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10 - 14 May 2010

History of Modern Earthquake Hazard Mapping and Assessment in California Using Deterministic or Scenario Approach

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Seismic Hazard

- Purpose-Driven
- Emergency Response, Insurance, etc
- Subjective
- Engineering

Motivators

- **Damaging Earthquakes**
- **Proportional to Level of Disaster**
- **Available Funding for Solution**

Important California Earthquakes

- **Pre-1925 Santa Barbara earthquakes**

First US Seismic Code of 1927

- **1933 Long Beach, M6.3**

Field Act: EQ-resistant schools

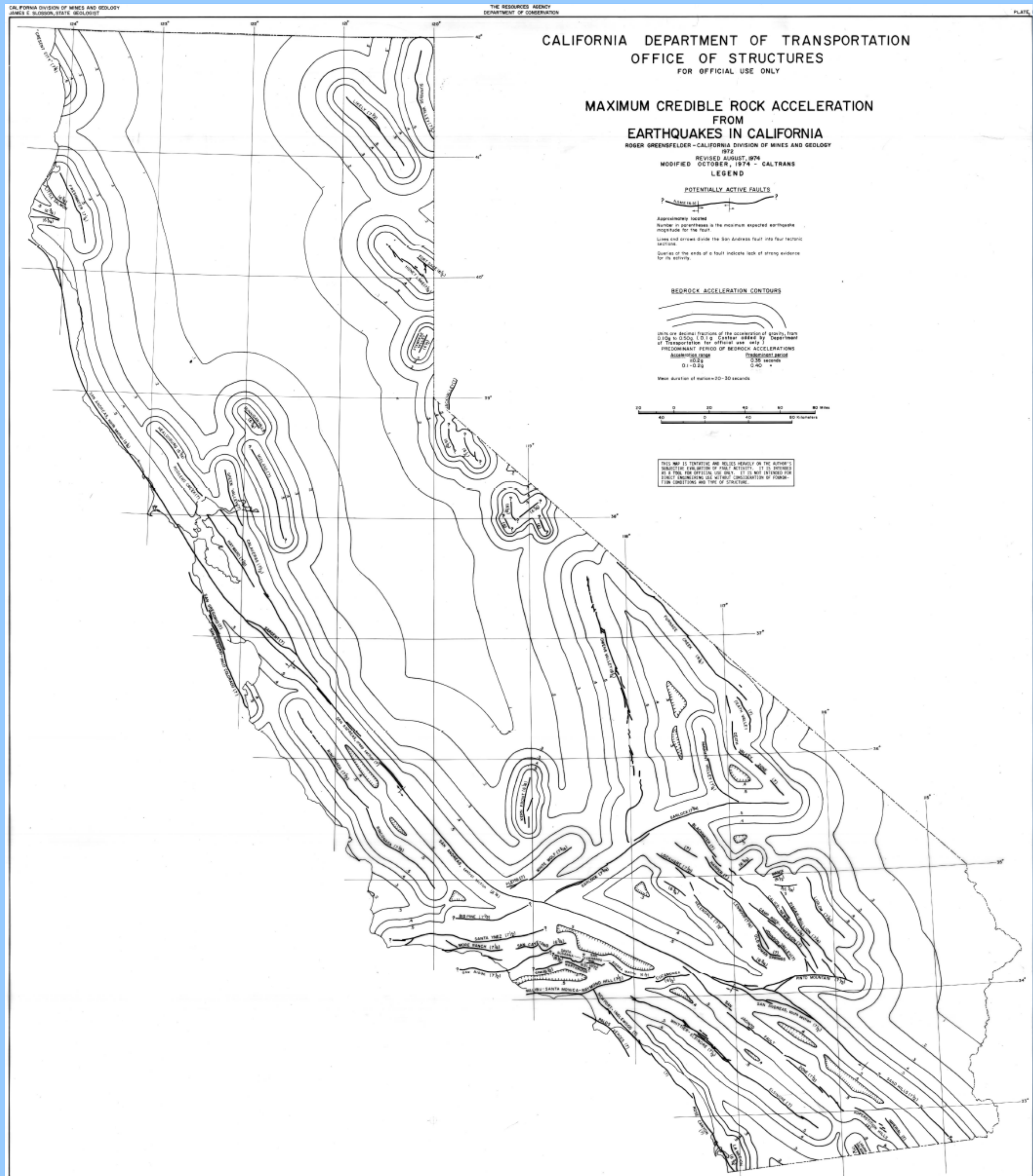
- **1971 San Fernando, M6.5**

Hospital Seismic Safety Act: to withstand EQs

First Seismic Hazard Map published by Calif. Div. Mines & Geology (CDMG)

First Edition California Seismic Hazard Map

- **Fault-based EQ Sources**
- **Used Maximum Credible Earthquake (MCE) Concept**
- **Used Peak Acceleration Attn Curves using available data & theory**
- **Later called "Deterministic"**
- **Accepted & Used for years**
- **By Calif. Dept. Trans. (Caltrans)**



CALIFORNIA DIVISION OF MINES AND GEOLOGY
JAMES E. SLOSSON, STATE GEOLOGIST
THE RESOURCES AGENCY
DEPARTMENT OF CONSERVATION
PLATE
CALIFORNIA DEPARTMENT OF TRANSPORTATION
OFFICE OF STRUCTURES
FOR OFFICIAL USE ONLY
MAXIMUM CREDIBLE ROCK ACCELERATION
FROM
EARTHQUAKES IN CALIFORNIA
ROGER GREENSFELDER - CALIFORNIA DIVISION OF MINES AND GEOLOGY
1972
REVISED AUGUST, 1974
MODIFIED OCTOBER, 1974 - CALTRANS
LEGEND
POTENTIALLY ACTIVE FAULTS
