1%	975
	Memphis	0.69	-33%	2.1%	975
	Charleston	0.88	-38%	2.2%	975
	Washington, DC	0.08	-38%	2.2%	974
	Boston	0.16	-41%	2.3%	975
	New York	0.16	-45%	2.4%	975

Figure 9 shows the distribution of notional risk of collapse for structures that would be attained if a uniform hazard with a 1,500 year return period were selected. As can be seen this would approximate 1.5% in 50 years for most structures. Figure 10 presents the ratio between the values that would be obtained under 1,500 year maps to the present specified design ground motion values based on 2018 IBC maps. In most parts of the country, the ground motion parameters would be reduced because and the risk of collapse would increase. However, in portions of California that are currently based on the deterministic cap ground motion parameters would increase somewhat. Table 2 summarizes this data.

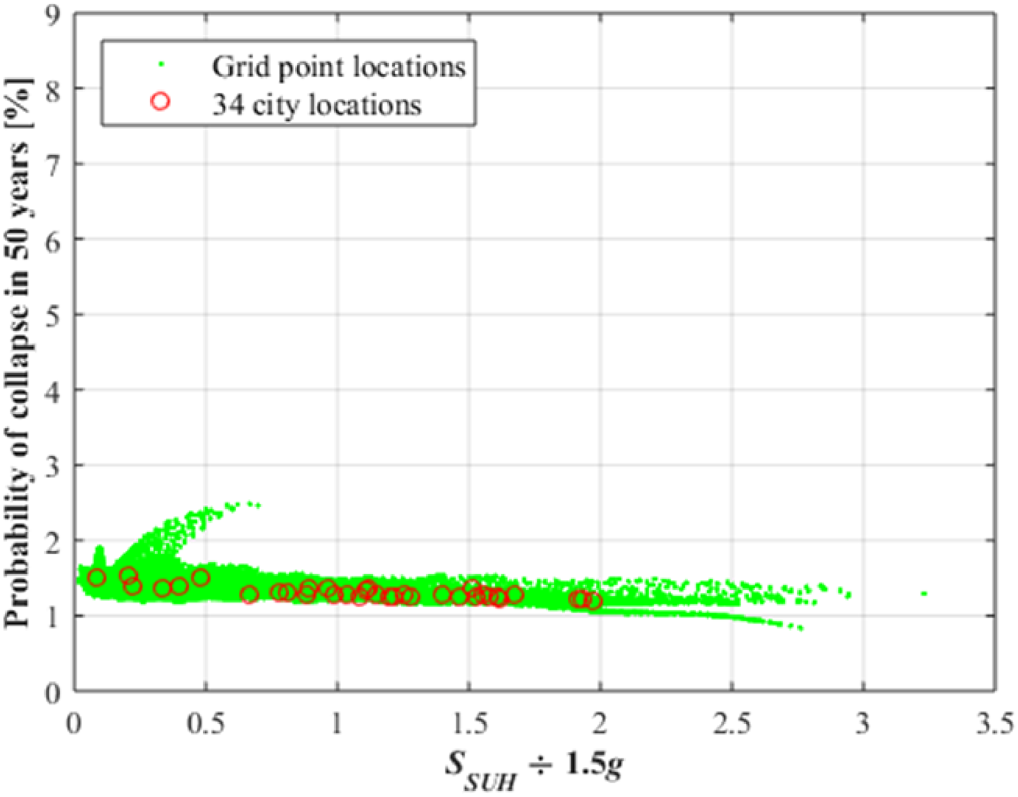

Figure 9 – Distribution of notional collapse risk, 1,500-year shaking

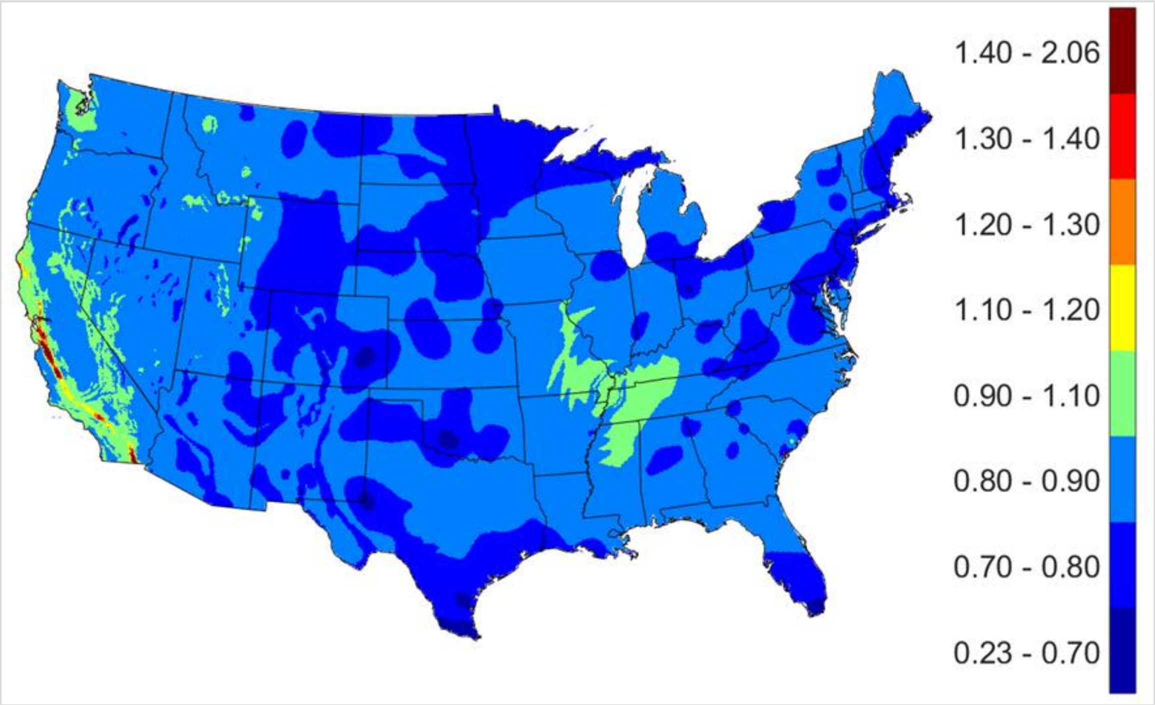

Figure 10 – Ratio of design values (S_s) 1,500-year motion to 2018 IBC maps

Table 2: Ground Motion Parameter Changes based on 1500 Year Shaking.

Region	City (Site Location)	Uniform-Hazard, 1500 Years			
		S_S (g)	Change	Risk	RP (yrs)
Southern California	Los Angeles	1.80	-9%	1.3%	1,500
	Long Beach	1.51	-10%	1.3%	1,500
	Irvine	1.10	-12%	1.4%	1,500
	Riverside	1.43	-5%	1.4%	1,500
	San Bernardino	2.43	5%	1.2%	1,500
	San Diego	1.42	-10%	1.2%	1,500
	Santa Barbara	1.94	-9%	1.2%	1,500
	Ventura	1.84	-9%	1.2%	1,500
Northern California	Oakland	2.10	11%	1.3%	1,500
	Concord	2.43	10%	1.2%	1,500
	Sacramento	0.50	-12%	1.4%	1,500
	San Francisco	1.64	9%	1.3%	1,500
	San Jose	1.96	30%	1.4%	1,500
	Santa Cruz	1.46	-9%	1.3%	1,500
	Vallejo	1.95	30%	1.3%	1,500
	Santa Rosa	2.45	2%	1.2%	1,500
Pac. NW	Seattle	1.26	-10%	1.3%	1,500
	Portland	0.79	-11%	1.3%	1,500
Other WUS	Salt Lake City	1.38	-11%	1.3%	1,500
	Denver	0.17	-21%	1.5%	1,500
	Reno	1.34	-8%	1.3%	1,500
	Las Vegas	0.50	-23%	1.5%	1,500
CEUS	St. Louis	0.40	-14%	1.4%	1,500
	Atlanta	0.16	-15%	1.4%	1,500
	Memphis	0.89	-13%	1.3%	1,500
	Charleston	1.21	-15%	1.3%	1,500
	Washington, DC	0.11	-20%	1.5%	1,500
	Boston	0.21	-22%	1.5%	1,500
	New York	0.22	-25%	1.5%	1,500

The sentiment within the Project 17 Committee is currently split between not making any change and moving to a uniform hazard approach. The main argument in favor of change is to keep consistency with what has been done, as a response to the concerns about ground motion variability. The main argument in favor of moving to a uniform hazard is the simplification in the ground motion definition, which would remove the need for a deterministic cap and the additional step of risk adjusting the hazard parameters, while still maintaining a somewhat uniform risk.

SEISMIC DESIGN CATEGORY DETERMINATION

Some engineers have suggested that changes to design ground motions between map editions might be less problematic, if the Seismic Design Categories remained more stable during relatively modest changes. The Seismic Design Category concept, developed as part of Project 97, was created to recognize that as ground motion intensity increased, progressively more stringent measures were necessary to provide adequate protection of structures. Loosely, the Seismic Design Category gradation were based on the anticipated Modified Mercalli Intensity (MMI) of MCE ground motions. The MMI scale is a qualitative rating of earthquake effects that ranges from I (ground motion not felt) to X (total destruction). The Seismic Design Categories were assigned as follows:

- SDC A MCE motion is MMI V or smaller - No real damage
- SDC B MCE motion is MMI VI Light nonstructural damage
- SDC C MCE motion is MMI VII - Hazardous nonstructural damage
- SDC D MCE motion is MMI VIII - Hazardous damage to susceptible structures
- SDC E MCE motion is MMI IX - Hazardous damage to robust structures

Progressively more stringent requirements were established for each SDC increasing in intensity. Requirements ranged from tying all elements of the structure together and having a complete lateral force resisting system, to nonstructural component anchorage, to criteria limiting types of structural systems and irregularities that could be designed in a region, requiring construction details that could provide ductile behavior and requiring complex analytical techniques to predict structure response.

During development of SDCs, the Project ’97 team felt it important to include site class effects in determination of SDC as site class could have significant impact on the intensity and destructive potential of ground shaking.

Professional Practice

Seismic Design Category (SDC) is central to structural seismic provisions and is used to determine a range of detailing requirements and limitations. From structural elements and design techniques to non-structural bracing and performance criteria, SDC can significantly impact final design and construction costs.

In addition to the economic impacts, there are significant life-safety implications as well. Ideally, every engineer should be well versed in seismic, wind, flood, and other extreme design condition procedures. And every governing jurisdiction should be fluent enough in the detailing requirements to competently perform plans review and site inspections. However, maintaining a competent level of expertise becomes more challenging as each successive design standard increases in complexity. Add in oscillating changes to SDC and related seismic design provisions, and each successive standard brings a potentially steep learning curve to the industry.

The reality is that engineers tend to specialize in the extreme events that dominate regions in which they routinely practice. Through sheer experience, governing jurisdictions similarly specialize in those same extreme events. For seismic design, this results in a measurable percentage of the local profession which might not possess the expertise required to apply more stringent seismic provisions, if seismic activity has not historically been the controlling event in their region. As observed in professional practice, sudden application of more stringent seismic requirements in an area not accustomed to seismic design results in one of the following:

1) Demand increases exponentially on local engineers competent in seismic design with a corresponding increase in project delivery times and design fees.
2) Projects go to national and multi-national firms with access to non-regional expertise, instead of local firms.
3) Projects are designed by inexperienced engineers and likely do not meet minimum life-safety performance requirements for design seismic events.
4) Local and State jurisdictions explore legislative amendments aimed at reducing new codes or preserving existing codes to avoid the cost implications of new seismic design provisions.

Stabilizing Seismic Design Category (SDC)

As previously stated, SDC is tied to the anticipated ground shaking intensity (MMI). As the ground shaking intensity increases, SDC and related detailing and design requirements increase correspondingly. Simply stated, the harder the ground shakes, the more attention is required to design and detailing to minimize loss of life and other undesirable societal impacts.

Oscillating changes between SDCs in successive standards generates frustration for the engineer, anger by owners at vacillating costs, lack of confidence in the standard by governing jurisdictions, and a dangerous period during which newly classified “high seismic” regions are learning how to implement the standards.

Considered approaches to stabilizing oscillations in ground motion changes have included but are not limited to:

- Updating mapped ground motions only for values that change by more than a specified percentage.
- Incrementally changing ground motions across multiple map editions to avoid sudden significant jumps.
- Changing the specified return period.
- Changing the acceptable collapse risk.
- Changing the reporting accuracy of ground motion values.

Each of these approaches modify the methods used to determine MCE_R ground motion values S_s and S_1. S_s and S_1, in conjunction with soil site class and building occupancy, are used to determine SDC. The theory is that if the MCE_R values can be stabilized, the seismic design requirements will follow.

A suggested approach being explored by Project 17 is to stabilize the SDCs instead of the mapped ground motions. The current relationship between S_S/S_1 and SDC, as provided in Chapter 11 of ASCE 7, would be loosened but not completely severed. The concept is to allow SDCs to remain responsive to major scientific changes in the USGS Hazard Model without being overly sensitive to modest numerical changes in the latest USGS Hazard Model.

Suggested Approach

Generate an SDC[1] map that relies on geographical and geological factors (including soil site class), but is unrelated to building type and occupancy. Minimum base design requirements and limitations would be imposed based on this SDC and should not be lowered within the designated geographical region. Building type, occupancy, and collapse risk should still be considered at a later step in the design process and might increase, but not decrease, design considerations.

The SDC map would be generated based on the last 3 official USGS Hazard Models (not MCE_R values). As USGS Hazard Models are developed, the new science would be incorporated but with equal weight given to the previous two established and fully vetted Hazard Models to minimize oscillations in ground motion values. The following is the process under consideration:

- Modify data points within each of the three hazard models by the soil site factors corresponding with the appropriate NEHRP version values.
- Normalize resulting values within each of the three hazard models to a chosen lat/long position.
- Average the three normalized values for each data point.
- Rank the averaged values into 4 or 5 equal bins.
    - The lowest value bin corresponds with the lowest geological seismic hazard. The highest value bin corresponds with the highest geological seismic hazard.
- Contour map the bins nationally for the new SDC map.

Still to be considered:

- Contour boundaries would adjust slightly with new Hazard Models. Criteria must be developed that would establish when numerical changes are significant enough to move the contours.
- Step functions would still exist at contour boundaries. Although brief discussions have been held regarding possible transition regions from one contour to the next, the general opinion is such transition regions would be difficult to establish and police through adoption, design, and enforcement.
- Bin relationships with MMI must be established, with corresponding definitions of expected degrees of damage.
    - The degree of damage definitions currently assigned to SDCs, as listed under the **Stability of Mapped Values** section above, are being reviewed by a separate Issue Team.
    - The number and size of bins in this suggested approach might be modified based on any proposals from the Issue Team regarding SDC definitions.

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[1] The name, SDC, which refers to the existing Seismic Design Category, would ultimately be changed for clarity, as required.

Geographically, potential ground shaking intensity does not change with successive standard versions. Only the scientific understanding and representation of that potential changes as new research and data are considered. Scientific understanding will continue to evolve, and the ground motion values will continue to change with updated GMPEs and data. However, the relative geological seismic hazard will generally remain unchanged between geographical locations. For example: San Francisco, CA will always remain a higher seismic hazard than Minneapolis, MN, barring a major scientific discovery of a new fault.

For Reference

The Uniform Building Code zone concept was based on a probability of occurrence of a level of ground motion on a rock site. Seismic Zones ranged from 0-4, with 0 the weakest and 4 the strongest ground motion. Zones were independent of building type and occupancy.

The *NEHRP Provisions* (1991, 1994) next introduced Seismic Performance Categories (SPC). SPCs ranged from A-E, with A the weakest and E the strongest seismic risk. The probability of ground motion occurrence on rock was still used with consideration now given to building type and occupancy. Therefore, structures with a higher potential for loss of life were pushed into higher SPCs, as compared to less important structures on the same site.

The *NEHRP Provisions* (1997) then introduced Seismic Design Categories (SDC). Building on Zone and SPC fundamentals, SDCs introduced soil type factors to further modify the design ground motion, with acceptable risk subsequently included. SDCs ranged from A-F, with A the lowest and F the highest seismic risk.

PRESENTATION: PROJECT 17 WORKSHOP ON DESIGN VALUE MAPPING

by

Ron Hamburger[1], SE, PE, SECB

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[1] Senior Principal, Simpson Gumpertz & Heger, San Francisco, CA, main committee Chair of Project 17.

Project
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Building Seismic Safety Council

Project 17 Workshop on Design Value Mapping Introduction

Ronald O. Hamburger, SE Project 17 Chair

SIMPSON GUMPERTZ & HEGER
Engineering of Structures
and Building Enclosures

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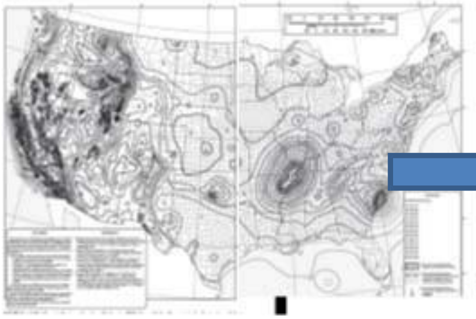
science for a changing world

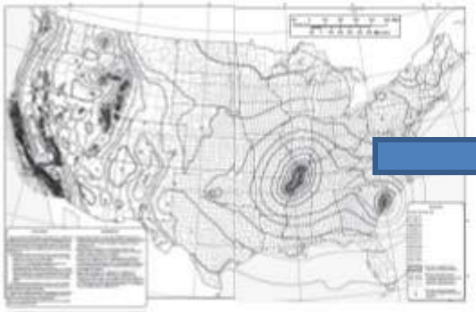
TOPICS

- Background
- Project 17 Purpose
- Key Issues
- Workshop Goals

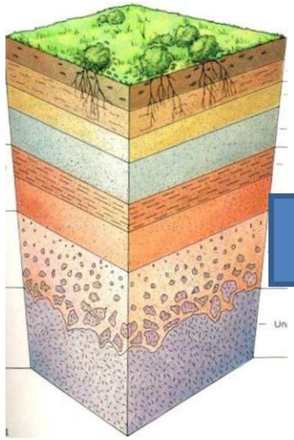
Seismic Design Value Maps



S_S



S_1



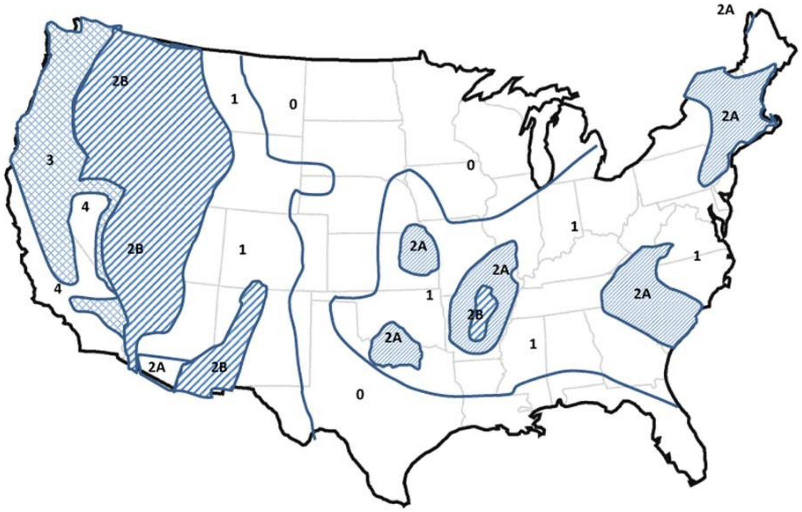
S_{DS}
S_{D1}

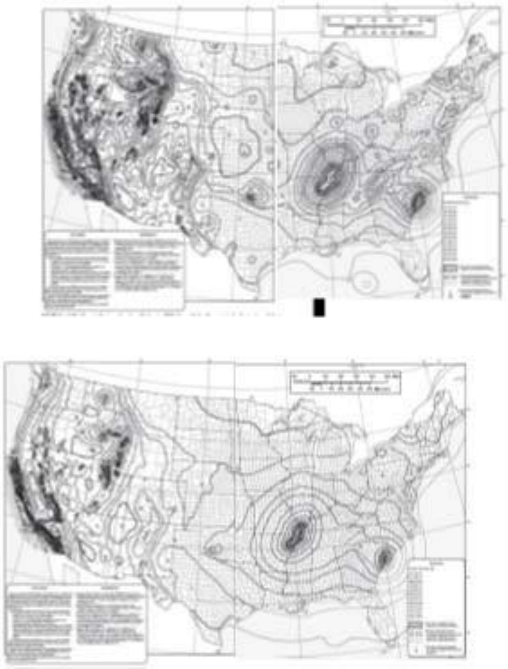
Required Strength

Seismic Design Category

- Permissible Systems
- Required Detailing
- Permissible Analysis
- Nonstructural
- Inspection

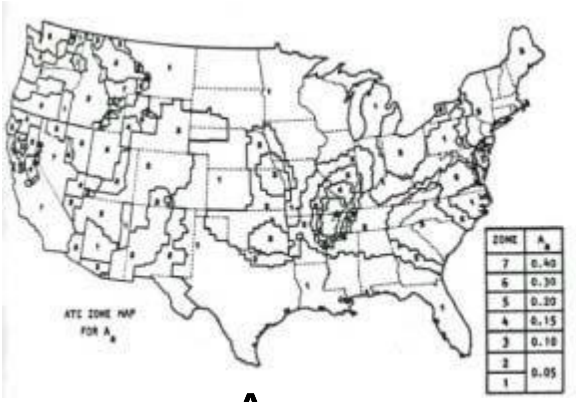
Evolution of the Maps



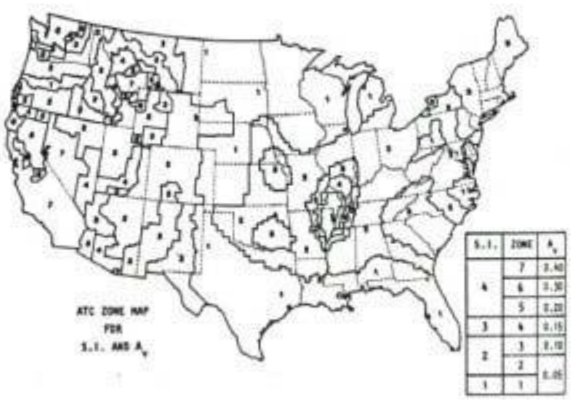


- **UBC maps**
  - Qualitatively represented seismic hazard
  - Based on historic seismicity
    - Grossly mis-represented hazard in some regions
    - Remained relatively stable
  - Seismic Design Categories based on zone and independent of site class effects or occupancy

ATC3-06



A_a



A_v

- **Mapped short period and long period parameters**
  - Aa – “effective” peak acceleration
  - Av – “effective” velocity-related acceleration
  - “475 year” (10%-50 year) motion
  - Informed UBC later UBC maps
  - Adopted by NEHRP Provisions – BOCA and SBCCI codes

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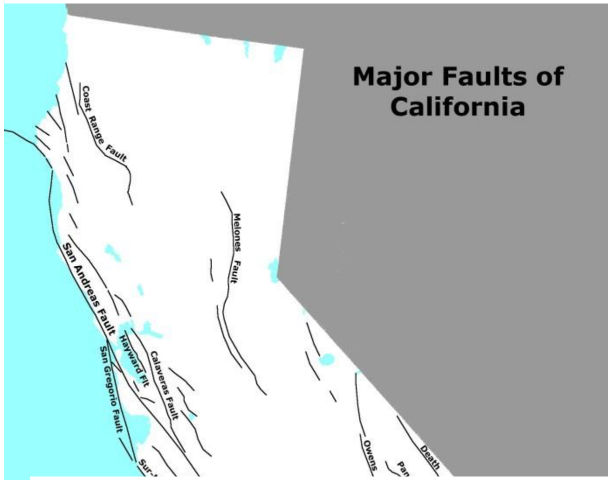
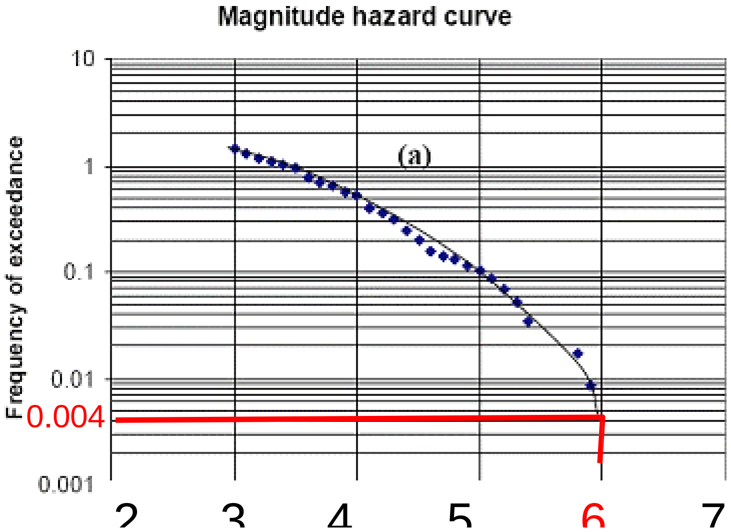
Project ‘97

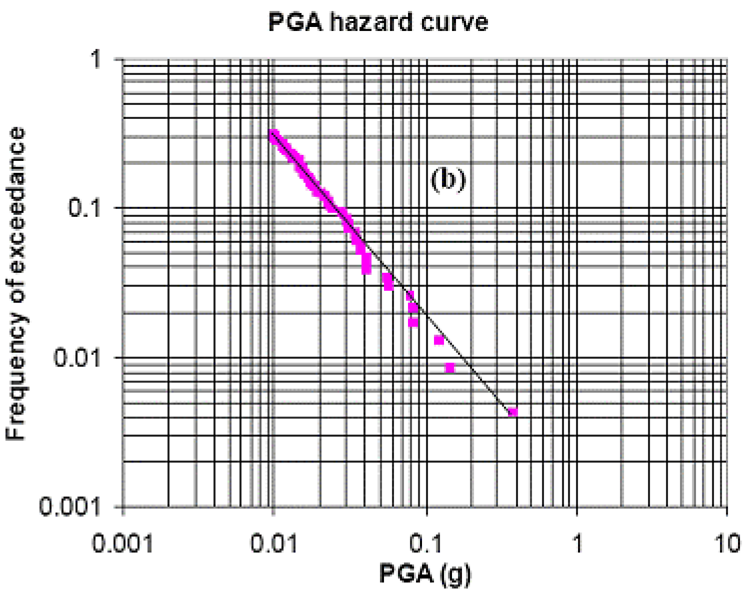
- **Purpose:**
  - Adopt nationally applicable seismic hazard maps in anticipation of the formation of ICC and publication of IBC
  - Avoid a foreseeable urban disaster such as the 1988 Armenia Earthquake

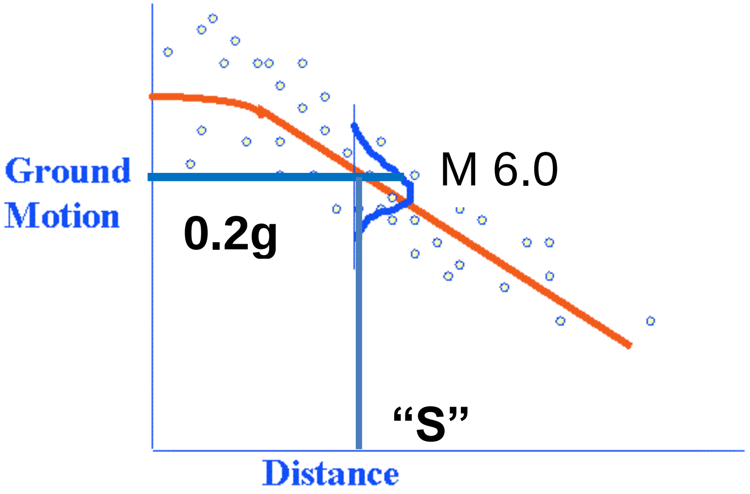
- **Hazard model**
  - Foreseeable urban disaster events had return periods ranging from:
    - 300 to 500 years in the west
    - 1,000 – 1,500 years in the east
      (now thought to be more like 500-1,000 years)

Seismic Hazard Process

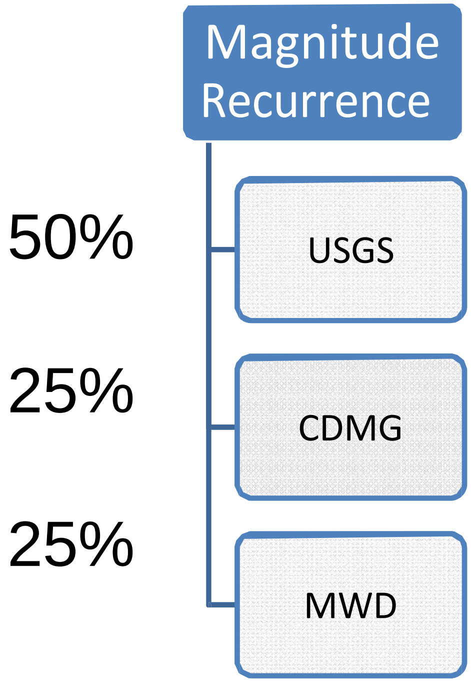








Seismic Hazard Process



Magnitude Recurrence

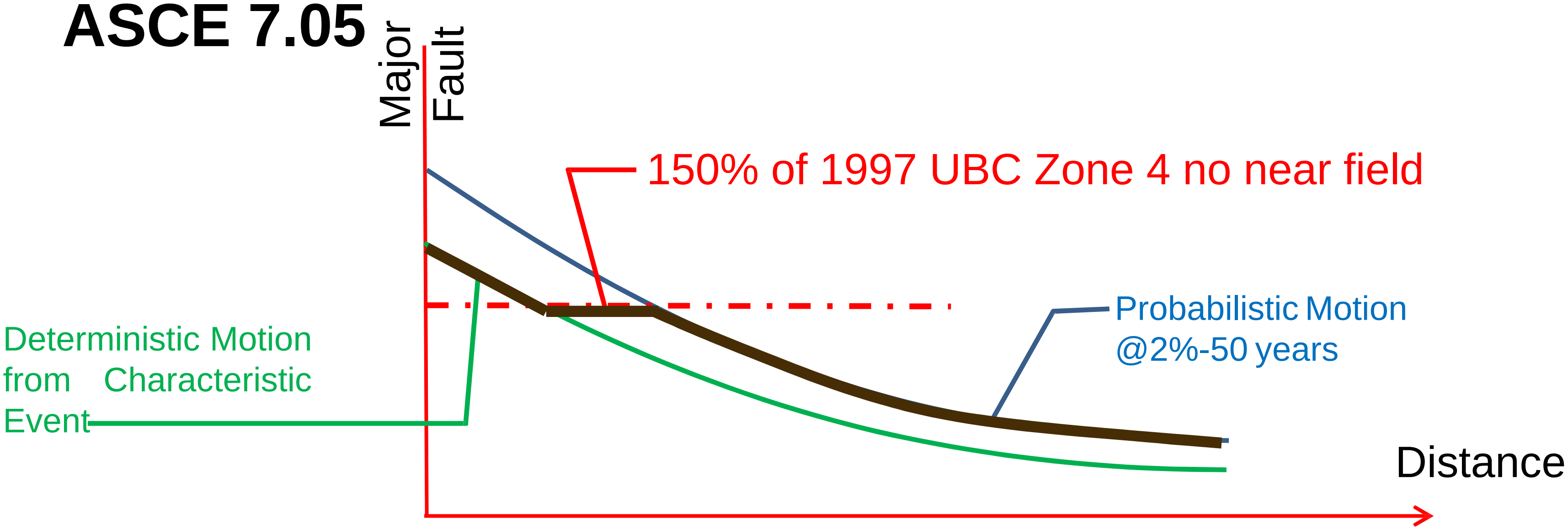
50% USGS

25% CDMG

25% MWD

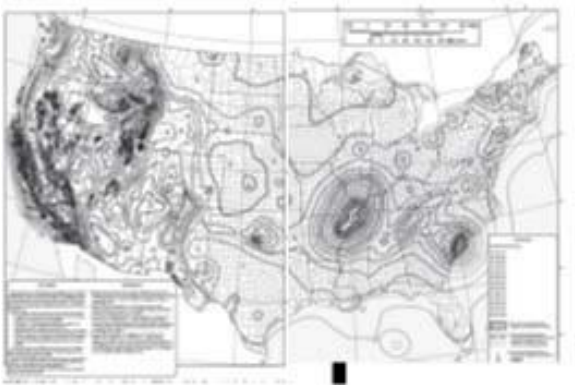
Final hazard is determined as sum over all faults, all magnitude recurrence relationships, all attenuation relationships (each with proper weighting)

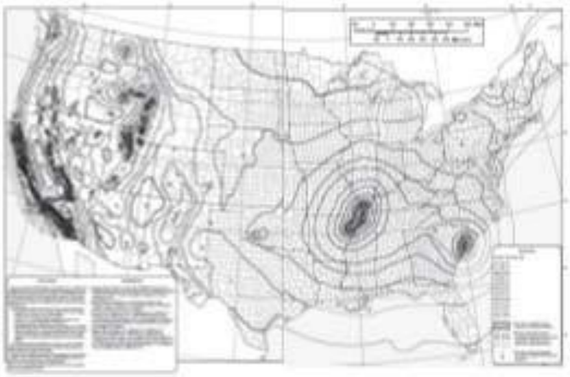
Maximum Considered Earthquake Shak ASCE 7.05



- MCE motion is 2%/50 year unless
  - 2%/50 year is > 150% 1997 UBC Zone 4
- Use greater of 150% of deterministic motion for maximum magnitude event on controlling fault, but not less than 150% 1997 UBC Zone 4
  - 150% deterministic approximately represents mean + 1σ

Project ‘97





- **MCE hazard level at 2,475 years (2%-50 yr)**
  - Introduced deterministic “cap” zones where probabilistic motion exceeded “practical” levels
- **Introduced S_{DS} and S_{D1} (2/3 site adusted MCE values) for design**
  - “Design” ground motion no longer had a specific probability of exceedance
- **Determination of Seismic Design Category based on site adjusted values + occupancy**

Project ‘97

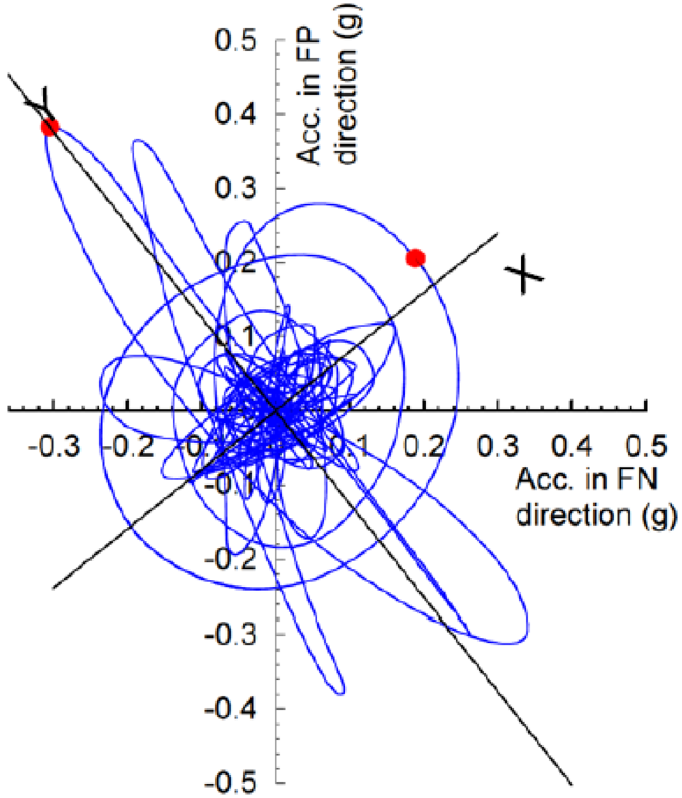
- **Maps used in 2000, 2003 IBC; ASCE 7-02**

- USGS updated seismic hazard model in 2003
- Updated maps adopted by ASCE 7-05
  - Mapped values changed +/-10%-20%
  - SDCs changed in some places
  - Adopted in IBC-2006, 2009

Project ‘07

- **Sponsored by FEMA/USGS to “Take a fresh look” after 10 years**
- New paradigm
  - PEER Next Generation Attenuation (NGA) Project
    - Substantially reduced ground motions in long period from large magnitude earthquakes
    - Reduced ground motions in the west
    - No impact in the east
    - Site soil factors “different”
- **Resolutions**
  - Move from “uniform hazard” 2%/50 year ground motions, to “uniform risk” 1%/50 year collapse probability
  - Move from “Geomean” to “Max Direction” motions

Ground Motion Directionality



Structural engineers on the committee felt GM had no particular relevance and felt more comfortable designing for the maximum component

- Typical ground motion recording includes
  - X component
  - Y component

  oriented at 90°
- Ground Motion Prediction Models use "geomean"

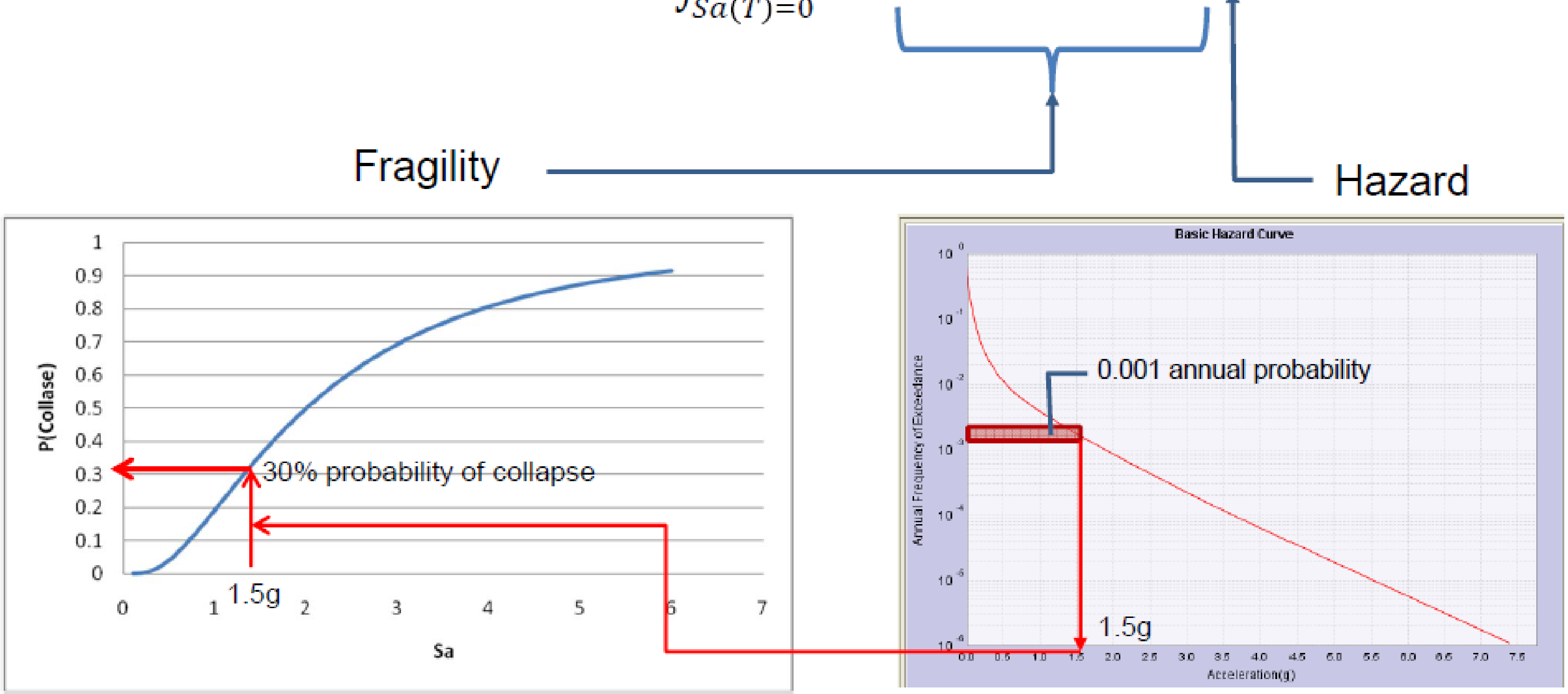
$$S_{a-gm} = \sqrt{(S_{a-X})(S_{a-Y})}$$

- For this motion:

X=0.28g, Y=0.5g, GM=0.37g

Seismic Risk = Risk of Collapse

$$P(collapse) = \#\text{ of collapses per yr} = \int_{Sa(T)=0}^{Sa(T)=\infty} P(collapse|Sa(T))P(S_a(T)d\lambda)$$

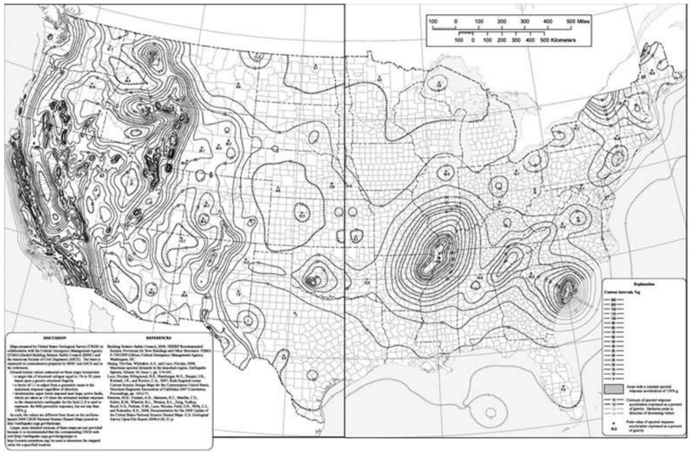


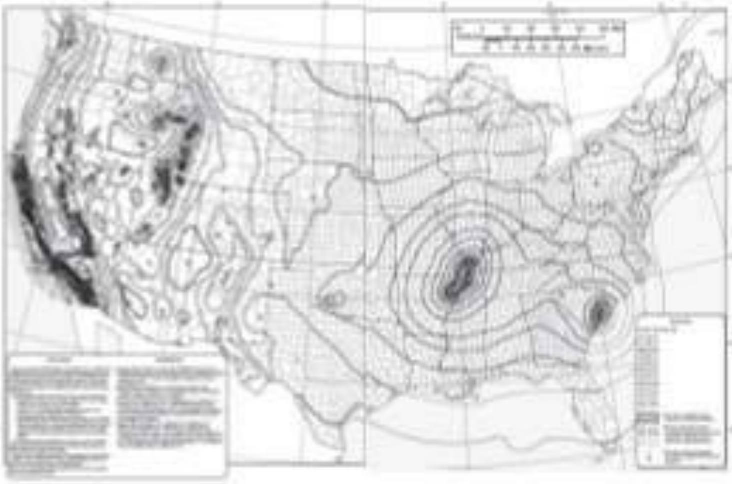
$$Annual\ Collapses\ at\ 1.5g = \frac{.001}{year} * 0.3prob\ given\ 1.5g$$

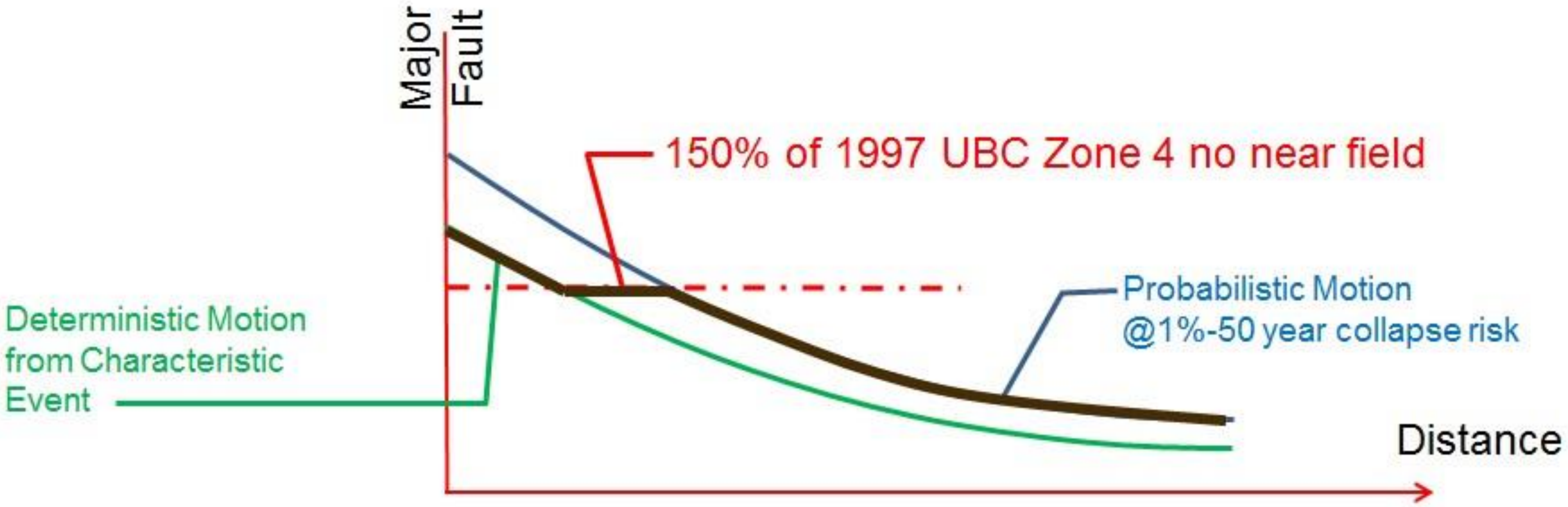
$$= 0.0003/year$$

San Francisco 1.64 9% 1.3% 1,500

Project ‘07



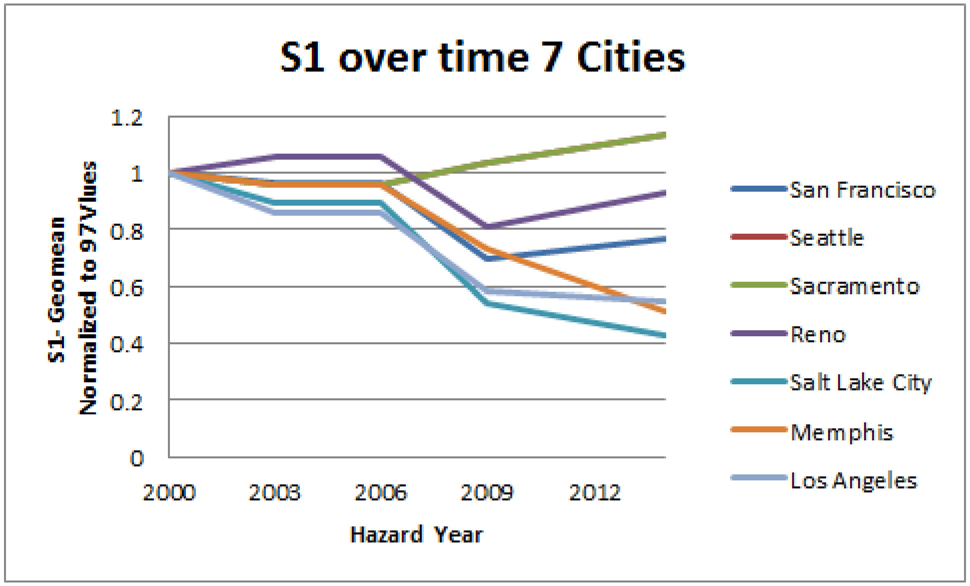



Major Fault
150% of 1997 UBC Zone 4 no near field
Probabilistic Motion
@1%-50 year collapse risk
Deterministic Motion from Characteristic Event
Distance

Project ‘07

- **Adopted by ASCE 7-10**
  - Basis for IBC 2012, IBC 2015
- **2014 USGS updated the hazard model to include:**
  - UCERF3
  - NGA II, III
- **BSSC – updated site class factors**
  - New maps and Site Classes adopted in ASCE 7-16
  - Appear in IBC 2018, 2021

Project 17



- **Goals:**
  - Take a “fresh look” after 20 years
  - Attempt to deal with instability in mapped values
  - Avoid a foreseeable earthquake disaster in the U.S.
    - Better knowledge of the hazard in east
    - Major events on New Madrid, Charleston zones more probable

Project 17 Committee

- Norm Abrahamson, UC Berkeley
- David Bonneville, Degenkolb Engineers
- C.B. Crouse, AECOM
- Dan Dolan, Washington State Univ.
- Ben Enfield, Seattle DCI
- Julie Furr, CSA Structures
- Ronald Hamburger, Simpson Gumpertz & Heger
- James Harris, J. R. Harris and Associates
- Jon Heintz, Applied Technology Council
- William Holmes, Rutherford & Chekene
- John Hooper, Magnusson Klemenic Associates
- Charles Kircher, Kircher & Associates
- Nico Luco, USGS
- Bob Pekelnicky, Degenkolb Engineers
- Senaz Resairean, USGS
- Jonathan Siu, Seattle DCI
- Greg Soules, CB&I
- Jonathan Stewart, UC Los Angeles

Decisions to date

- **The new maps will incorporate site class effects directly into the mapped parameters**
  - Simplify procedure
  - Account for NGA Site Class effects (ignored for 10 years)
  - F_a, F_v will disappear
  - Web lookup tool will directly comptue S_{MS}, S_{M1}, S_{DS}, S_{D1} considering site class
  - More site classes in D/E range
  - S_a will be provided at more periods

Goals of this workshop

- **Acceptable Risk**
  - Should we “stay the course with mapped values based on “uniform risk of collapse”?
  - Should we maintain the risk level ~2,000 years, or recognizing that eastern earthquakes are more probable, revise ~1,000 years?
  - Can we remove the deterministic caps and have a more honest “uniform” basis for maps?
- **Seismic Design Category Determination**
  - Should we continue to select seismic design category considering effect of site class?
  - Can we find a more stable way of assigning SDCs?
  - Do we have too many SDCs?