Approximately located
Number in parentheses is the maximum expected earthquake magnitude for the fault.
Lines and arrows divide the San Andreas fault into four tectonic sections.
Queries at the ends of a fault indicate lack of strong evidence for its activity.
BEDROCK ACCELERATION CONTOURS
Units are decimal fractions of the acceleration of gravity, from 0.10g to 0.50g. (0.1 g Contour added by Department of Transportation for official use only)
PREDOMINANT PERIOD OF BEDROCK ACCELERATIONS
Acceleration range
Predominant period
≥0.2g
0.35 seconds
0.1 - 0.2g
0.40 "
Mean duration of motion = 20 - 30 seconds
20 0 20 40 60 80 Miles
40 0 40 80 Kilometers
THIS MAP IS TENTATIVE AND RELIES HEAVILY ON THE AUTHOR'S SUBJECTIVE EVALUATION OF FAULT ACTIVITY. IT IS INTENDED AS A TOOL FOR OFFICIAL USE ONLY. IT IS NOT INTENDED FOR DIRECT ENGINEERING USE WITHOUT CONSIDERATION OF FOUNDATION CONDITIONS AND TYPE OF STRUCTURE.

Comments on the First Edition Map

- EERI objected its publication
- Already released by the State Geologist
- Well accepted by public & private agencies, consultants, etc.
- Confidence in the applications

Data for First Edition Map

- No of Faults Used: 77
- Quaternary Faults
- Dip, Width, or Type of Faults Not Considered

Clarifications

- DSHA used Probability
- EQ rate not explicitly considered
- Single EQ magnitude label misleading
- Smaller EQs considered automatically
- Step by Step Procedure

Living Document

- Revise or Update
- Incorporate New Information & Knowledge
- Use Emerging New Technology
- Evaluate Usefulness or Effectiveness

Related Information

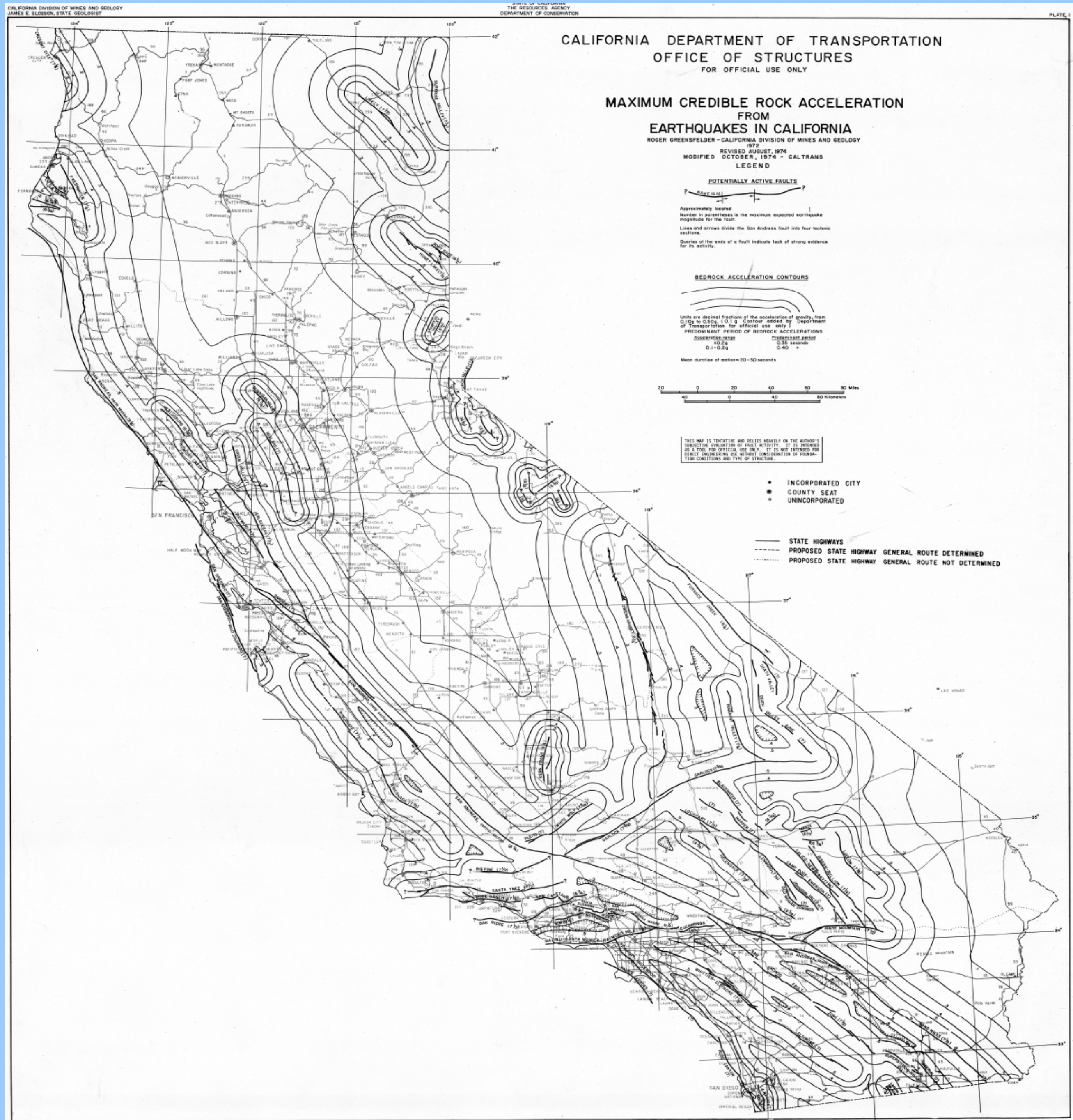
- **1976: First USGS Probabilistic Seismic Hazard Map**
- **1982: Second USGS Probabilistic Seismic Hazard Map**
- **1988: PSHA-Report of the Panel on Seismic Hazard Analysis, National Research Council**