The Big Questions

1. Is the community willing to accept a major change in the mapped values?
2. Is it desirable to eliminate the “deterministic caps” and place the entire country at the same risk level?
3. Uniform risk of collapse or uniform hazard?
4. If uniform risk of collapse is to be maintained, can this be done approximately, while maintaining uniform hazard?
5. If ground motions are reduced in the mid-south and east (because big earthquakes happen more often) is this acceptable?
6. Can SDCs be assigned “regionally” rather than on a site and building-specific basis?
7. Can SDCs be assigned independent of Risk Category?

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Project 17 Workshop on Design Value Mapping

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U.S. DEPARTMENT OF HOMELAND SECURITY

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USGS
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PRESENTATION: PENDING UPDATES OF USGS NATIONAL SEISMIC HAZARD MODEL (NSHM)

by

Nicolas Luco[1], PhD

[1] Senior Research Structural Engineer, U.S. Geological Survey (USGS), Golden, CO.

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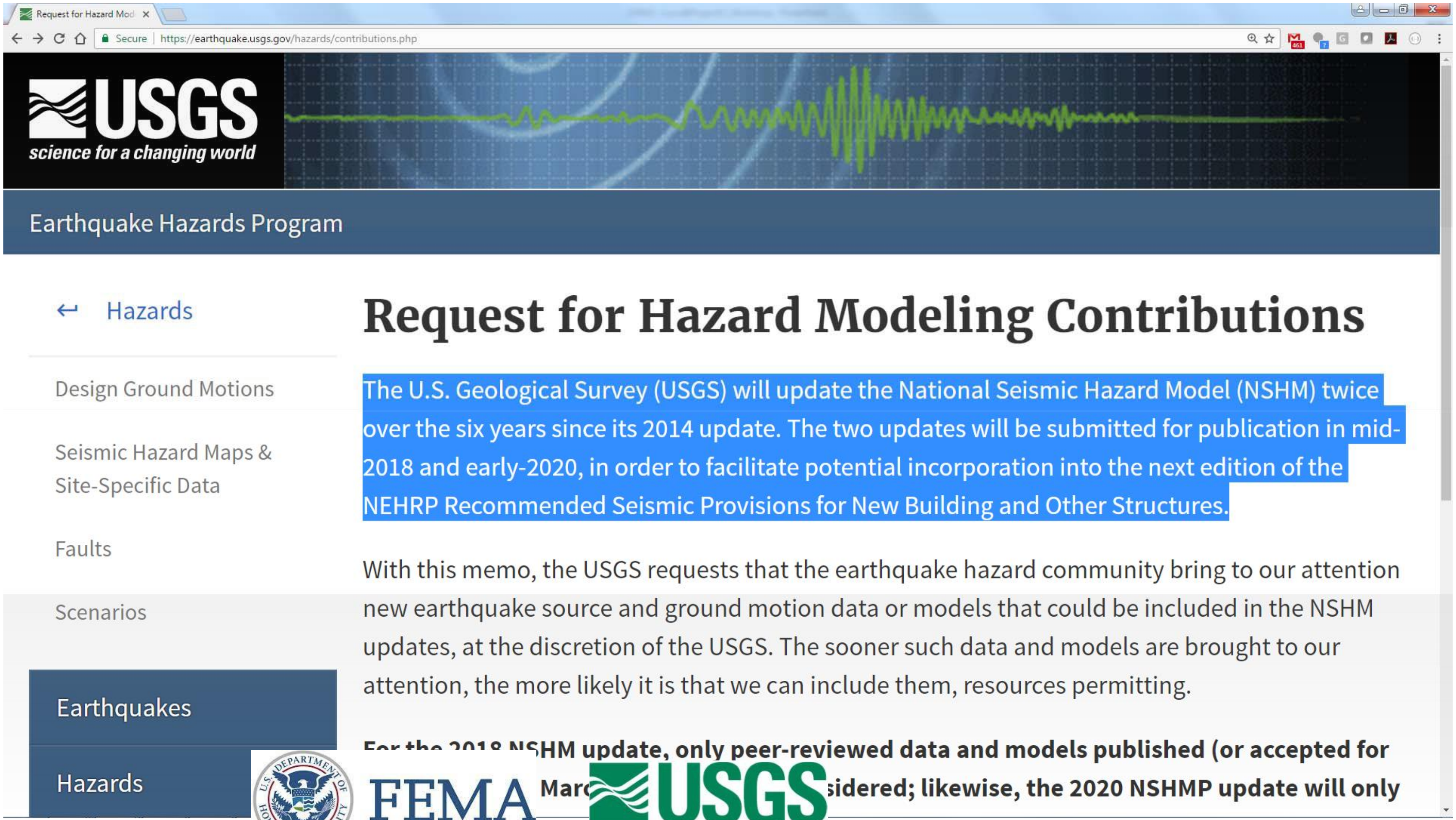
Pending Updates of USGS National Seismic Hazard Model (NSHM)

Nicolas Luco, PhD
Research Structural Engineer
U.S. Geological Survey (USGS), Golden, CO

nehrp FEMA USGS
science for a changing world

Schedule



Request for Hazard Modeling Contributions

The U.S. Geological Survey (USGS) will update the National Seismic Hazard Model (NSHM) twice over the six years since its 2014 update. The two updates will be submitted for publication in mid-2018 and early-2020, in order to facilitate potential incorporation into the next edition of the NEHRP Recommended Seismic Provisions for New Building and Other Structures.

With this memo, the USGS requests that the earthquake hazard community bring to our attention new earthquake source and ground motion data or models that could be included in the NSHM updates, at the discretion of the USGS. The sooner such data and models are brought to our attention, the more likely it is that we can include them, resources permitting.

For the 2018 NSHM update, only peer-reviewed data and models published (or accepted for Marc sidered; likewise, the 2020 NSHMP update will only

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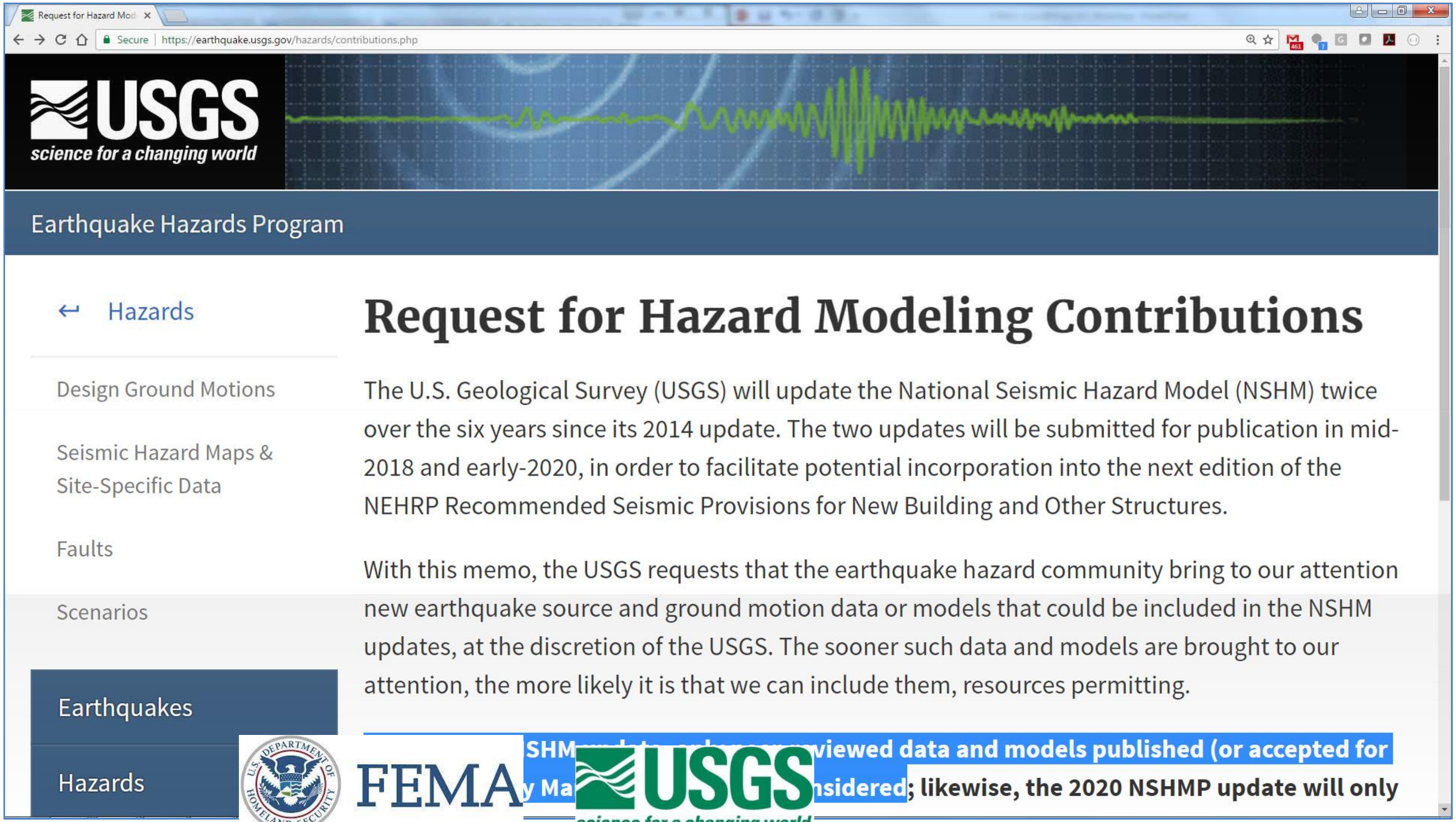
Schedule



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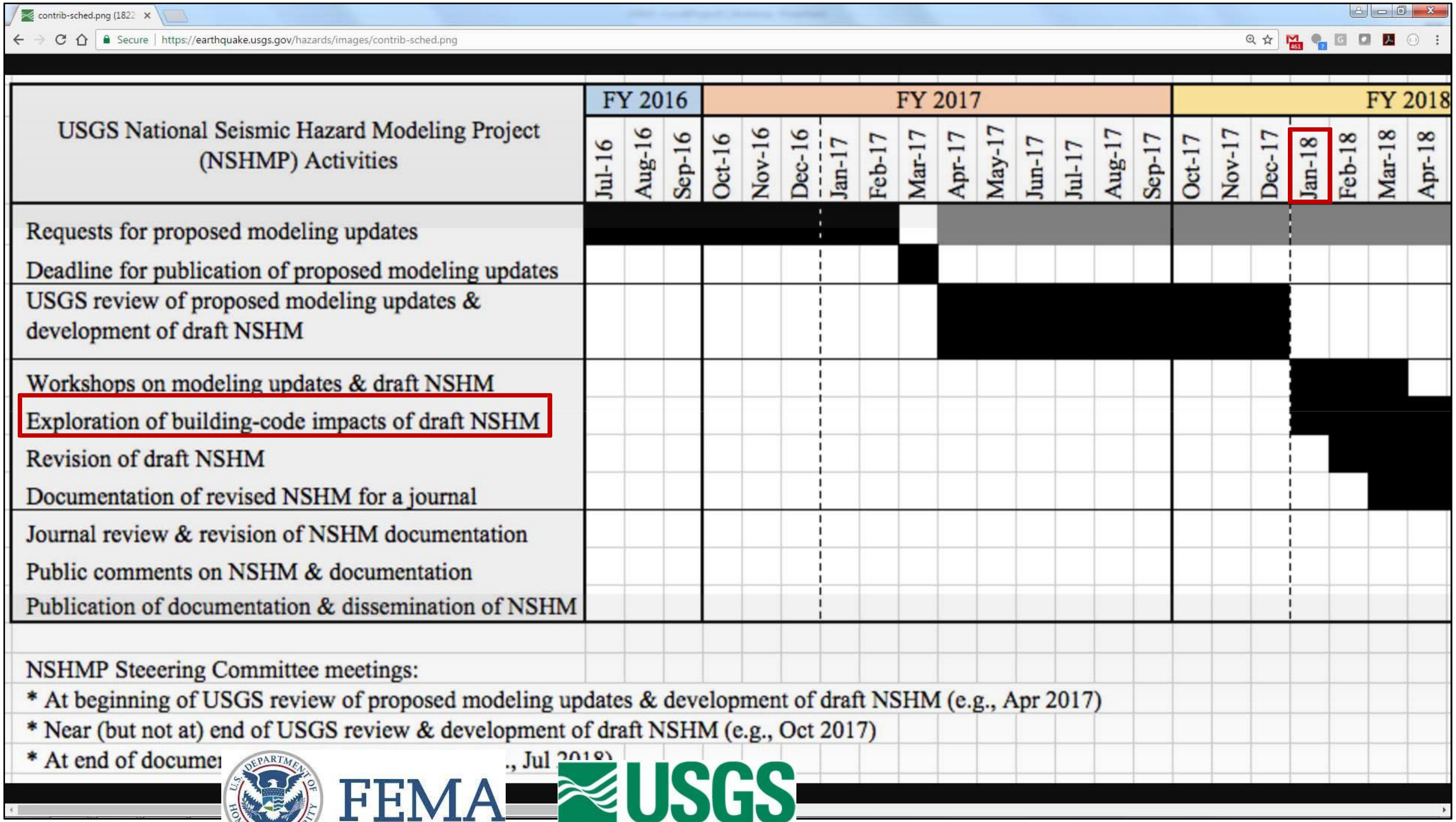
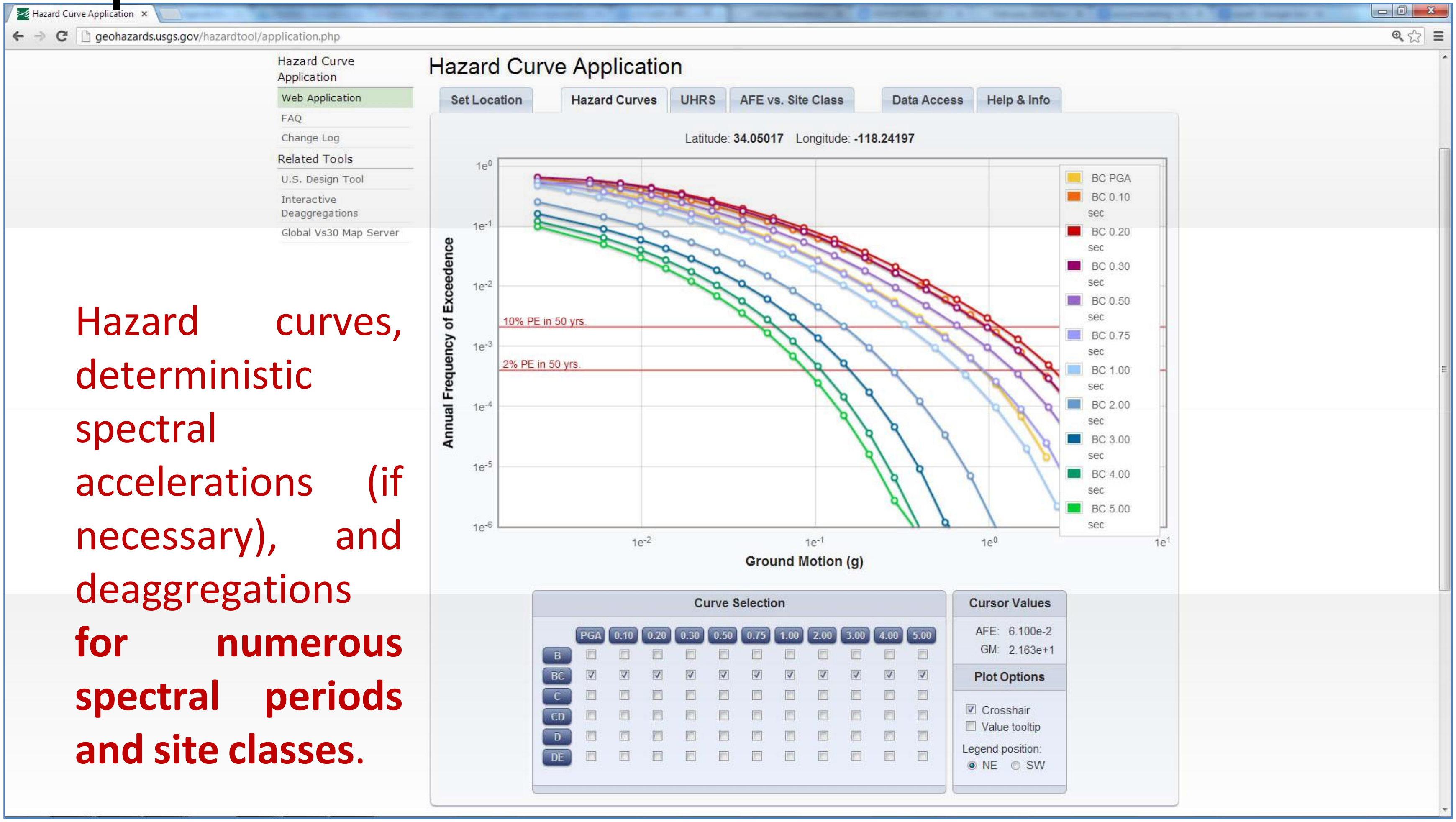
Schedule



USGS National Seismic Hazard Modeling Project (NSHMP) Activities	FY 2016			FY 2017												FY 2018						
	Jul-16	Aug-16	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17	Jan-18	Feb-18	Mar-18	Apr-18
Requests for proposed modeling updates	■	■	■	■	■	■	■	■		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Deadline for publication of proposed modeling updates									■													
USGS review of proposed modeling updates & development of draft NSHM										■	■	■	■	■	■	■	■	■				
Workshops on modeling updates & draft NSHM																			■	■	■	
Exploration of building-code impacts of draft NSHM																			■	■	■	■
Revision of draft NSHM																				■	■	■
Documentation of revised NSHM for a journal																					■	■
Journal review & revision of NSHM documentation																						
Public comments on NSHM & documentation																						
Publication of documentation & dissemination of NSHM																						

NSHMP Steering Committee meetings:
* At beginning of USGS review of proposed modeling updates & development of draft NSHM (e.g., Apr 2017)
* Near (but not at) end of USGS review & development of draft NSHM (e.g., Oct 2017)
* At end of documen ., Jul 2018)

Output



Hazard Curve Application

Latitude: **34.05017** Longitude: **-118.24197**

Curve Selection

	PGA	0.10	0.20	0.30	0.50	0.75	1.00	2.00	3.00	4.00	5.00
B	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
BC	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
C	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
CD	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
D	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
DE	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Cursor Values

AFE: 6.100e-2
GM: 2.163e+1

Plot Options

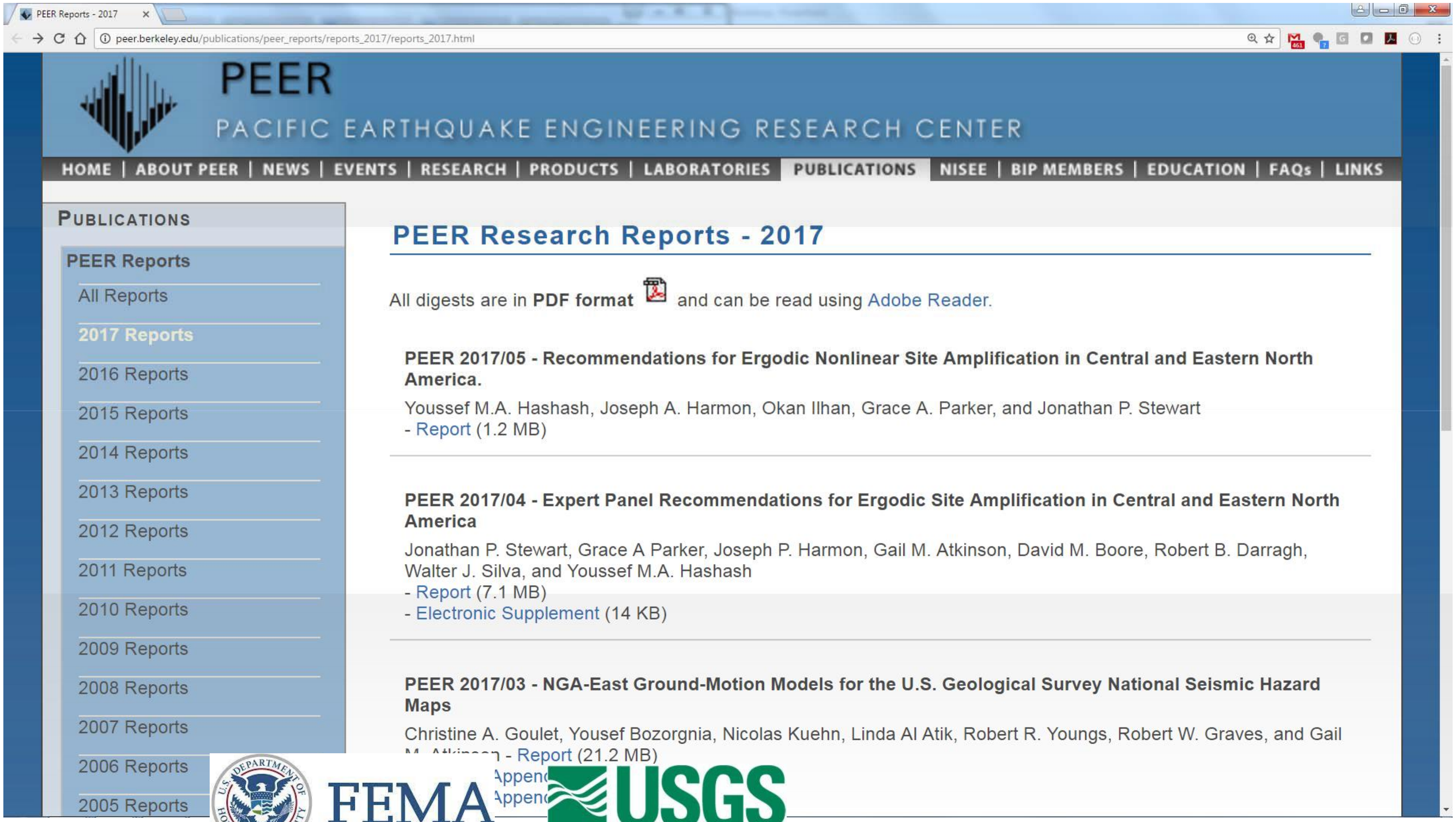
☑ Crosshair
☐ Value tooltip
Legend position:
● NE ○ SW

Hazard curves, deterministic spectral accelerations (if necessary), and deaggregations **for numerous spectral periods and site classes.**

Possible Updates for 2018 NSHM

Source Characterization	Ground Motion Characterization
California ❑ Minor (no UCERF4)	***Western U.S. Crustal*** ❑ Basin effects for L.A., S.F., S.L.C., Seattle ❑ Effects from CyberShake for L.A. ❑ Re-weighting (Idriss, 2013) ❑ Graizer & Kalkan, 2015
Intermountain West ❑ Working Group on Utah Earthquake Probabilities, 2016	
Pacific Northwest ❑ None/minor	***Cascadia Subduction*** ❑ Re-weighting (Atkinson & Boore, 2003) ❑ Basin effects for Seattle?
Central & Eastern U.S. ❑ Catalog of past earthquakes ❑ Induced seismicity exclusions	***Central & Eastern U.S.*** ❑ NGA-East ❑ Graizer, 2016

NGA-East



PEER Research Reports - 2017

All digests are in **PDF format** and can be read using Adobe Reader.

PEER 2017/05 - Recommendations for Ergodic Nonlinear Site Amplification in Central and Eastern North America.

Youssef M.A. Hashash, Joseph A. Harmon, Okan Ilhan, Grace A. Parker, and Jonathan P. Stewart
- Report (1.2 MB)

PEER 2017/04 - Expert Panel Recommendations for Ergodic Site Amplification in Central and Eastern North America

Jonathan P. Stewart, Grace A Parker, Joseph P. Harmon, Gail M. Atkinson, David M. Boore, Robert B. Darragh, Walter J. Silva, and Youssef M.A. Hashash
- Report (7.1 MB)
- Electronic Supplement (14 KB)

PEER 2017/03 - NGA-East Ground-Motion Models for the U.S. Geological Survey National Seismic Hazard Maps

Christine A. Goulet, Yousef Bozorgnia, Nicolas Kuehn, Linda Al Atik, Robert R. Youngs, Robert W. Graves, and Gail M. Atkinson - Report (21.2 MB)
Append
Append

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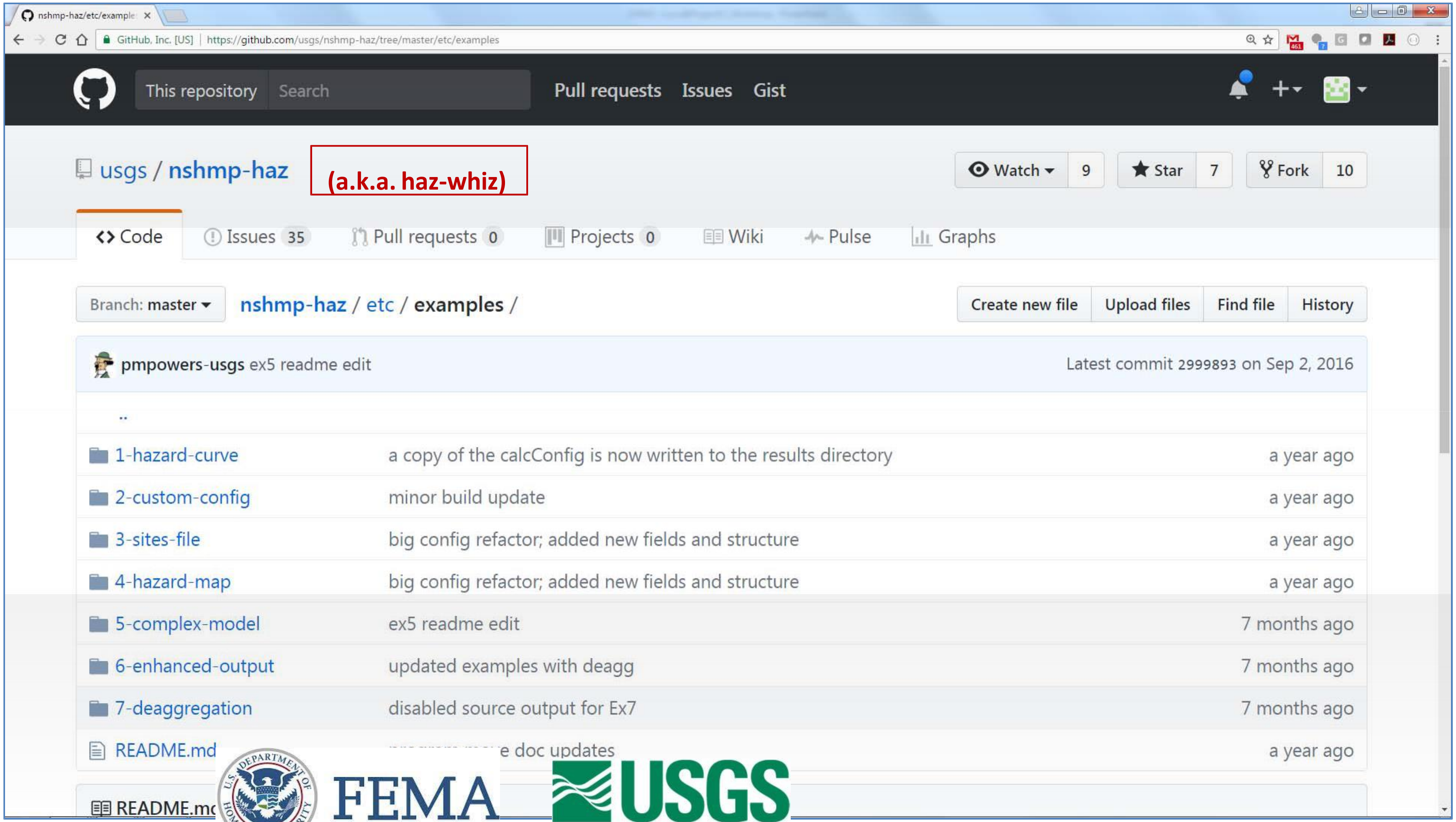
New Software



https://github.com/usgs/nshmp-haz/tree/master/etc/examples

usgs / **nshmp-haz** (a.k.a. haz-whiz)

nshmp-haz / etc / **examples** /

pmpowers-usgs ex5 readme edit — Latest commit 2999893 on Sep 2, 2016

..

1-hazard-curve	a copy of the calcConfig is now written to the results directory	a year ago
2-custom-config	minor build update	a year ago
3-sites-file	big config refactor; added new fields and structure	a year ago
4-hazard-map	big config refactor; added new fields and structure	a year ago
5-complex-model	ex5 readme edit	7 months ago
6-enhanced-output	updated examples with deagg	7 months ago
7-deaggregation	disabled source output for Ex7	7 months ago
README.md	e doc updates	a year ago

README.m

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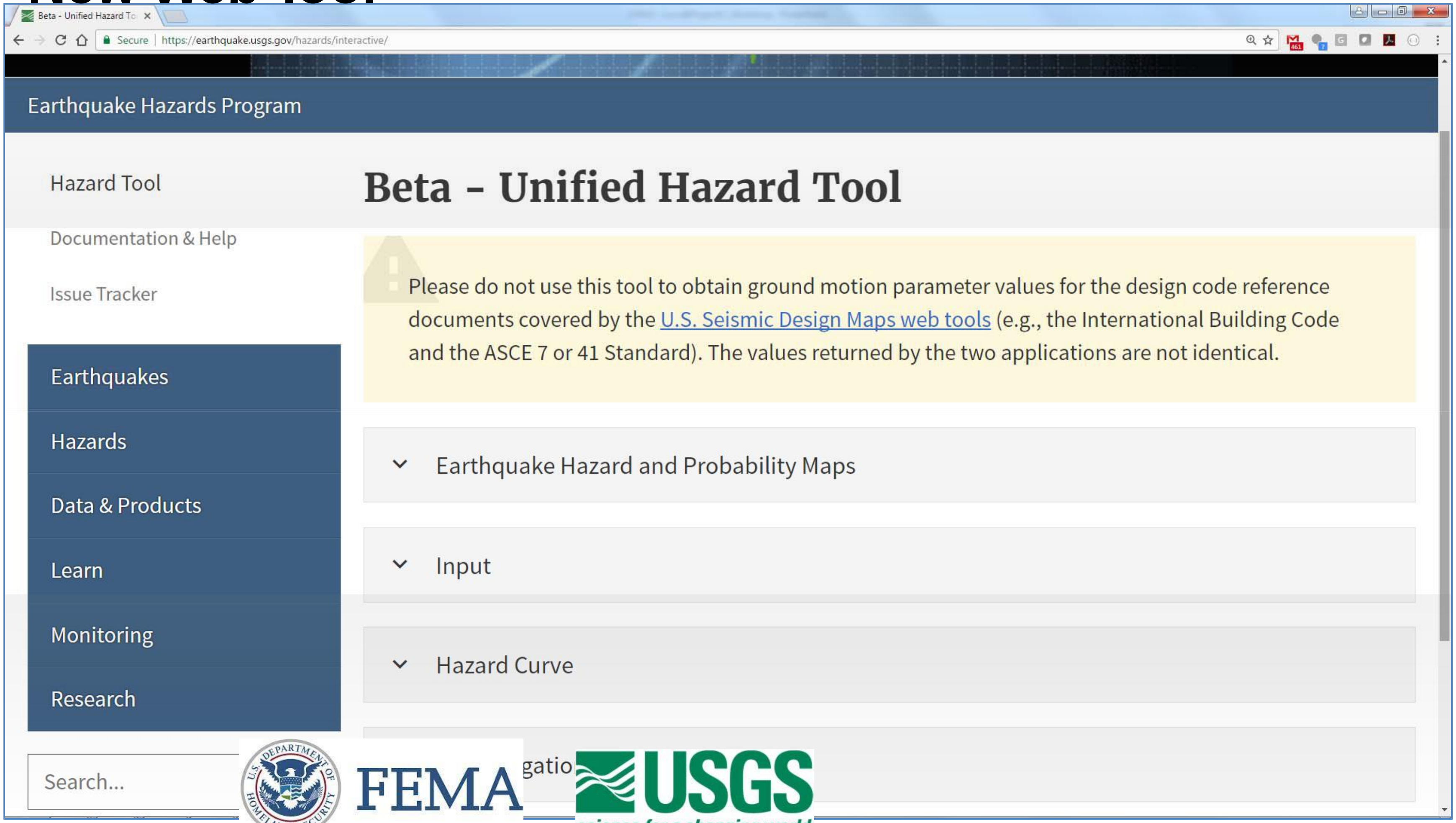
New Web Tool



Beta – Unified Hazard Tool

Please do not use this tool to obtain ground motion parameter values for the design code reference documents covered by the U.S. Seismic Design Maps web tools (e.g., the International Building Code and the ASCE 7 or 41 Standard). The values returned by the two applications are not identical.

Summary

- Draft of 2018 USGS National Seismic Hazard Model (NSHM) to be completed by end of 2017
- Output will include additional spectral periods (including longer periods) and site classes (softer)
- Numerous possible updates to source and ground motion characterizations, including NGA-East
- Updated NSHM will be developed with new software and disseminated with new web tool

- Draft of 2020 USGS NSHM by mid-2018

PRESENTATION: ACCEPTABLE RISK

by

Robert Pekelnicky[1], SE, PE

[1] Principal, Degenkolb Engineers, San Francisco, CA, Acceptable Risk work group chair of Project 17.

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Project 17 Workshop

Acceptable Risk

Robert Pekelnicky, PE, SE

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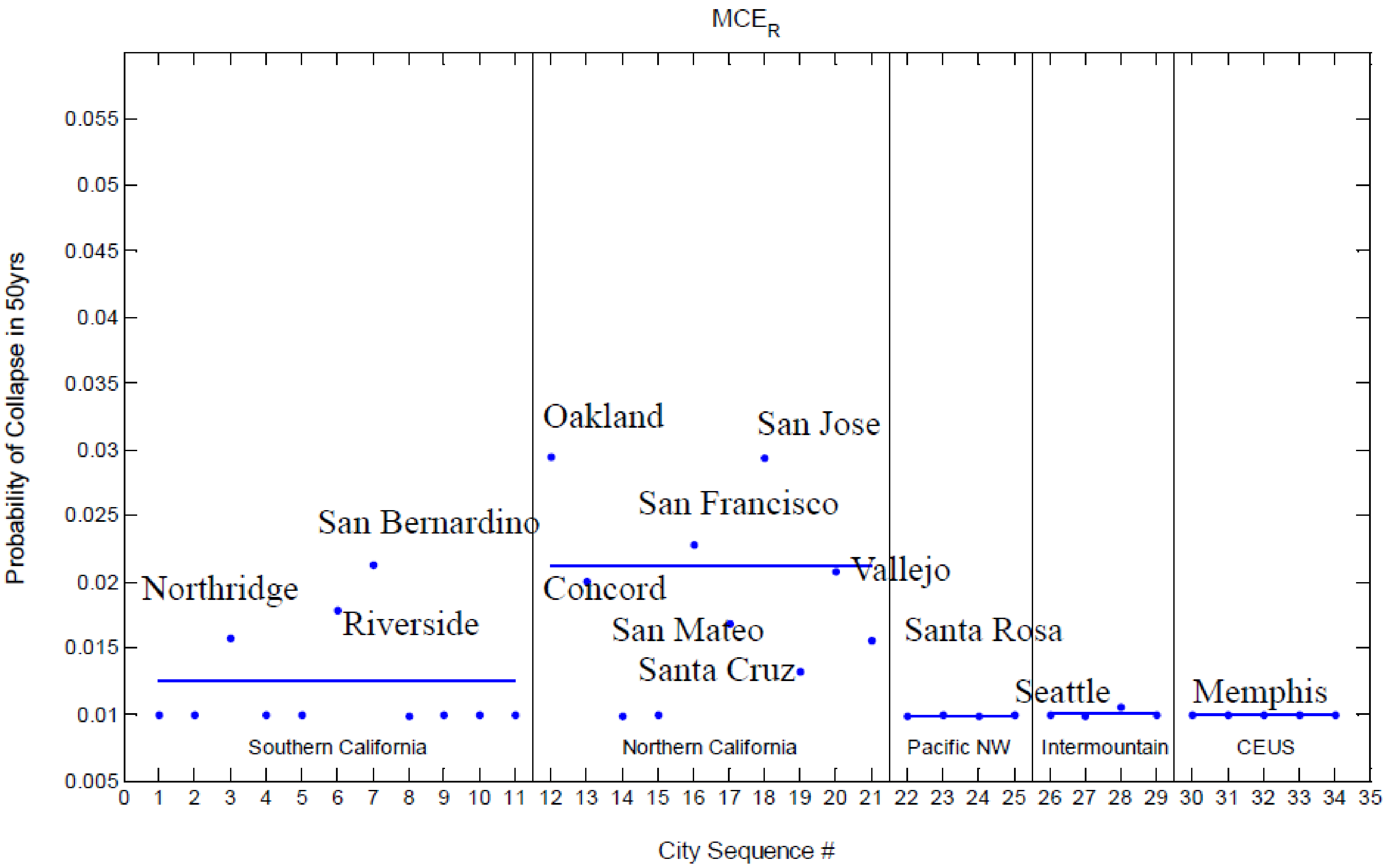
nehrp FEMA USGS
science for a changing world

Overview

This issue focuses on:

- 10% probability of “collapse” in the MCE_R
- Absolute risk target of 1% “collapse” risk in 50 years where the probabilistic, risk targeted hazard parameters govern
- In regions where the deterministic hazard governs over the probabilistic, the absolute risk of collapse is greater than 1%

Collapse Risk of MCE_R



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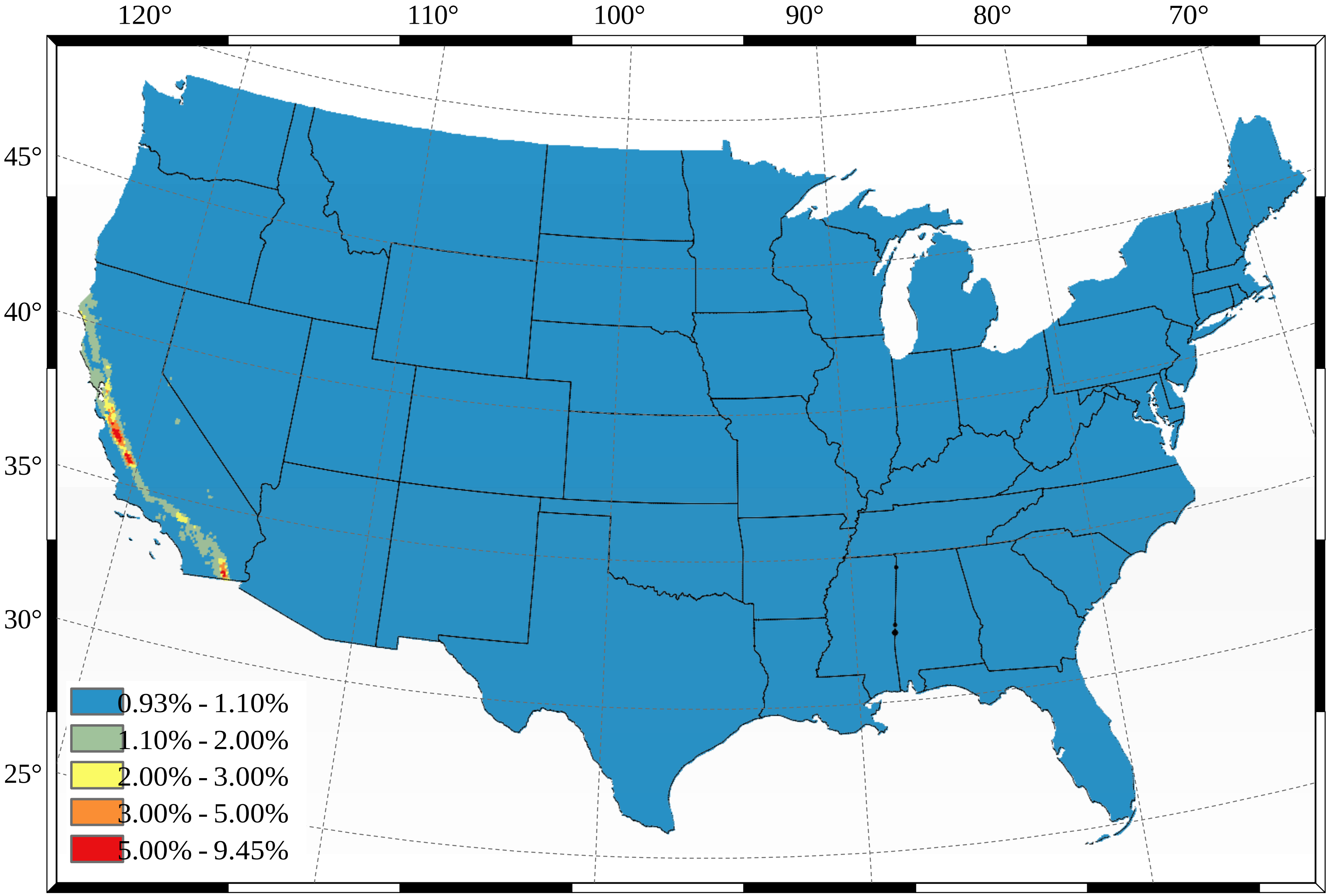
Fundamental Questions

Is there anywhere in the country where we are currently providing designs with an unacceptable risk of collapse?

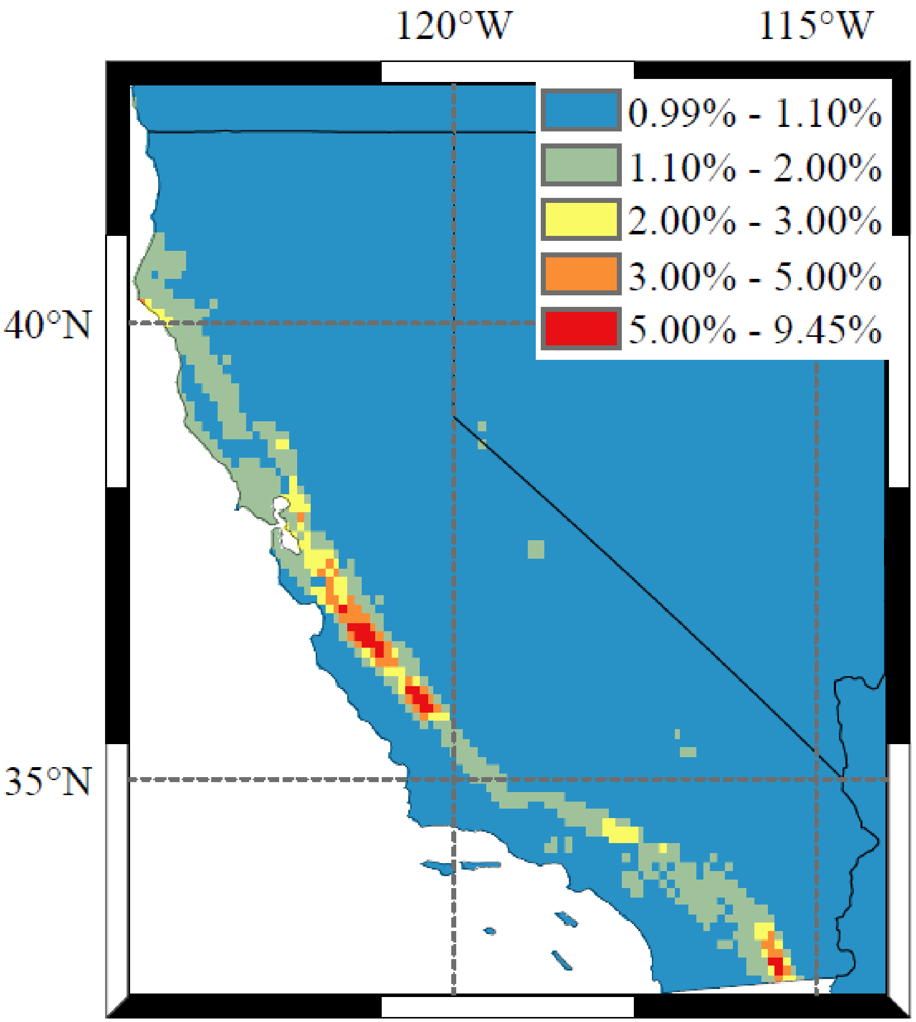
Is there anywhere in the country where our current ground motion intensities are providing too much safety?