Second Edition California Seismic Hazard Map-1

- **1985 October: Ready for publication as CDMG Map Sheet 45**
- **Publication Delayed ....**
- **1989 May: Ad-hoc Committee on “Deterministic/Probabilistic Procedures for Evaluating Seismic Hazard” meeting put the map in limbo**
- **List of MCEs to be published as CDMG Note 34, already referenced in Title 24 CAC**

Second Edition California Seismic Hazard Map-2

- **1989 October: Loma Prieta EQ caused a great damage in the San Francisco area**
- **Board of Inquiry of the EQ got the Map**
- **1992: CDMG released the Map at the demand of Caltrans, seven years after its completion**


CALIFORNIA DIVISION OF MINES AND GEOLOGY
JAMES E. SLOSSON, STATE GEOLOGIST
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF CONSERVATION
PLATE 1
CALIFORNIA DEPARTMENT OF TRANSPORTATION
OFFICE OF STRUCTURES
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INCORPORATED CITY
COUNTY SEAT
UNINCORPORATED
STATE HIGHWAYS
PROPOSED STATE HIGHWAY GENERAL ROUTE DETERMINED
PROPOSED STATE HIGHWAY GENERAL ROUTE NOT DETERMINED
SACRAMENTO
SAN FRANCISCO
SAN DIEGO

Data for Second Edition Map

- No of Faults Used: 234
- Late Quaternary Faults
- Dip, Width, or Type of Faults Considered
- Deep-seated or Blind Faults (1st time)
- Northridge Hills fault dipping south as a possible 1994 Northridge EQ source!
- New Attenuation Curves
- Magnitude (¼ unit)

Third Edition California Seismic Hazard Map

- **Used GIS technology**
- **Easily associated with bridges & other structures**
- **Most visited Caltrans website**

http://www.dot.ca.gov/hq/esc/earthquake_engineering/Seismology/

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JAMES W. VAN LOBEN SELS, DIRECTOR