Collapse Risks from Current MCE$_R$ Maps



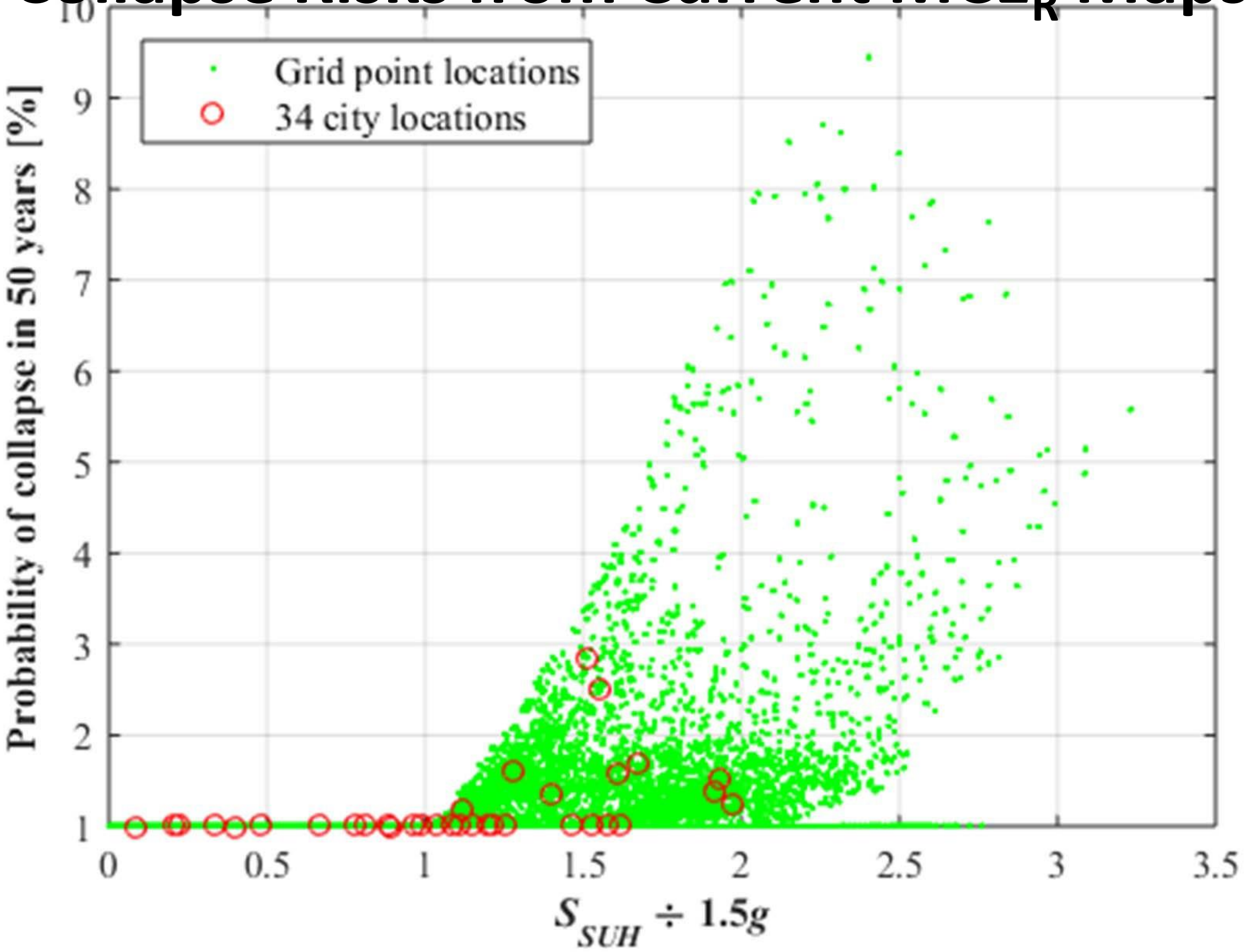
“ ollapse risks, ground motion return periods, and largest values … ,” N. Luco et al (USGS)

Collapse Risks from Current MCE$_R$ Maps



"Theoretical collapse risks, ground motion return periods, and largest values … ," N. Luco et al (USGS)

Collapse Risks from Current MCE$_R$ Maps



"Theoretical collapse risks, ground motion return periods, and largest values … ," N. Luco et al (USGS)

Return Periods of Current MCE_R Maps

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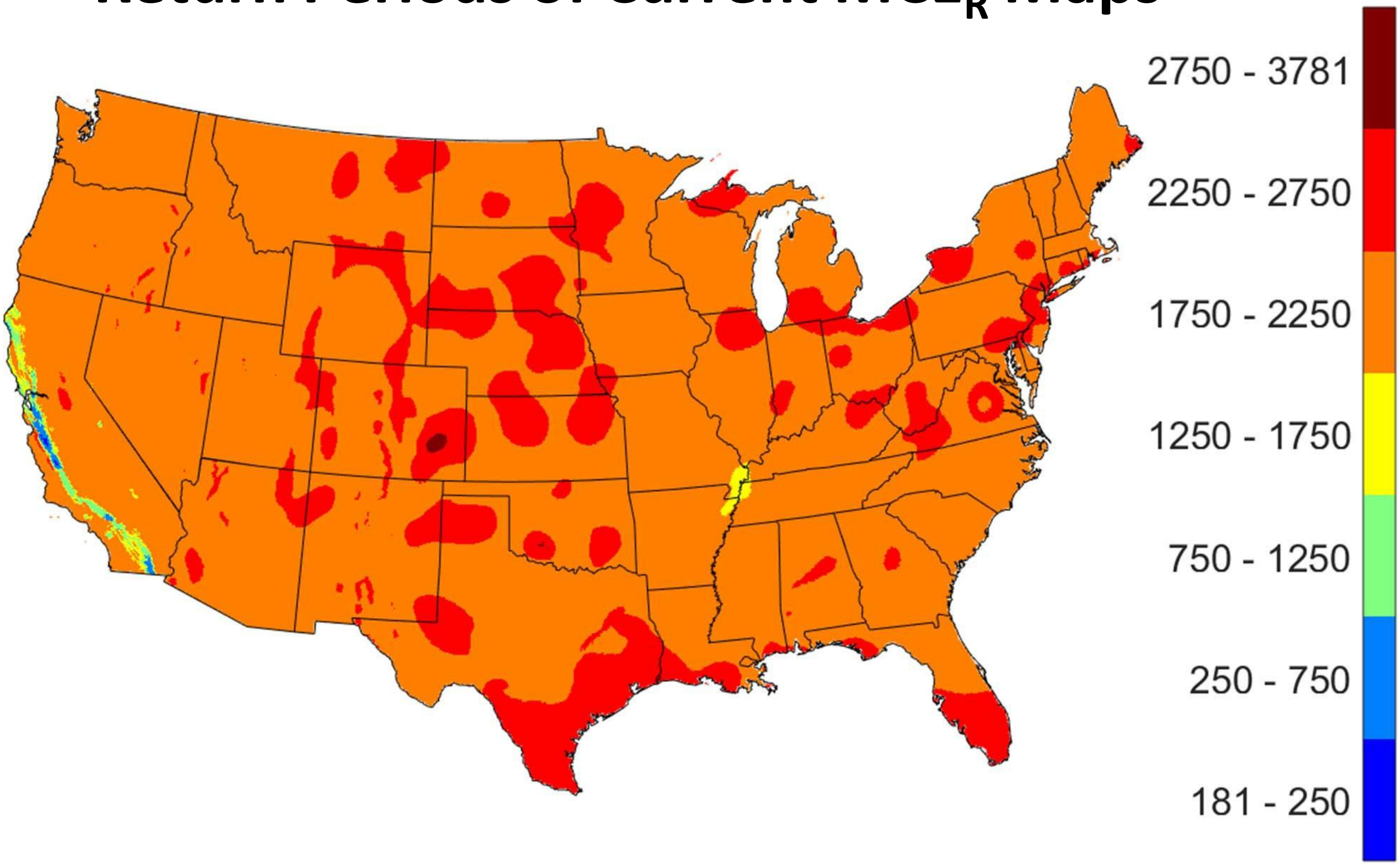

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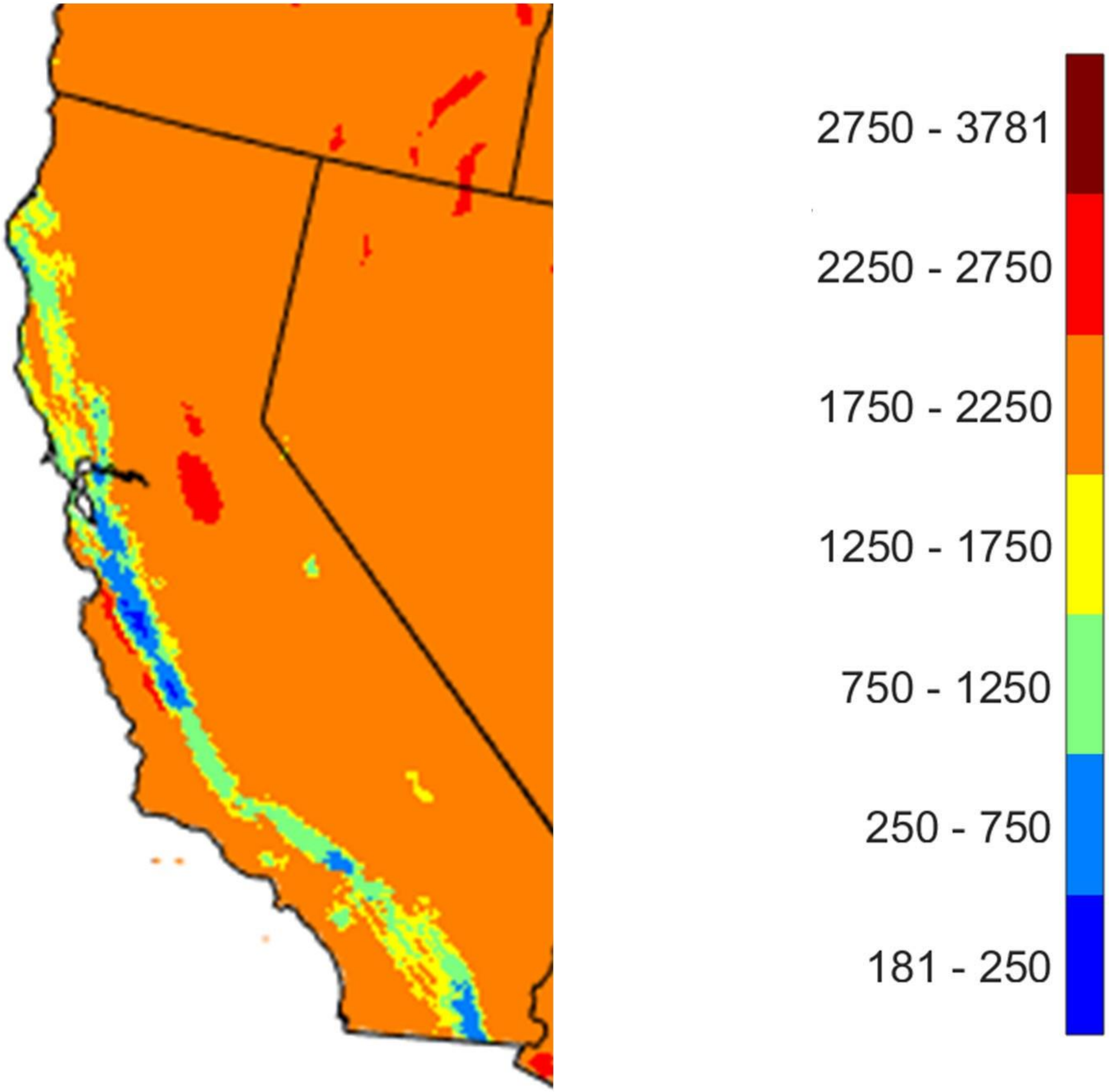
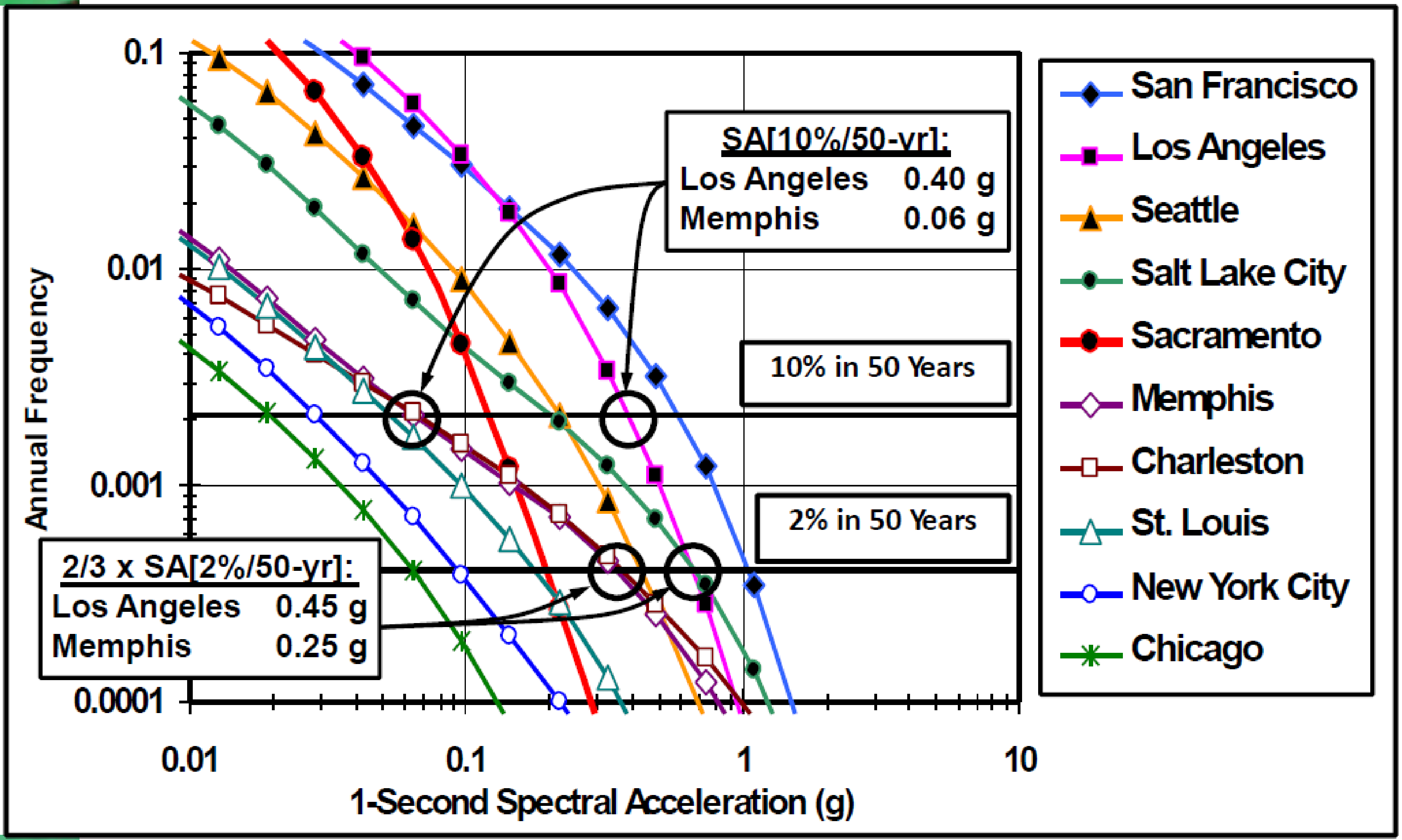
Return Periods of Current MCE_R Maps



“Theoretical collapse risks, ground motion return periods, and largest values … ,” N. Luco et al (USGS)

Deterministic Caps

Example Hazard Curves



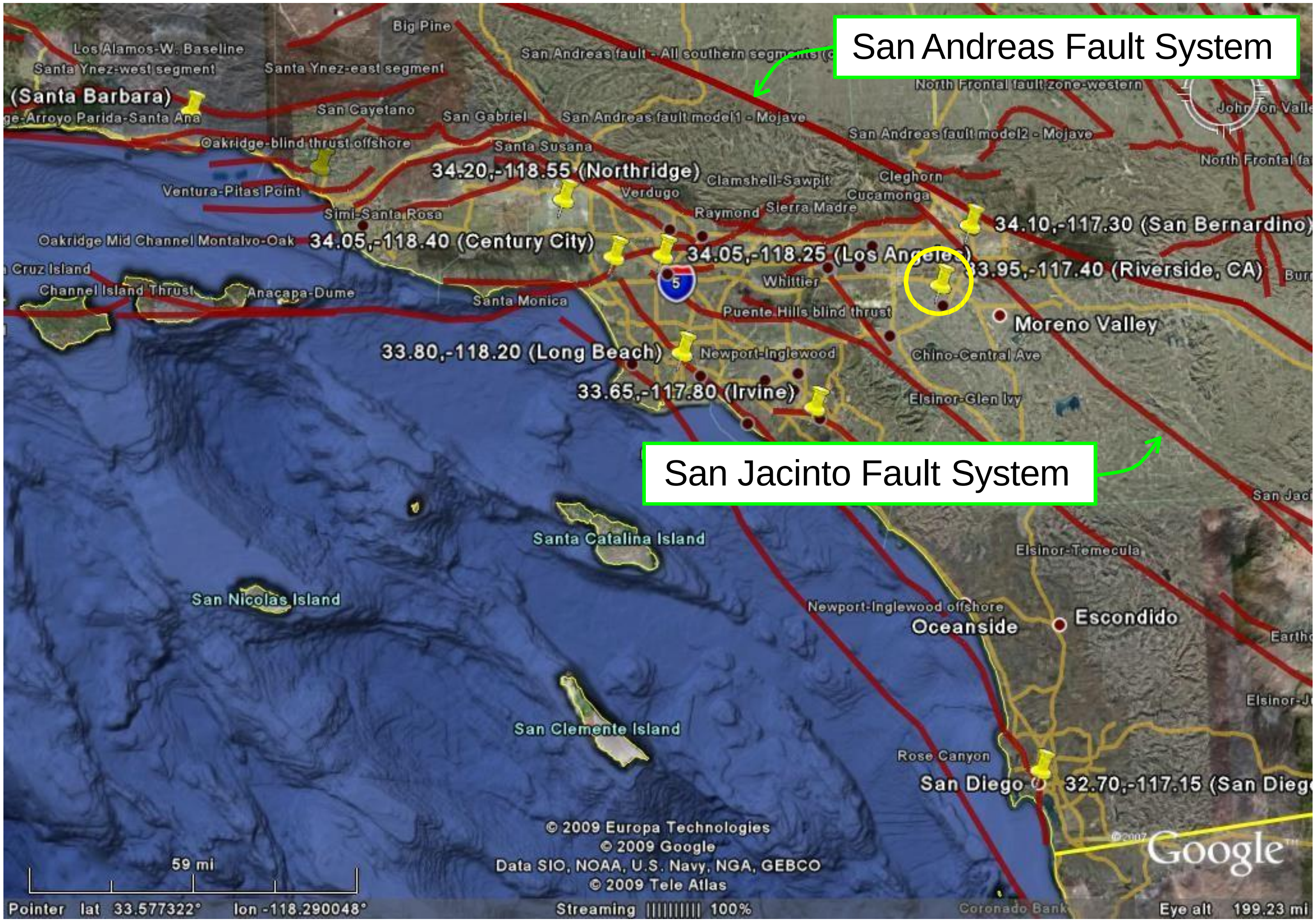
SA[10%/50-yr]:

Los Angeles	0.40 g
Memphis	0.06 g

2/3 x SA[2%/50-yr]:

Los Angeles	0.45 g
Memphis	0.25 g

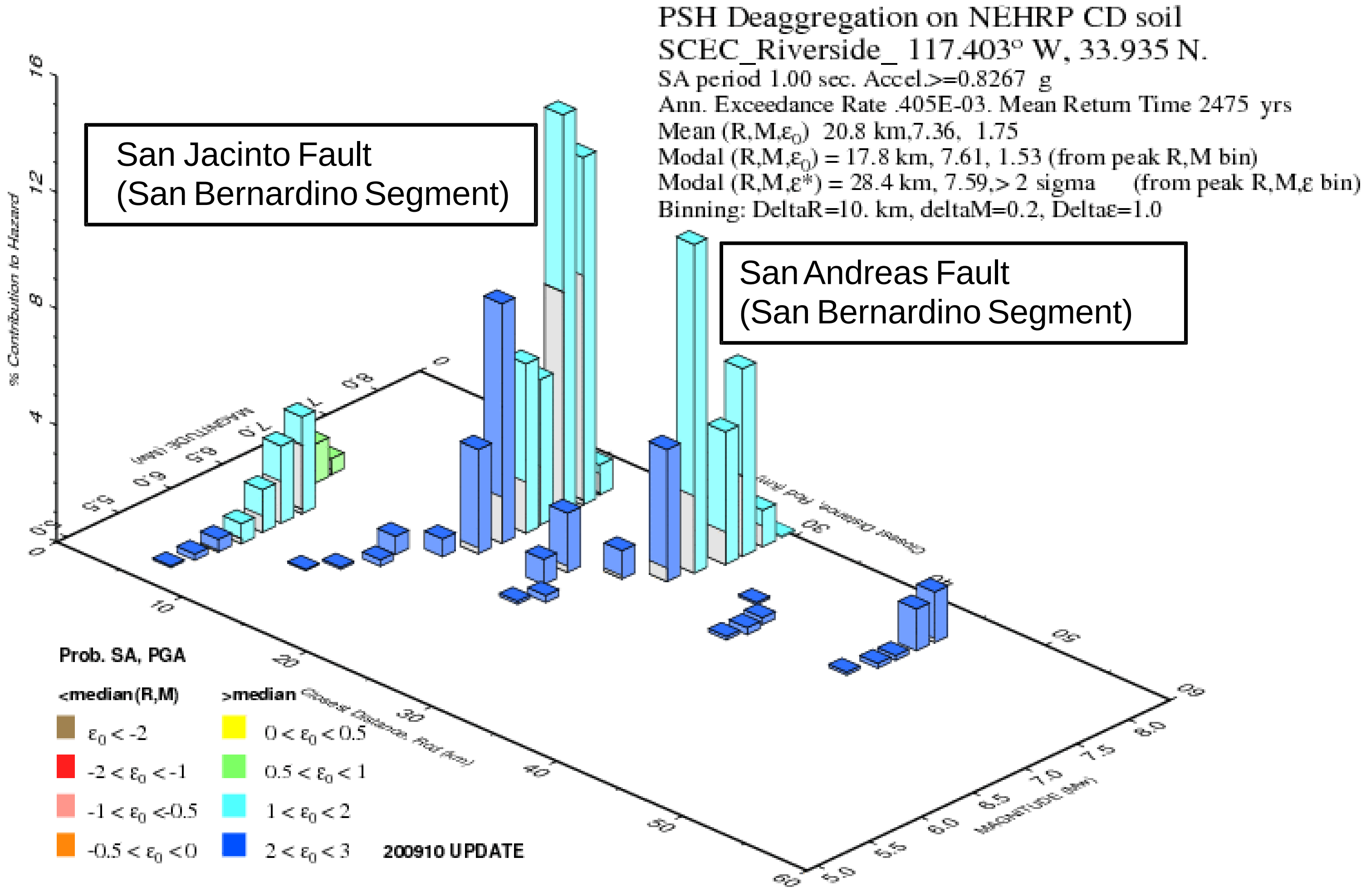
Map showing selected Southern California city sites used to compare MCE$_R$ ground motions (and high slip rate WUS faults)



San Andreas Fault System

San Jacinto Fault System

De-aggregation of 2,475-year mean annual return period seismic hazard at the SCEC Riverside site - 1s response (USGS)



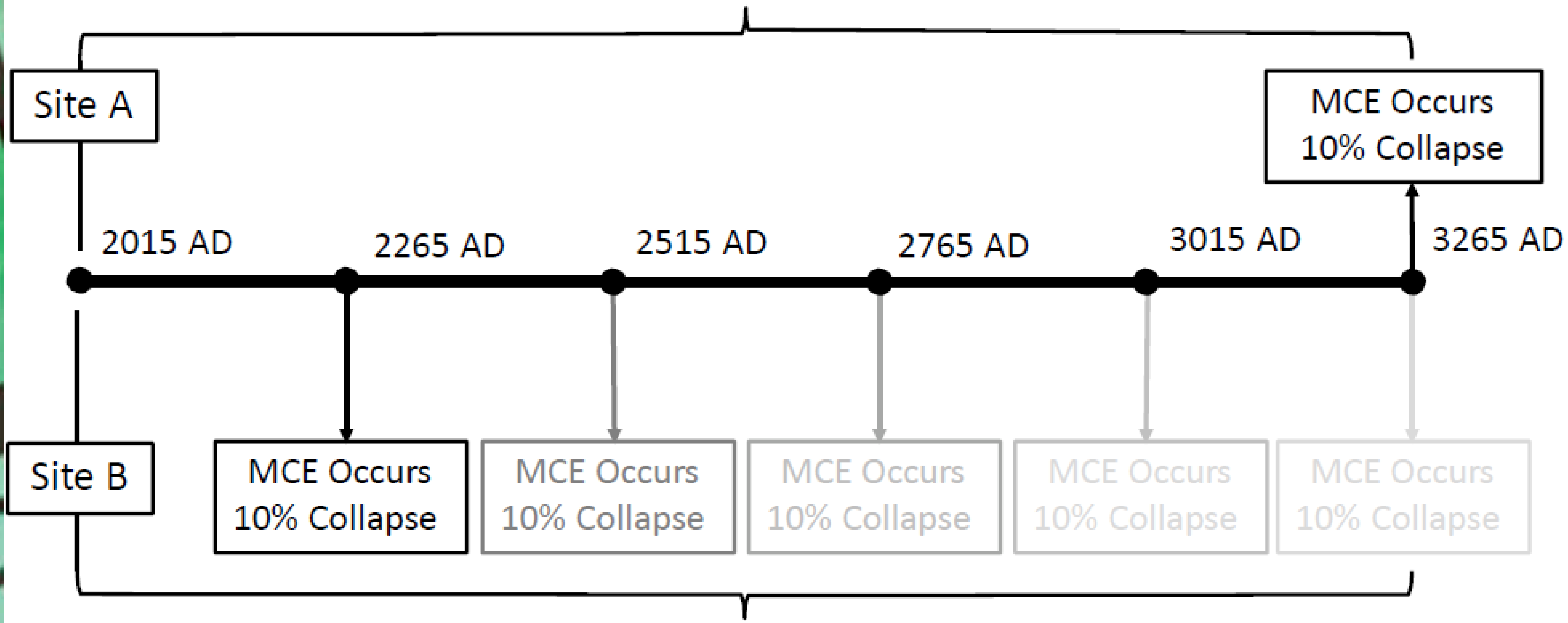
PSH Deaggregation on NEHRP CD soil
SCEC_Riverside_ 117.403° W, 33.935 N.
SA period 1.00 sec. Accel.>=0.8267 g
Ann. Exceedance Rate .405E-03. Mean Return Time 2475 yrs
Mean (R,M,ε_0) 20.8 km,7.36, 1.75
Modal (R,M,ε_0) = 17.8 km, 7.61, 1.53 (from peak R,M bin)
Modal (R,M,ε^*) = 28.4 km, 7.59,> 2 sigma (from peak R,M,ε bin)
Binning: DeltaR=10. km, deltaM=0.2, Deltaε=1.0

San Jacinto Fault
(San Bernardino Segment)

San Andreas Fault
(San Bernardino Segment)

Comparison of Notional Collapse Risk for Frequent (250-yr MAF) and Infrequent (1,250-yr MAF) Deterministic MCE Ground Motions

If deterministic MCE ground motions occur every 1,250 years, or so, on average, then:
Collapse Risk (MCE only) = 0.4% probability of collapse in 50 years (i.e., 10% x 50/1,250)



Site A

MCE Occurs
10% Collapse

2015 AD
2265 AD
2515 AD
2765 AD
3015 AD
3265 AD

Site B

MCE Occurs
10% Collapse

MCE Occurs
10% Collapse

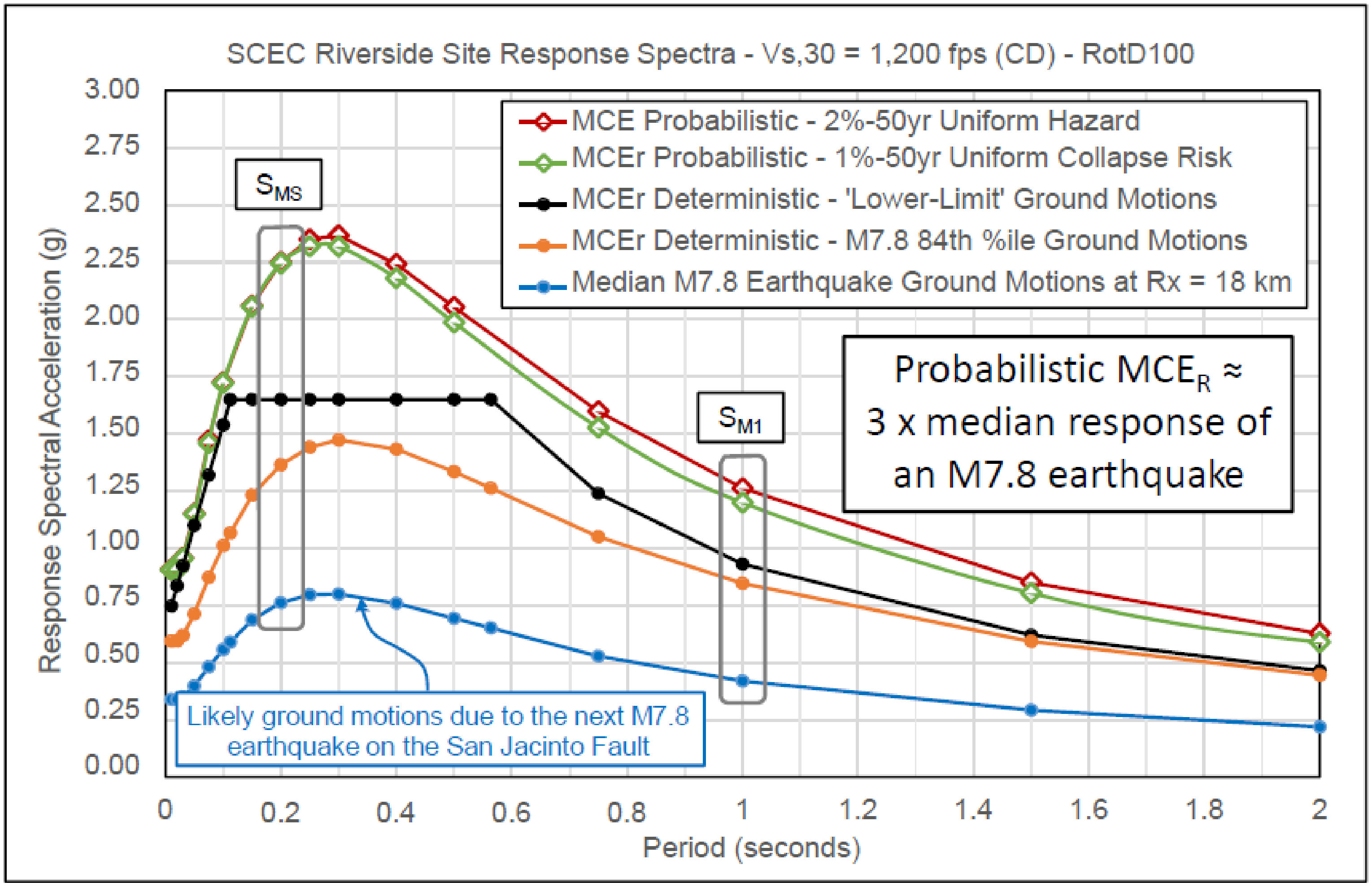
MCE Occurs
10% Collapse

MCE Occurs
10% Collapse

MCE Occurs
10% Collapse

If deterministic MCE ground motions occur every 250 years, or so, on average, then:
Collapse Risk (MCE only) = 2.0% probability of collapse in 50 years (i.e., 10% x 50/250)

Comparison of Probabilistic and Deterministic MCE_R Response Spectra - SCEC Riverside Site



Probabilistic MCE_R ≈ 3 x median response of an M7.8 earthquake

Likely ground motions due to the next M7.8 earthquake on the San Jacinto Fault

Deterministic Cap Return Periods

Region	City (Site Location)	Latitude	Longitude	ASCE 7-16 MCE_R		
				S_S	RP (yrs)	Risk
Southern California	Northridge	34.20	-118.55	1.74	1,402	1.4%
	Riverside	33.95	-117.40	1.50	1,738	1.2%
	San Bernardino	34.10	-117.30	2.33	1,337	1.4%
Northern California	Oakland	37.80	-122.25	1.88	1,119	1.7%
	Concord	37.95	-122.00	2.22	1,206	1.5%
	San Francisco	37.75	-122.40	1.50	1,175	1.6%
	San Mateo	37.55	-122.30	1.80	1,172	1.6%
	San Jose	37.35	-121.90	1.50	646	2.9%
	Vallejo	38.10	-122.25	1.50	736	2.5%
	Santa Rosa	38.45	-122.70	2.41	1,436	1.2%

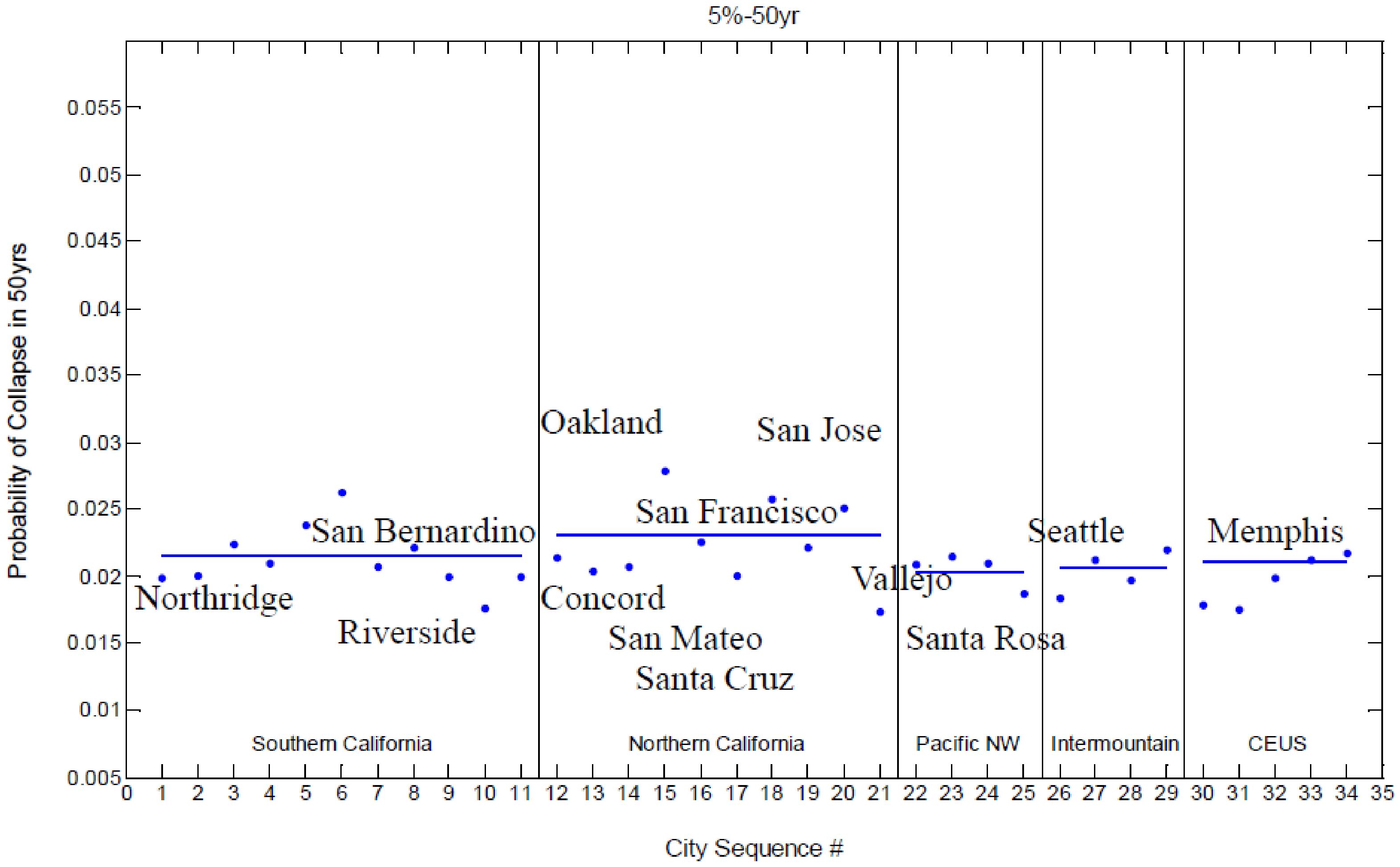
Summary of Deterministic MCE_R Issue

- Eliminate Deterministic MCE_R Ground Motions:
  - Use probabilistic MCE_R ground motions (only) for all seismic regions with consistent 1% in 50-year collapse risk objective
  - Issue - Overly conservative seismic loads for design of buildings in regions of very high seismicity
- Retain Deterministic MCE_R:
  - Avoid unwarranted over conservatism in seismic design loads for locations with highly active faults.
  - Issue - Inconsistent with uniform risk and uniform hazard objectives.

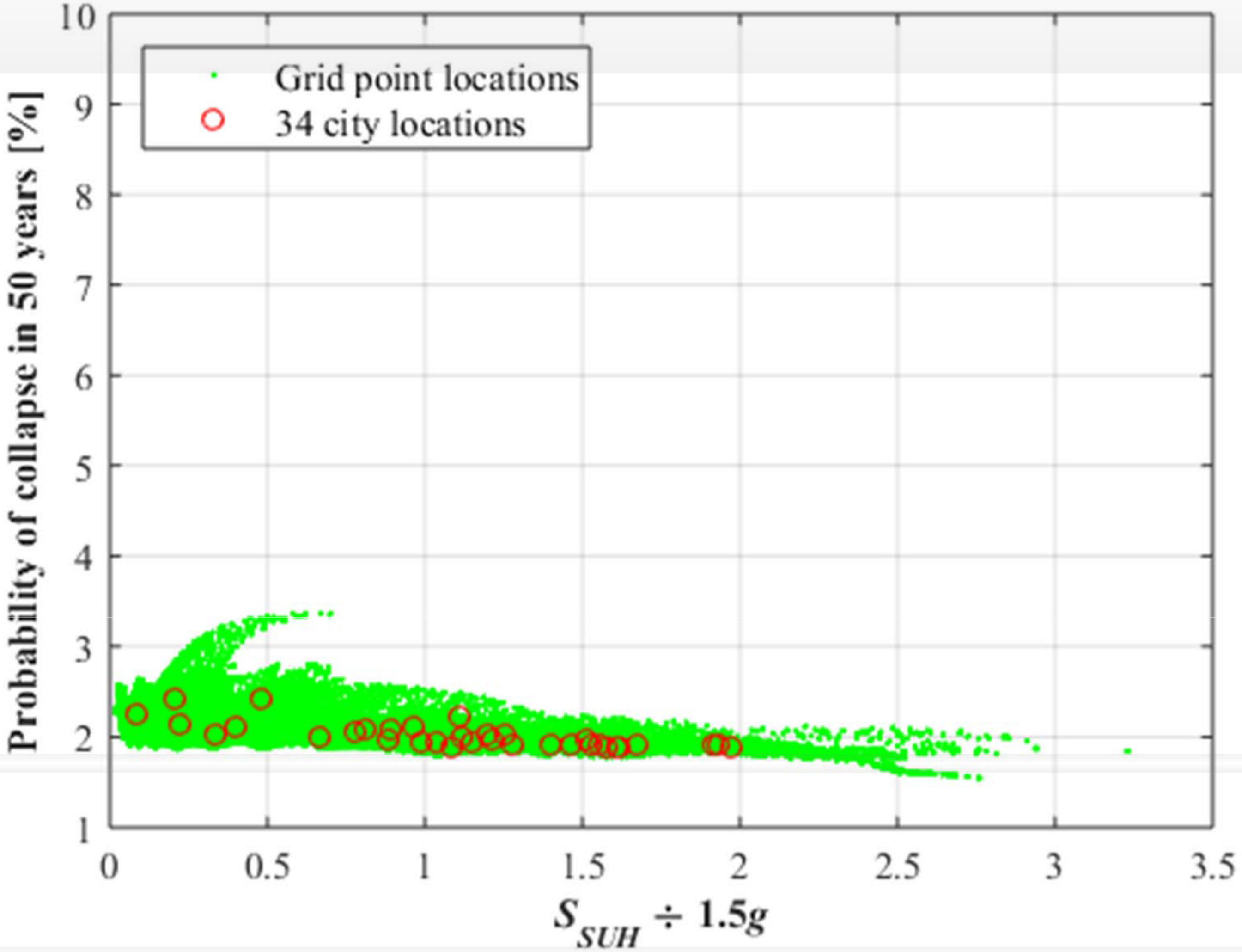
Current & Alternative Maps

- Current (ASCE 7-16): Risk-targeted (1%-in-50yrs) w/ deterministic cap
- Risk Target without deterministic cap.
- Alternative: Return to uniform-hazard
  - 975yr
  - 1500yr

Uniform Hazard w/ 975yr RP

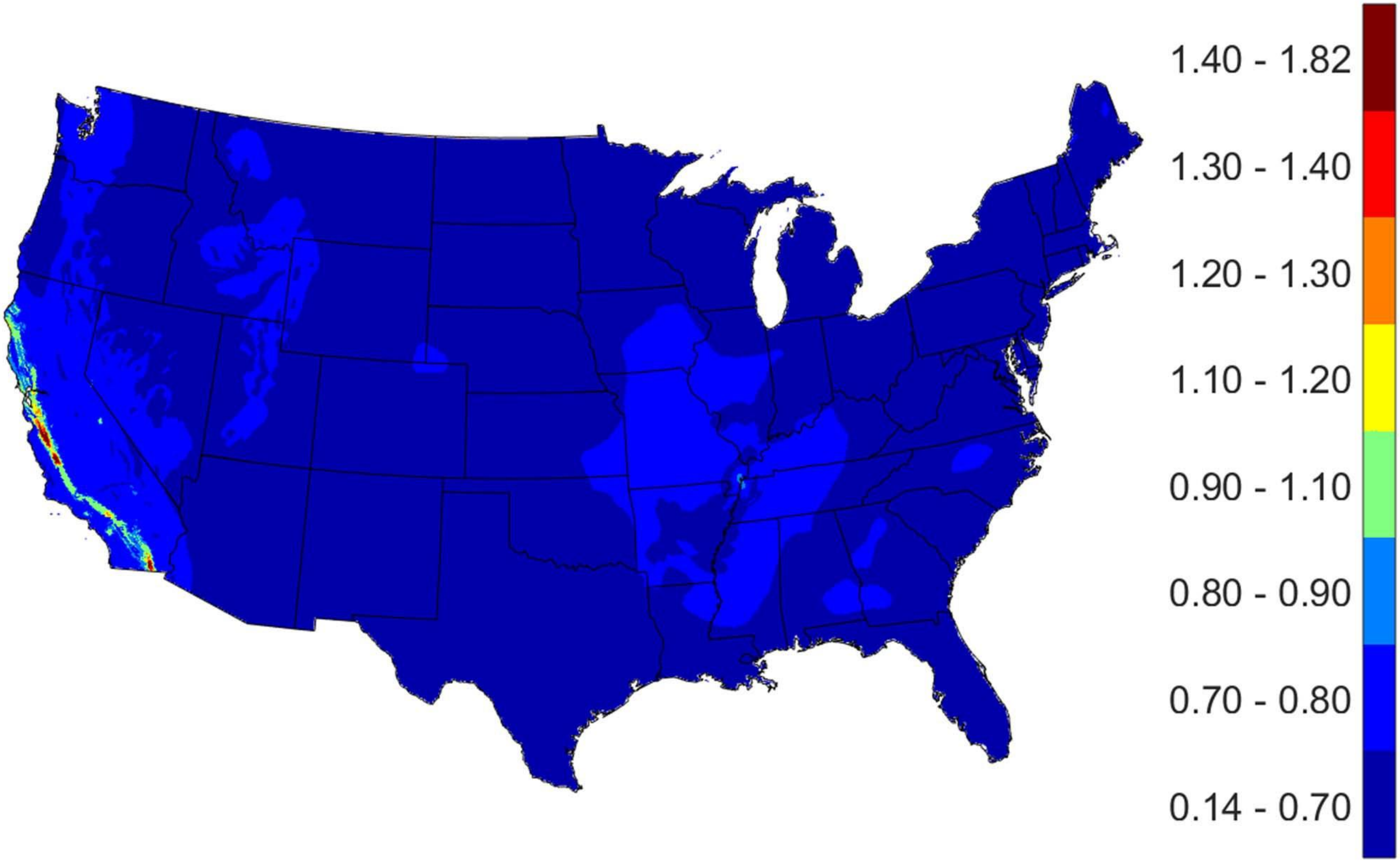

5%-50yr
Probability of Collapse in 50yrs
0.055
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35
City Sequence #
Southern California
Northern California
Pacific NW
Intermountain
CEUS
Northridge
San Bernardino
Riverside
Oakland
San Jose
San Francisco
Concord
San Mateo
Santa Cruz
Vallejo
Santa Rosa
Seattle
Memphis

Collapse Risks from 975yr RP Hazard



“Theoretical collapse risks, ground motion return periods, and largest values … ,” N. Luco et al (USGS)

Alternative ÷ Current Maps



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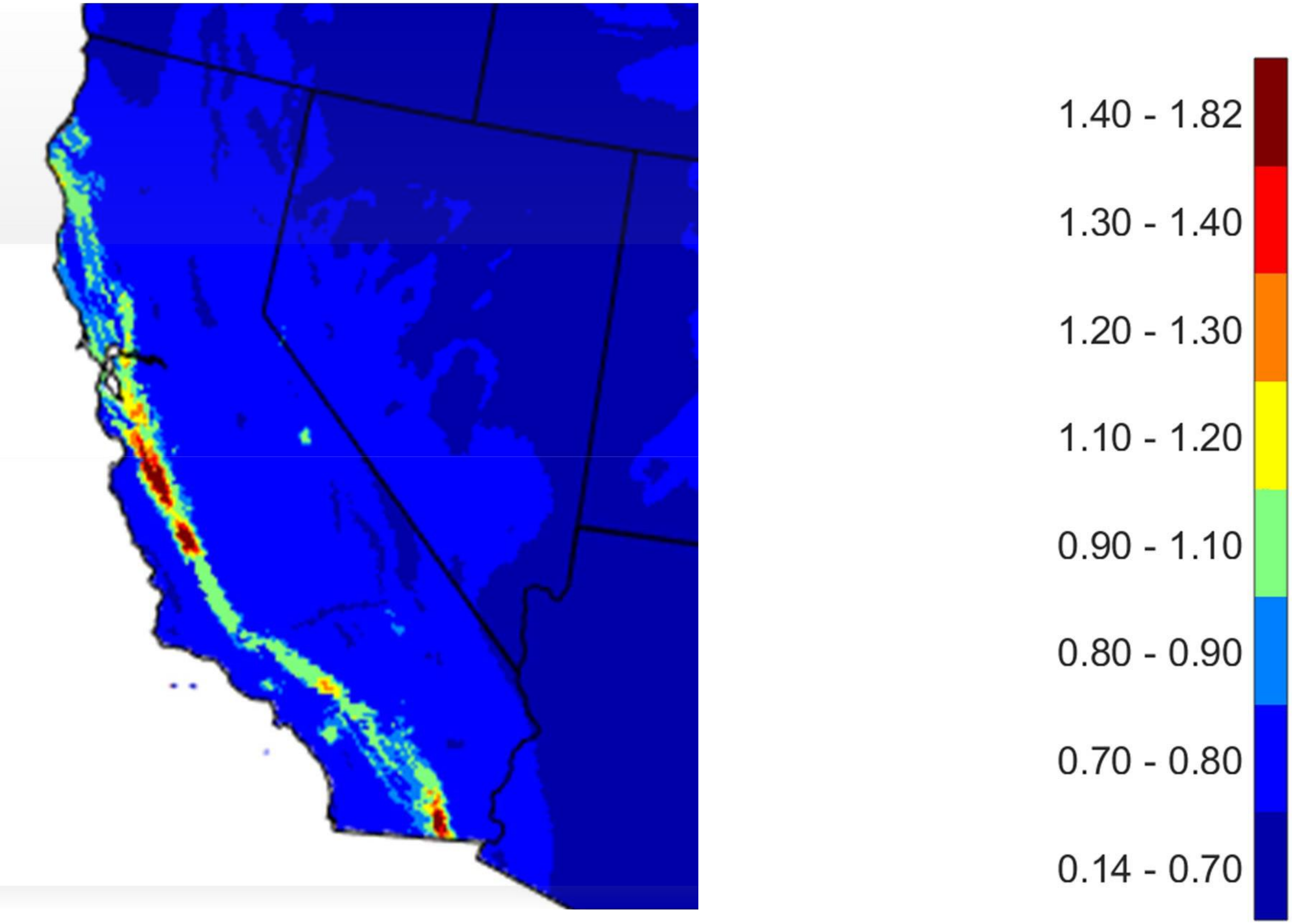