STATE OF CALIFORNIA
BUSINESS, TRANSPORTATION AND HOUSING AGENCY
DEAN R. DUNPHY, SECRETARY

ENGINEERING SERVICE CENTER
JAMES E. ROBERTS, DIRECTOR

CALIFORNIA SEISMIC HAZARD MAP 1996

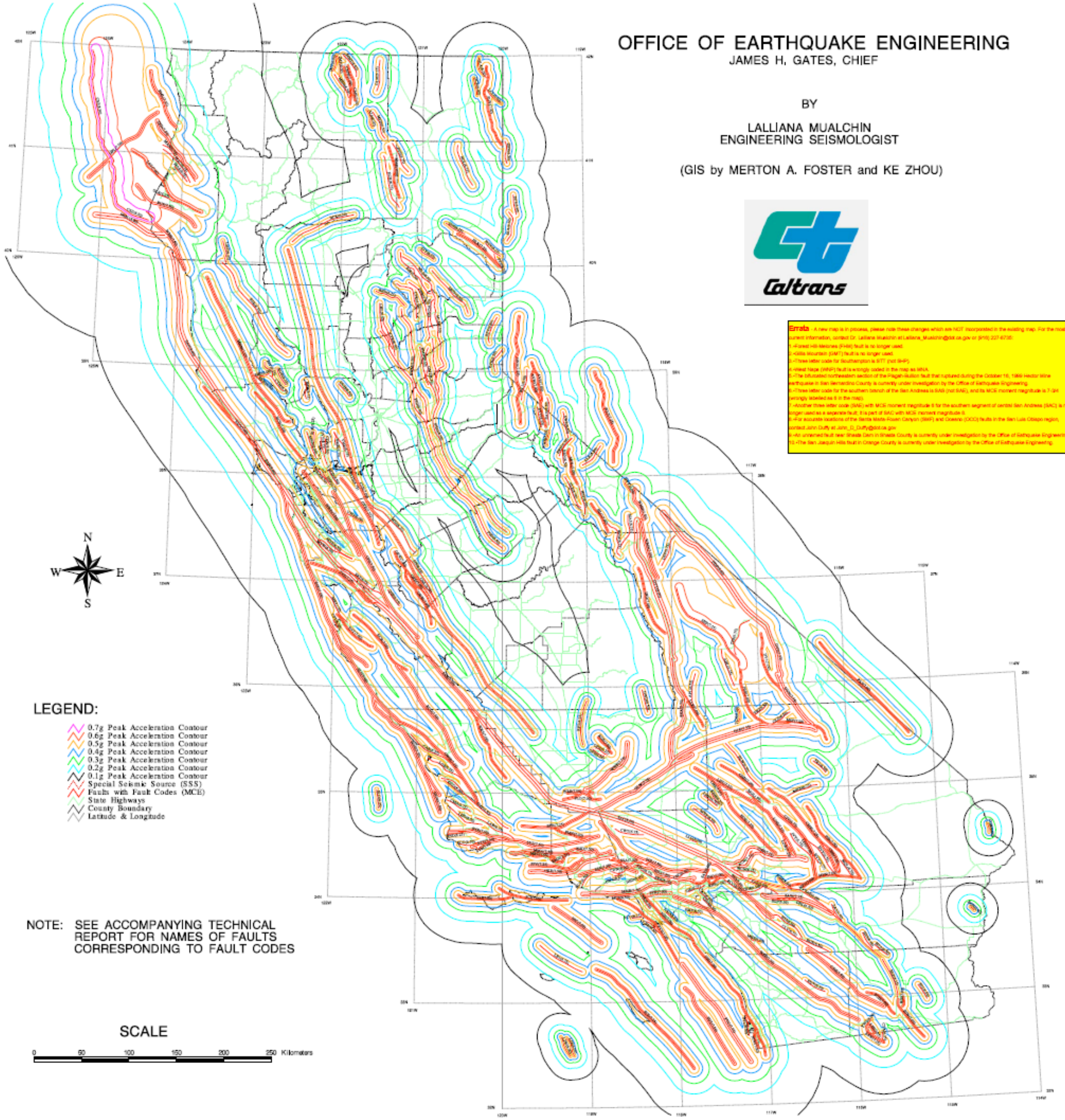
BASED ON MAXIMUM CREDIBLE EARTHQUAKES (MCE)

OFFICE OF EARTHQUAKE ENGINEERING
JAMES H. GATES, CHIEF

BY

LALLIANA MUALCHIN
ENGINEERING SEISMOLOGIST

(GIS by MERTON A. FOSTER and KE ZHOU)



Errata - A new map is in process, please note these changes which are NOT incorporated in the existing map. For the most current information, contact Dr. Lalliana Mualchin at Lalliana_Mualchin@dot.ca.gov or (916) 227-6735:

1.-Forest Hill-Melones (FHM) fault is no longer used.
2.-Gillis Mountain (GMT) fault is no longer used.
3.-Three letter code for Southampton is STT (not SHP).
4.-West Napa (WNP) fault is wrongly coded in the map as MNA.
5.-The bifurcated northeastern section of the Pisgah-Bullion fault that ruptured during the October 16, 1999 Hector Mine earthquake in San Bernardino County is currently under investigation by the Office of Earthquake Engineering.
6.-Three letter code for the southern branch of the San Andreas is SAS (not SAE), and its MCE moment magnitude is 7-3/4 (wrongly labelled as 8 in the map).
7.-Another three letter code (SAE) with MCE moment magnitude 8 for the southern segment of central San Andreas (SAC) is no longer used as a separate fault; it is part of SAC with MCE moment magnitude 8.
8.-For accurate locations of the Santa Maria-Foxen Canyon (SMF) and Oceano (OCO) faults in the San Luis Obispo region, contact John Duffy at John_D_Duffy@dot.ca.gov
9.-An unnamed fault near Shasta Dam in Shasta County is currently under investigation by the Office of Earthquake Engineering.
10.-The San Joaquin Hills fault in Orange County is currently under investigation by the Office of Earthquake Engineering.