"Theoretical collapse risks, ground motion return periods, and largest values … ," N. Luco et al (USGS)

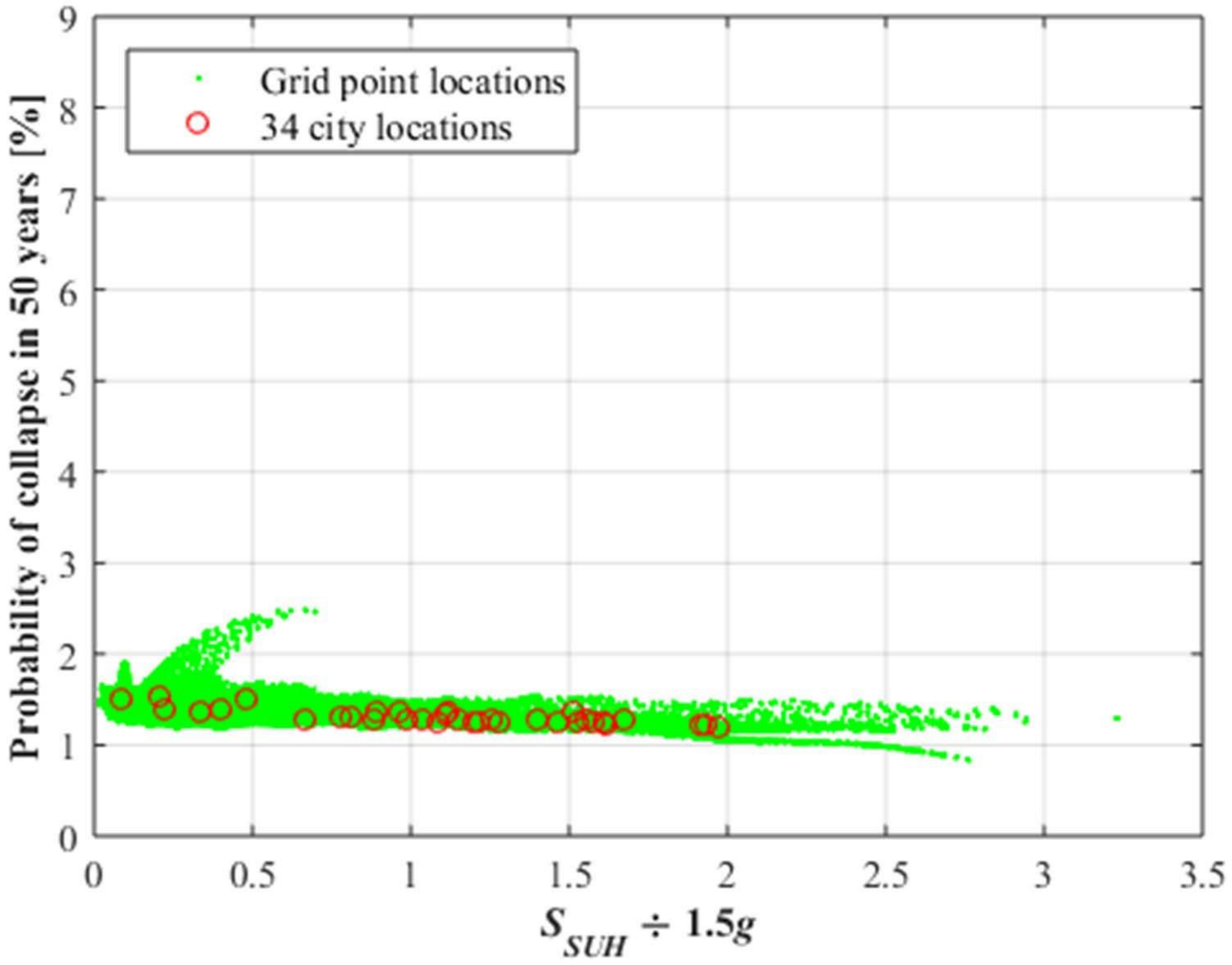
`Region	City (Site Location)	Uniform-Hazard, 975 Years			
		S_S (g)	Change	Risk	RP (yrs)
Southern California	Los Angeles	1.50	-24%	1.9%	975
	Irvine	0.92	-26%	2.1%	975
	Riverside	1.23	-18%	2.0%	975
	San Bernardino	2.05	-12%	1.9%	975
	San Luis Obispo	0.78	-29%	2.1%	975
	San Diego	1.11	-30%	2.0%	975
	Santa Barbara	1.59	-25%	1.9%	975
Northern California	Oakland	1.79	-5%	1.9%	975
	Monterey	0.97	-27%	2.1%	975
	Sacramento	0.42	-25%	2.1%	975
	San Francisco	1.40	-7%	1.9%	975
	San Jose	1.72	15%	2.0%	975
	Santa Cruz	1.25	-22%	1.9%	975
	Vallejo	1.68	12%	1.9%	975
	Santa Rosa	2.01	-17%	1.9%	975
Pac. NW	Seattle	1.06	-24%	1.9%	975
	Portland	0.63	-29%	2.0%	975
Other WUS	Salt Lake City	1.05	-32%	2.0%	975
	Boise	0.21	-33%	2.1%	974
	Denver	0.13	-38%	2.3%	974
	Reno	1.14	-22%	1.9%	975
	Las Vegas	0.37	-43%	2.4%	975
CEUS	St. Louis	0.32	-31%	2.0%	975
	Memphis	0.69	-33%	2.1%	975
	Charleston	0.88	-38%	2.2%	975
	Washington, DC	0.08	-38%	2.2%	974
	Boston	0.16	-41%	2.3%	975
	New York	0.16	-45%	2.4%	975

Notes on % Change

- ASCE 7-16 Site Factors are about 20% higher than ASCE 7-10.
- ASCE 7-16 raised the modal response spectrum floor from $0.85V_{ELF}$ to $1.0V_{ELF}$

Uniform Hazard w/ 1,500yr RP

Collapse Risks from Alternative Maps



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Alternative ÷ Current Maps

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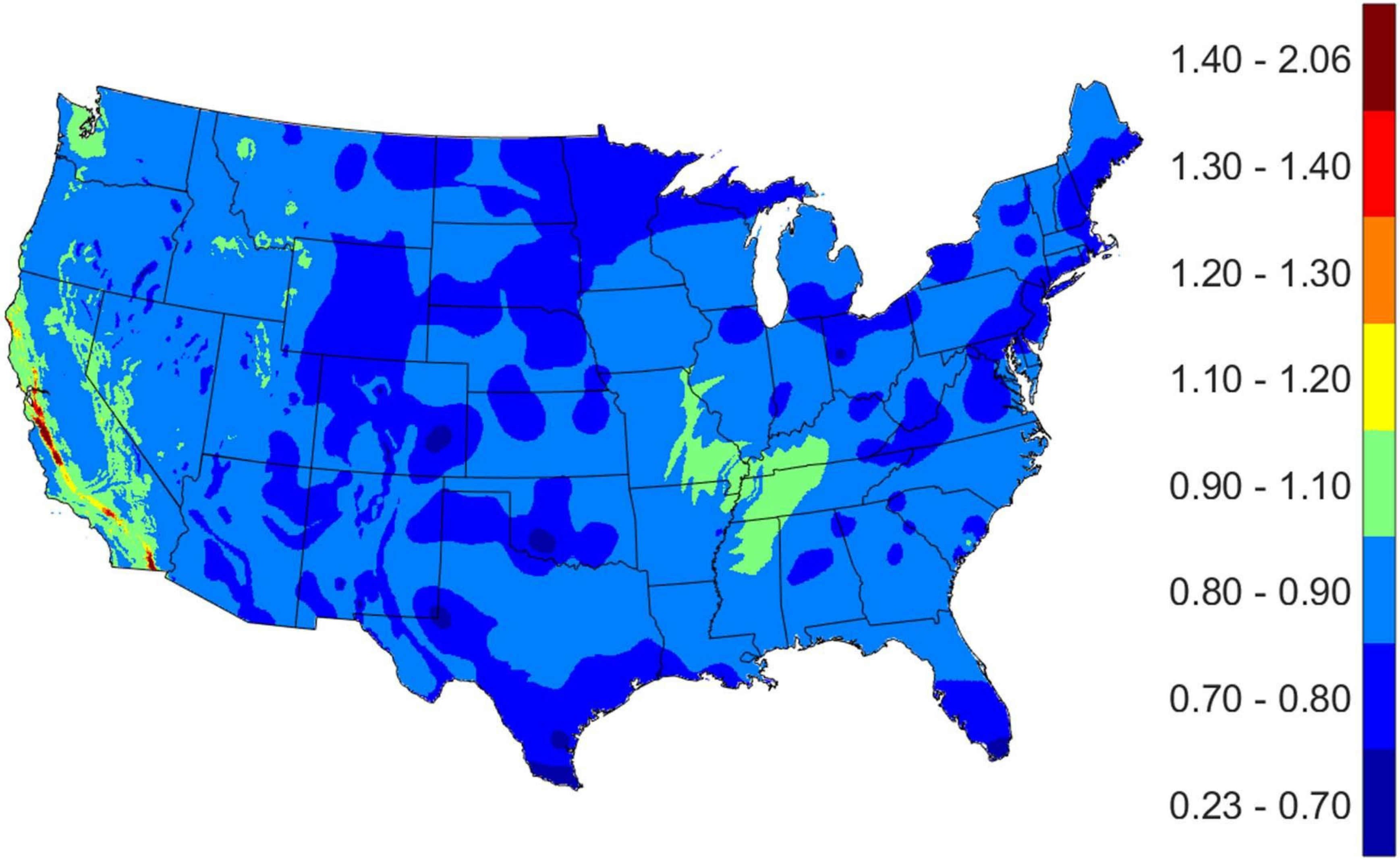

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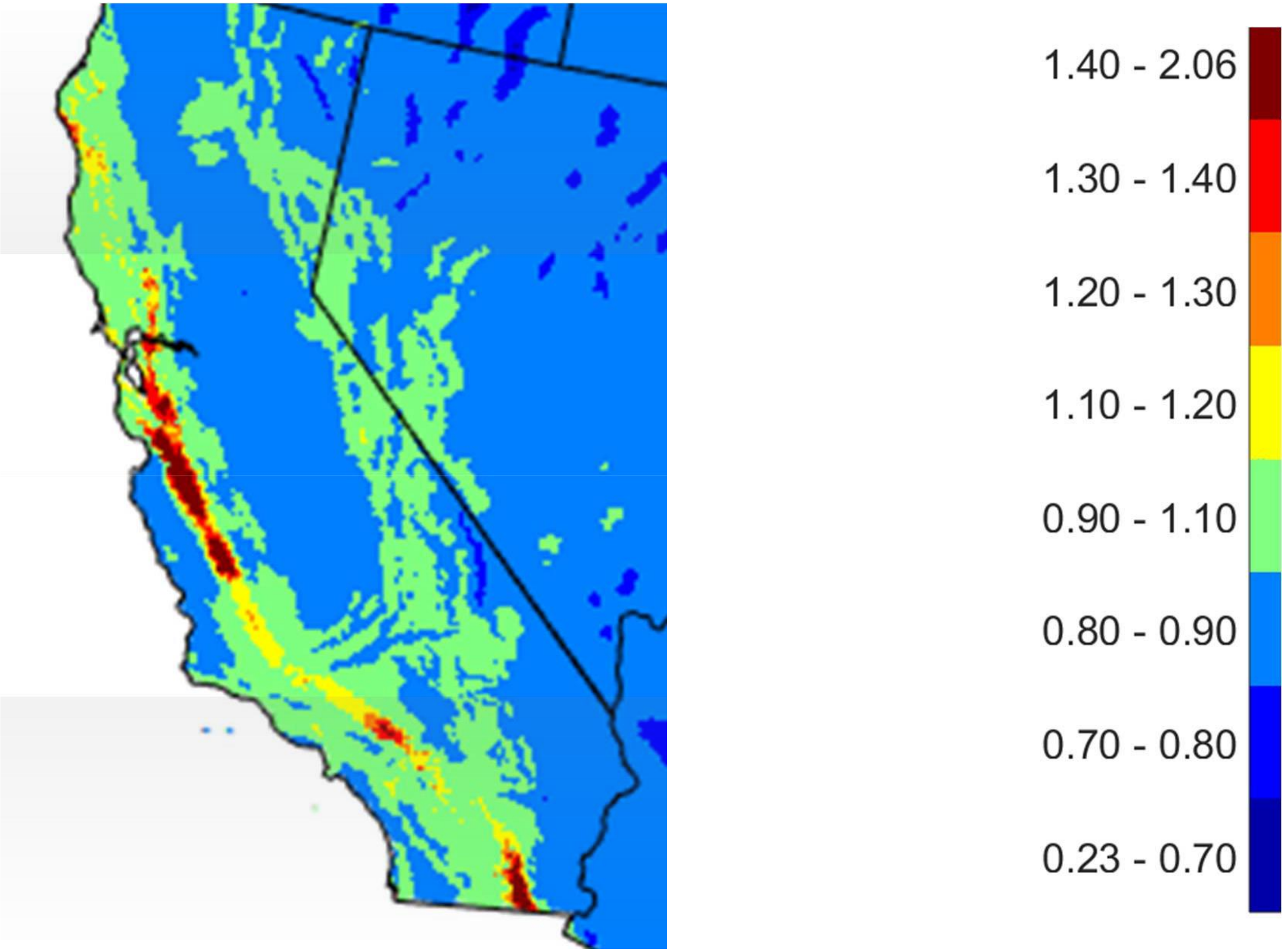
Alternative ÷ Current Maps



"Theoretical collapse risks, ground motion return periods, and largest values … ," N. Luco et al (USGS)

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Region	City (Site Location)	Uniform-Hazard, 1500 Years			
		S_S (g)	Change	Risk	RP (yrs)
Southern California	Los Angeles	1.80	-9%	1.3%	1,500
	Irvine	1.10	-12%	1.4%	1,500
	Riverside	1.43	-5%	1.4%	1,500
	San Bernardino	2.43	5%	1.2%	1,500
	San Luis Obispo	0.96	-12%	1.3%	1,500
	San Diego	1.42	-10%	1.2%	1,500
	Santa Barbara	1.94	-9%	1.2%	1,500
Northern California	Oakland	2.10	11%	1.3%	1,500
	Monterey	1.17	-12%	1.4%	1,500
	Sacramento	0.50	-12%	1.4%	1,500
	San Francisco	1.64	9%	1.3%	1,500
	San Jose	1.96	30%	1.4%	1,500
	Santa Cruz	1.46	-9%	1.3%	1,500
	Vallejo	1.95	30%	1.3%	1,500
	Santa Rosa	2.45	2%	1.2%	1,500
Pac. NW	Seattle	1.26	-10%	1.3%	1,500
	Portland	0.79	-11%	1.3%	1,500
Other WUS	Salt Lake City	1.38	-11%	1.3%	1,500
	Boise	0.26	-15%	1.4%	1,500
	Denver	0.17	-21%	1.5%	1,500
	Reno	1.34	-8%	1.3%	1,500
	Las Vegas	0.50	-23%	1.5%	1,500
CEUS	St. Louis	0.40	-14%	1.4%	1,500
	Memphis	0.89	-13%	1.3%	1,500
	Charleston	1.21	-15%	1.3%	1,500
	Washington, DC	0.11	-20%	1.5%	1,500
	Boston	0.21	-22%	1.5%	1,500
	New York	0.22	-25%	1.5%	1,500

Straw Poll of Working Group

- 5 favor returning to Uniform Hazard
  - 4 chose 1,500 year
  - 3 voted 1,500 as a second choice
- 3 favor keeping current MCE_R definition
- 2 favor going to 1% to 3% variable risk
  - One other member expressed this is second choice

Reasons to go to Uniform Hazard

- Avoids using a fragility curve.
- Avoiding the risk calculation, the GM computations are simplified.
- Avoids deterministic areas, removing the wide variations in collapse probabilities observed now.
- Achieves a somewhat consistent degree of mean collapse risk regardless of hazard intensity.

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Reasons to Stay w/ Current MCE_R

- No change.
- Does not create another “yo” in the yo-yo issue.
- Alternates produce too big a drop?
- “While there are opportunities for marginal improvement, changing the target without a *very* compelling reason will create more problems than it solves.”

Discussion Topics

- Willingness to make a major change?
- Uniform risk of collapse or uniform hazard?
- Retain or eliminate deterministic zones?

PRESENTATION: SEISMIC DESING CATEGORIES

by

Julie Furr[1], SE, SECB

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[1] CSA Engineering, Inc., Lakeland, TN, is the Seismic Design Category work group chair of Project 17.

National Institute of BUILDING SCIENCES

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Building Seismic Safety Council

Project 17 Workshop

Seismic Design Categories

Julie C. Furr, PE

CSA Engineering, Inc.

Chair - P17 SDC Working Group

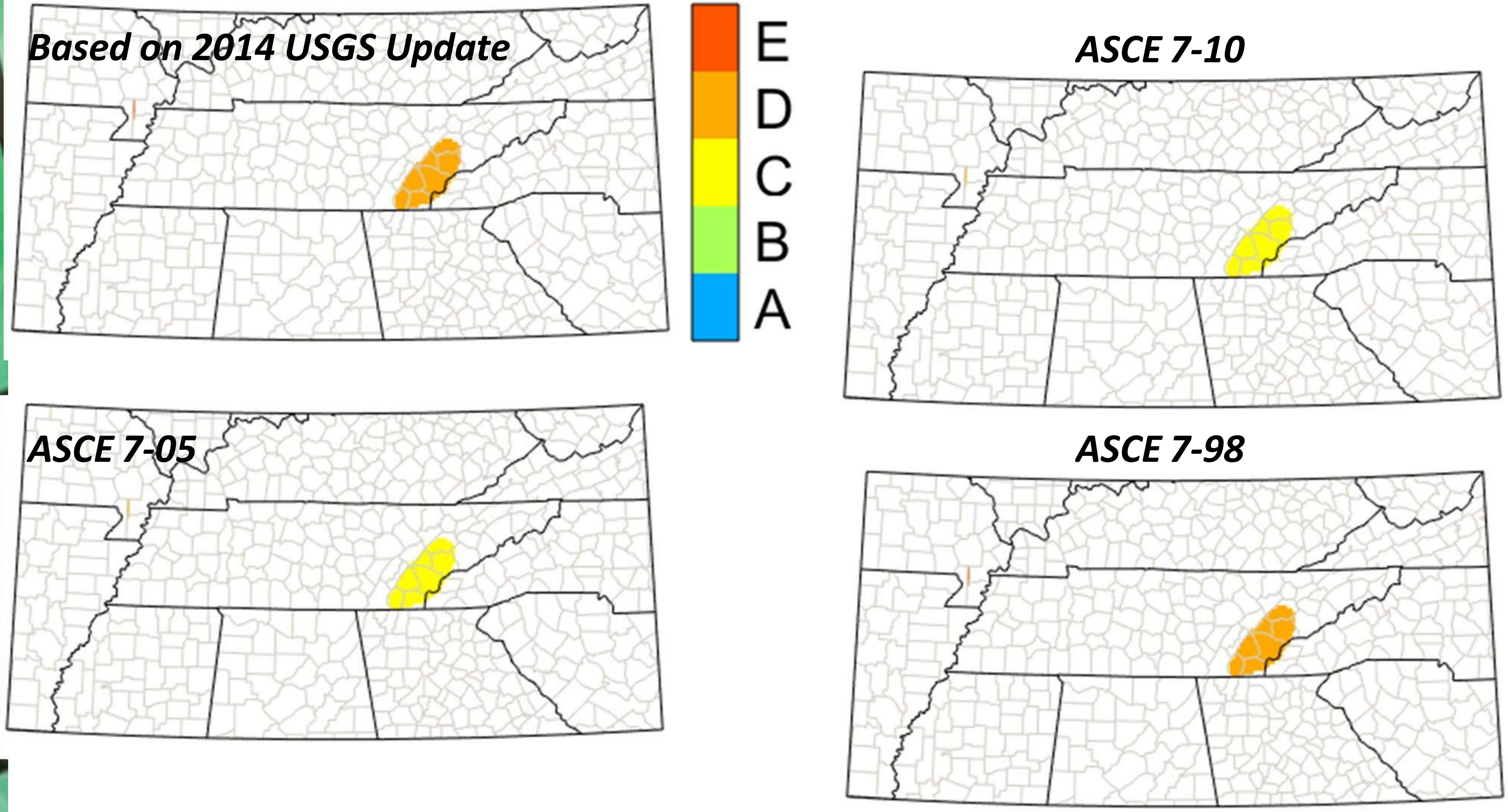
SDC Stability

Why is SDC Stability an issue?

- Life-safety implications
  - SDC C => D : “Are all buildings designed under the previous standard now unsafe?”
  - Federal Standard compliance (ICSSC RP8)
    - SDC A => B
    - Exempt buildings: SDS < 0.167 and SD1 < 0.067
    - Federal Personnel still want to know what “zone” the building is located in.
  - Enforcement of Standards

SDC Stability

Why is SDC Stability an issue?...Knoxville, TN



Default Site Class, Risk Category I/II/III

SDC Stability

1. **Why is SDC Stability an issue?**

- Consistent structure performance
  - Patchwork of SDC B, C, D between standards (Shelby County)
  - “Why do I have to upgrade this building and not the one next door?”
  - Insurance Ratings
  - Contractor Familiarity

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SDC Stability

Why is SDC Stability an issue?

- Economic Impacts
  - Identical building repeated within office complex over successive years, now required to meet SDC D requirements. Updated plans required with more expensive detailing, why? VE to make up the difference...
  - Spaced leased to Federal agencies no longer compliant (VA, SSA, etc.)
  - (Memphis) ATC-89 addressed the change to the 2012 IBC satisfactorily...but a similar study is not likely to be performed for each code cycle.

SDC Stability

Why is SDC Stability an issue?

- Loss of confidence in design standards
  - “We’ll wait to adopt {ASCE 7-10} until they are finished with the maps...we’ll stay with the {1999 SBC} until then.”
    - *City of Memphis public official statement, paraphrased, during 2012 code adoption review process*
  - Assign the county to SDC C specifically to exempt region from seismic standards
  - Change state law to make seismic standards optional
  - Change state building code to allow alternate seismic design rationale

SDC Stability

SDC Stability

Why is SDC Stability an issue?

Question

Are oscillating SDC's an important enough issue to affect potentially significant changes or should the status quo be maintained?

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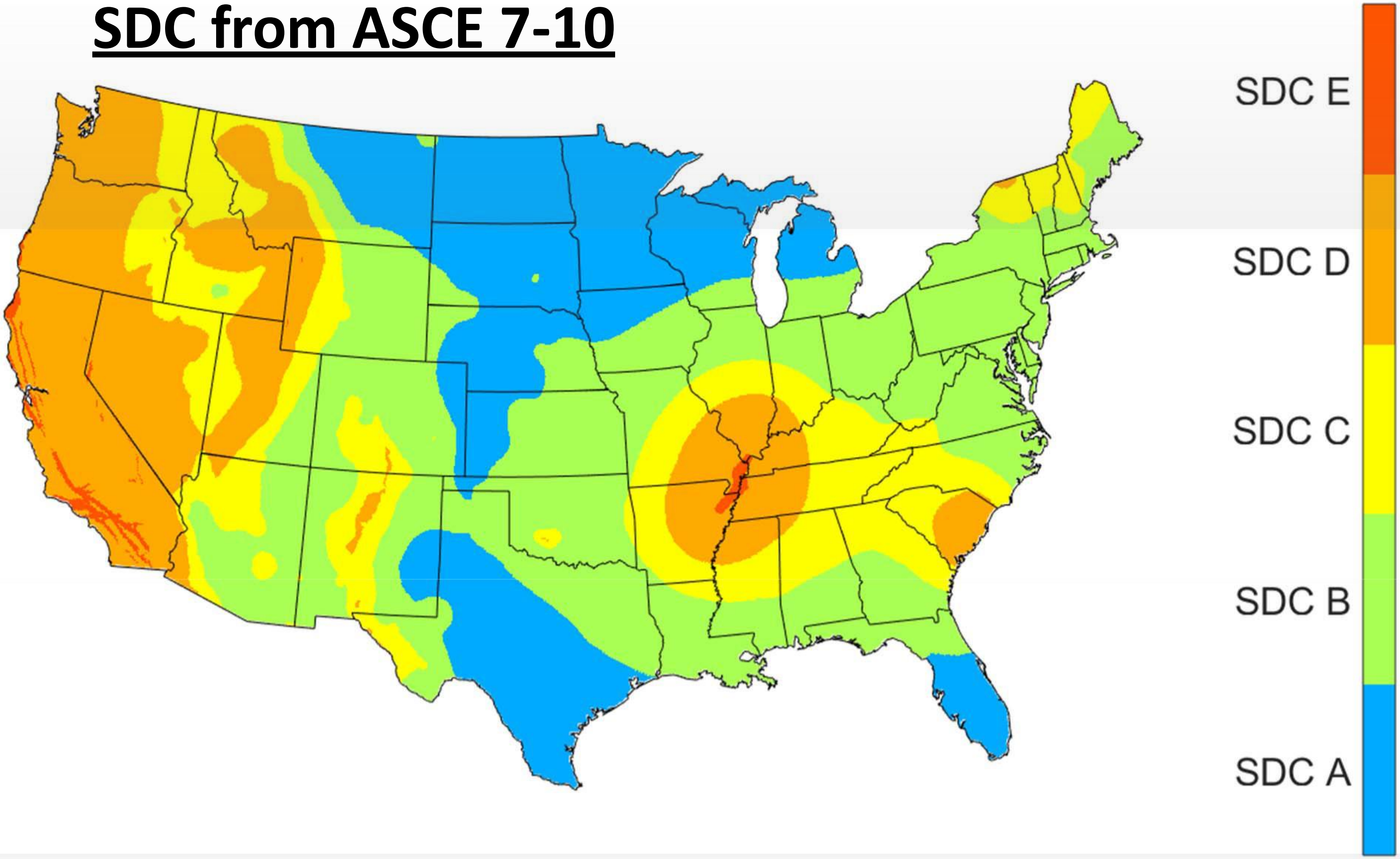
• SDC Stability

Do SDC’s change that much?

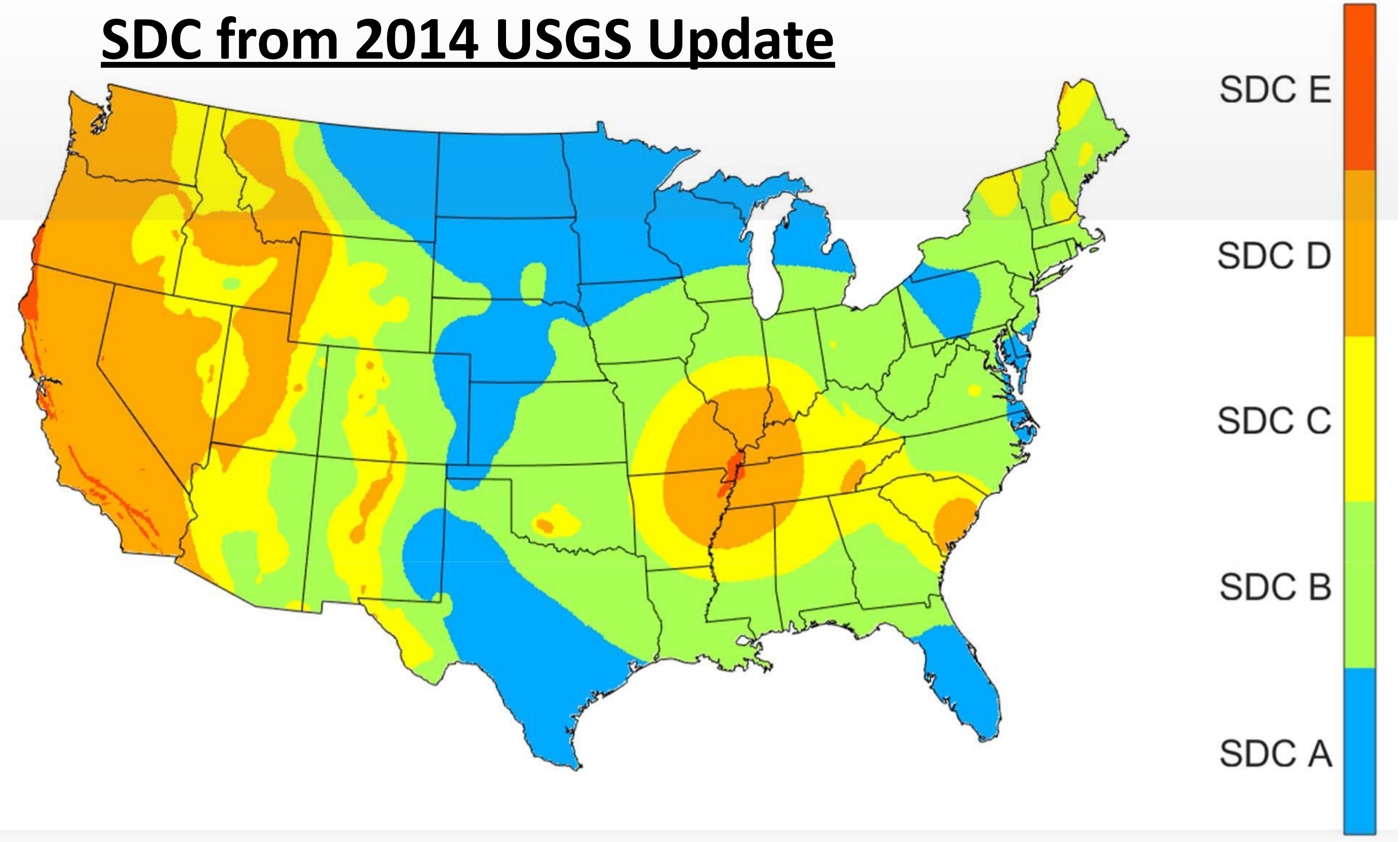
SDC from ASCE 7-10



SDC Stability

Do SDC's change that much?

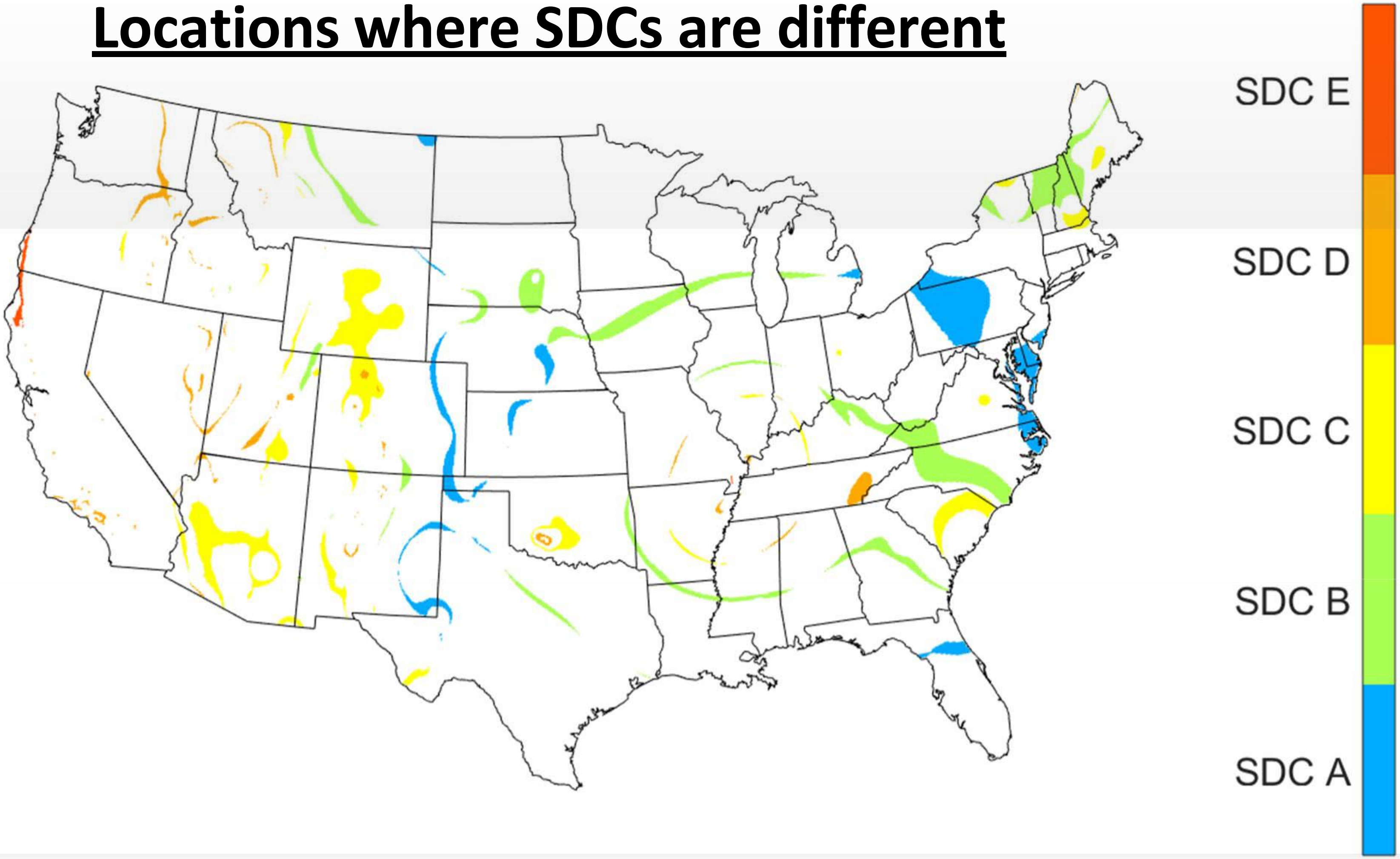
SDC from 2014 USGS Update



SDC Stability

Do SDC's change that much?

Locations where SDCs are different



• SDC Stability

Seismic Design Category Map Creation

- Approaches Assume
  - Same number of SDC’s (A-E)
  - Same Risk of Collapse
  - Same Return Period
- Does not restrict ground motion!
  - Actual ground motion values from the latest USGS Hazard Model would still be utilized in design, just not in SDC determination
- Building importance factor would be applied further in the design process

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SDC Stability

Seismic Design Category Map Creation

- Drawbacks
  - Applies to full geographical region regardless of site class variations
  - Worst soil conditions would likely be assumed
  - SDC reduction would not be allowed for improved site class
  - Some structures would be subjected to more severe criteria (overly conservative in design)

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SDC Stability

Seismic Design Category Map Creation

- Benefits
  - Known SDC based solely on geographic location
  - Baseline minimum detailing requirements applied uniformly to all structures in same region
  - Predictability in key cost items for specific system types (i.e. prequalified connections are/are not required)
  - Familiarity with requirements through experience (engineers, code officials, contractors)

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SDC Stability

Seismic Design Category Map Creation

- Boundaries
  - Set as contours using predetermined spectral acceleration values *(currently Tables 11.6-1 and 11.6-2 in ASCE 7)*
  - Pushed beyond current municipalities to avoid “across the street” issues
  - Eventually need to be revisited as municipalities expand, but can be addressed on a case by case basis
  - Must still allow for radical changes in science

SDC Stability

SDC Map Creation – CEUS Workshop

- Stabilizing SDCs is good in concept
  - Ground motion values should be allowed to fluctuate
- Precision & Uncertainty in the reporting is not a priority.
  - Do not reduce to 1 decimal, but no objections to 2 or 3 decimals
  - Problem using Tables 11.6-1 and 11.6-2
- Deterministic Floor to ensure 1811-1812 events are captured
- Site class factors are major concern
  - 1000 m to bedrock in Mississippi Embayment

SDC Stability

SDC Map Creation – CEUS Workshop

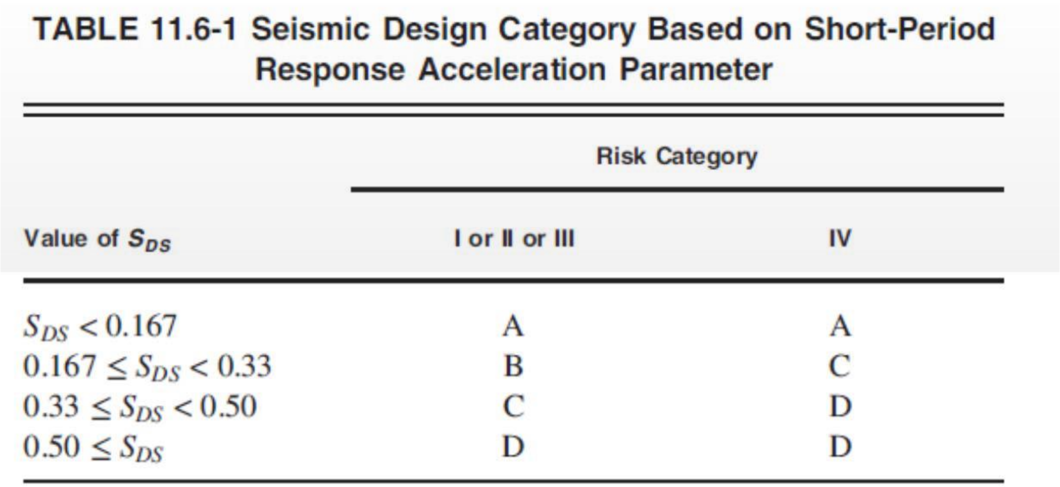

TABLE 11.6-1 Seismic Design Category Based on Short-Period Response Acceleration Parameter

	Risk Category	
Value of S_{DS}	I or II or III	IV
$S_{DS} < 0.167$	A	A
$0.167 \leq S_{DS} < 0.33$	B	C
$0.33 \leq S_{DS} < 0.50$	C	D
$0.50 \leq S_{DS}$	D	D

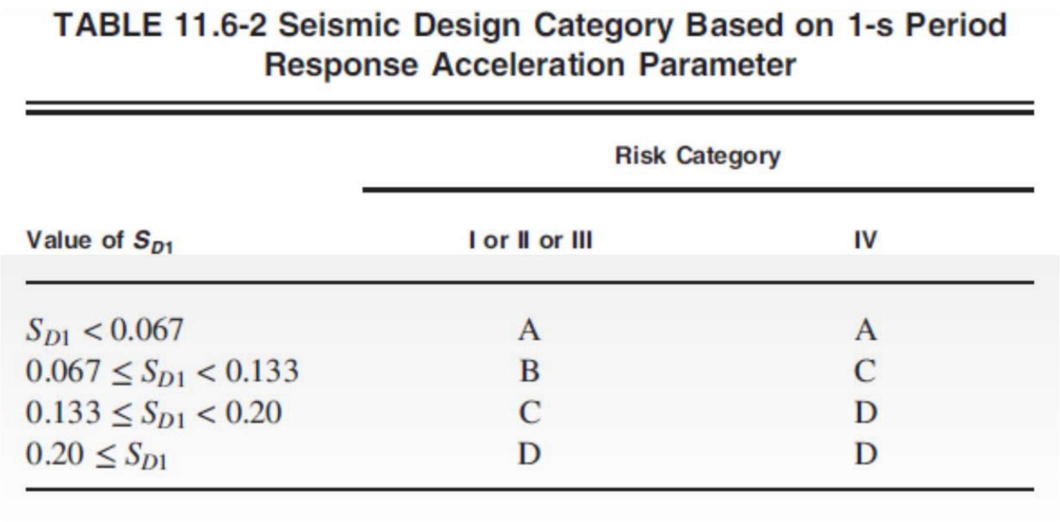

TABLE 11.6-2 Seismic Design Category Based on 1-s Period Response Acceleration Parameter

	Risk Category	
Value of S_{D1}	I or II or III	IV
$S_{D1} < 0.067$	A	A
$0.067 \leq S_{D1} < 0.133$	B	C
$0.133 \leq S_{D1} < 0.20$	C	D
$0.20 \leq S_{D1}$	D	D

SDC Stability

SDC Map Creation – CEUS Workshop

Short Periods: Fa needs to be higher

Long Periods: Fv needs to be lower

- *Paper conclusions*

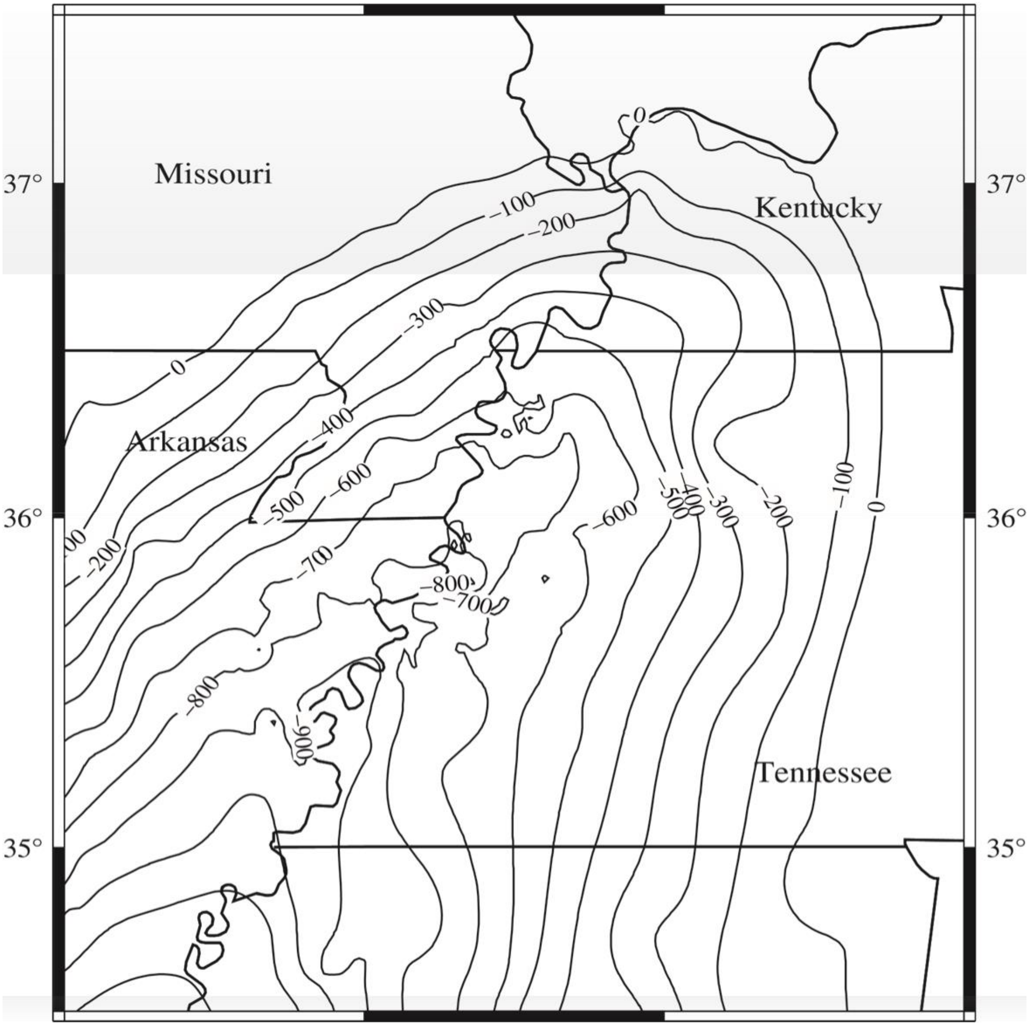

Figure 1. Top of the Paleozoic strata of the Mississippi embayment (adapted from Van Arsdale and TenBrink 2000)

"Ground Motion Site Amplification Factors," M. Malekmohammadi et al

SDC Stability

Seismic Design Category Map – Option 1

- Simple...
  1. Generate new and previous MCE_R maps by same rule set
  2. Identify where ground motions change by more than the uncertainty, e.g., by > 20% (or > 10%)
  3. If change is less than 20%(?), SDC does not change
  4. If change is greater than 20%(?) PUC to consider underlying causes and subjectively determine if SDC should change

5. Note: Tables 11.6-1 and 11.6-2 would be moved to commentary and no longer required by typical user

SDC Stability

Seismic Design Category Map – Option 2

- Variation on Simple...
  1. Generate new and previous MCE_R maps by same rule set
  2. Identify where ground motions change by more than the uncertainty, e.g., by > 20% (or > 10%)
  3. **Identify where SDC changes by Tables 11.6-1 and 11.6-2**
  4. If change is less than 20%(?) **and is generally around the Table values** SDC does not change
  5. If change is greater than 20%(?) **and/or is significantly different from Table values** PUC to consider underlying causes and **variation from Tables** and subjectively determine if SDC should change

SDC Stability

Seismic Design Category Map – Option 3

- Not so Simple...
  1. Generate MCE_R maps by same rule set for the latest 3 hazard model versions (i.e., 2014, 2008, 2002)
  2. Determine an average MCE_R ground motion based on these 3 models
  3. Identify where new ground motions vary from the average by more than the uncertainty, e.g., by > 20% (or > 10%)
  4. If change is less than 20%(?) SDC does not change
  5. If change is greater than 20%(?) PUC to consider underlying causes and subjectively determine if SDC should change

SDC Stability

Questions for the Workshop

1. Are oscillating SDC’s an important enough issue to affect potentially significant changes or should the status quo be maintained?

2. If no, why not?

SDC Stability

Questions for the Workshop

3. If yes:
   a. Does a simple approach address the issue or is a more complicated approach warranted?
   b. Are current SDC's adequate (A-F) or should there be more/less?
   c. Should multiple previous generation maps be blended or rely only on the preceding version for comparison?
   d. Should deterministic caps be included?
   e. Will resulting step changes be acceptable or cause more issues?

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