LEGEND:

- 0.7g Peak Acceleration Contour
- 0.6g Peak Acceleration Contour
- 0.5g Peak Acceleration Contour
- 0.4g Peak Acceleration Contour
- 0.3g Peak Acceleration Contour
- 0.2g Peak Acceleration Contour
- 0.1g Peak Acceleration Contour
- Special Seismic Source (SSS)
- Faults with Fault Codes (MCE)
- State Highways
- County Boundary
- Latitude & Longitude

NOTE: SEE ACCOMPANYING TECHNICAL REPORT FOR NAMES OF FAULTS CORRESPONDING TO FAULT CODES

SCALE

0 50 100 150 200 250 Kilometers

Data for Third Edition Map

- **No of Faults used: 275**
- **Late Quaternary faults**
- **Dip, Width, or Type of faults considered**

Comments for Third Edition Map

- Type of faults still not available for some faults

- Dip & Width also still not available for some faults

Updating & Errata for Third Edition Map

- New faults, including the San Joaquin Hills fault in Orange County
- Faults no longer used
- Fault letter codes corrections

Opinions

- Problems in the national map
- Are map developer responsible?
- Authoritative vs Research project map
- More maps for different applications

Use of the Map

- In preparing bridge design spectrum, including incorporation of site response
- Design spectrum shape/level as a function of MCE magnitude
- May use as a starting source model for ground motion simulations

Personal Experience with PSHA

- **San Onofre** NPP - Christianitos fault by Gutenberg-Richter equation, inadequate data.
- **Diablo Canyon** NPP - Hosgri fault, no problem with DSHA and problem with PSHA.
- **Bolsa Chica** Project - Newport-Inglewood fault, unrealistic result by PSHA.
- **Hospital** Seismic Reports - Too low hazard for Central Valley.
- **California Seismic Hazard Map** for Caltrans - Critical input not available for many faults and PSHA results not correlated with proximity to earthquake source.

Unresolved points on PSHA

- **Doubt on combining hazards in PSHA**
- **Not a return period but just a numerical probability**
- **Arbitrary 'p' percent exceedance probability in 't' years & return period**
- **Problems and lack of data in slip rate**
- **Physically unrealistic extreme ground motions for long return periods**

Remarks on DSHA

- **Strengths for DSHA/NDSHA**
- **Need to formalize DSHA/NDSHA**
- **Variability or Uncertainty wrt MCE**

For DSHA & PSHA

- Refine magnitude estimates using regional empirical fault parameter-magnitude relationships
- Use both empirical data & simulated ground motion estimates for continuity and confidence in practice
- When in doubt, err on the conservative side and avoid over-analysis

Personal Experience/Observation

- For Caltrans Toll Bridges
- San Francisco-Oakland Bay Bridge
- Caltrans Seismic Advisory Board

Concluding Remarks

- DSHA/NeoDSHA withstand the test of time for engineering applications!
- Incorporate source modelling & advanced simulations
- Use earthquake rate for "Risk Analysis" if & when required
- Open-mind, and avoid polarization & control of ideas in SHA

Recommendations

- **DSHA demonstrated its stability and usefulness for engineering**
- **Neo-DSHA can be used for realistic ground motion estimates in conjunction with DSHA**
- **PSHA demonstrated its lack of credibility, intractable and costly method, and must be adjusted for engineering**
- **DSHA can be used for Seismic Risk Analysis if and when required*.**

*Klugel, J.-U., Mualchin, L. and Panza, G. F. (2006): Eng. Geology: 88, 1-22.

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THANK YOU!