scenarios or deterministic ground motions, which the Project currently develops only for a limited number of uses. Earthquake scenarios would be used by technical and non-technical users, and the description of seismic hazard as a suite of deterministic ground motions could augment probabilistic hazard values, providing a parallel way to understand and communicate seismic hazard.

This presentation summarizes suggestions for improvements to the transfer of seismic-hazard knowledge and numerical values from the USGS National Seismic Hazard Mapping Project to the wider seismic hazard community.

Project '17: Balancing Precision in Ground Motion Mapping with Uncertainty

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In 1997, the U.S. Geological Survey (USGS) and Building Seismic Safety Council (BSSC) collaborated to develop seismic design maps for the 2000 International Building Code. The Project '97 spectral acceleration contour maps have since served, with periodic revisions (in 2003, 2009, and 2015), as the basis for seismic design procedures in the U.S. Earlier maps used broad zonation, with the zones relating to ground motion in an approximate manner. Zone 4 design effective peak ground acceleration was declared, over a broad region, to have a value of 0.4g. Values in other zones were taken as fractions of this. Engineers understood these design accelerations were approximate. Regardless, the values could be used for design of most structures and changed relatively infrequently. The Project '97 contour maps specified acceleration in 0.05g increments and, with interpolation, engineers derived design values with greater apparent precision. With continued research, the ground motion prediction equations used to produce the maps and the earthquake source characteristics changed. Mapped design acceleration values fluctuated, with ±20% changes common, creating a lack of confidence among users. More troubling still was the yo-yo effect in which mapped values would first rise then fall. Most recently, an American Society of Civil Engineers committee initially rejected the 2014 edition of the maps based on a belief that the information portrayed was not substantially more valid than that contained in earlier editions. Dissatisfaction with the maps can be attributed to: lack of appreciation of the uncertainty underlying mapped values; 2) design procedures that treat the mapped values as highly certain; and 3) a mapping process that results in significant change in mapped values with each update. Project '17, a new joint USGS-BSSC project, is considering these and other issues and preparing recommendations for the next generation of maps to be incorporated into building codes.

Effects of Epistemic Uncertainty in Seismic Hazard Estimates on Building Portfolio Losses

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In catastrophe risk modeling, a defensible estimation of impact severity and its likelihood of occurrence can only be made through a rigorous treatment of uncertainty and the consideration of multiple alternative models. To limit the demand on computational time and resource, a frequent practice in the industry is to estimate the distribution of earthquake-induced losses using a simulated catalog of events from a representative mean ground motion hazard model for the region without epistemic uncertainties. This simplified approach is faster but may underestimate the likelihood of occurrence of the large losses that drive many decisions. Investigation through case studies on different portfolios of assets located in San Francisco Bay Region shows the potential for both a bias in the mean loss estimates and an underestimation of their central 70% inter-percentile ranges (between 15th and 85th empirical quantiles). An alternative simplified and computationally practical approach that removes or reduces such a bias in mean is proposed, which however did not show improvement in estimated inter-percentile range.

The original idea for this study was conceived several years ago during a discussion of one of the authors with Dr. Nesrin Basöz of GeoVera, Her contribution is gratefully acknowledged. This work also benefitted from the discussions with Dr. Nilesh Shome of RMS and Dr. Mario Ordaz of ERN. Most of the analytical work was done in 2013 at Understanding and Managing Extremes (UME) Graduate School, Pavia, Italy

Seismic Site Characterizations and Earthquake Loss Estimation Analyses for 25 Schools in Thurston County, Washington State

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The mission of The Washington Department of Natural Resources–Division of Geology and Earth Resources is to "reduce or eliminate risks to life and property from natural hazards." We conducted active and passive seismic surveys, and estimated Shear-wave velocity (Vs) profiles, then determined the NEHRP soil classifications using calculated Vs30m values at 25 public school sites in Thurston County, Washington. We conducted active and passive surveys: 1D and 2D MASW and MAM, P- and S-wave refraction, horizontal-to-vertical spectral ratio (H/V), and 2ST-SPAC to measure Vs and Vp at shallow (0-70m) and greater (10 to 500 or 10 -3000 meters) depths at the sites. We then ran Ground Penetrating Radar surveys along each seismic line to check possible horizontal subsurface variations between the survey line and the actual location of the school buildings. We estimated, 1D and 2D shear-wave velocities, 2D Vp, Vp/Vs for top 30 to 70m depth range, and shear-wave velocities at depths (>30m) by using passive single-station (H/V) and array (MAM and/or 2ST-SPAC) measurements. These survey results were then used for calculations of Vs30m for determining the NEHRP site classifications; soil classes C and D were found at 12 and 13 school sites, respectively. These site classes were also used for determining soil amplification effects on the ground motions affecting structural damage estimations of the school buildings. The detailed Vs information can be used for further earthquake site response analyses. These seismic site characterization results associated with structural engineering evaluations were then used as inputs in FEMA Hazus-Advanced Engineering Building Module (AEBM) analysis to provide estimated casualties, nonstructural, and structural losses. Damage estimations from the Hazus-AEBM analysis can be used to prioritize future mitigation of the schools exposed to potential nearby and regional earthquakes.

Quantifying the Location, Width, and Style of Coseismic Surface-Fault Displacement at Gas Transmission Pipeline Fault Crossings in Northern California

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Pacific Gas and Electric Company maintains a program to evaluate the integrity of their gas transmission pipeline network where pipelines intersect mapped Holocene-active faults. In 2015, this program evaluated 63 pipeline fault crossings across 10 faults, a significant increase from previous years. These studies synthesized available geologic data to provide defensible assessments of the location of fault strands at the pipeline crossing and the probable width, style, and distribution of future coseismic deformation. A logic-tree-based deterministic fault displacement hazard analysis developed for this program (see companion abstract by Thompson *et al*.) used multiple fault parameters to estimate coseismic displacement. These displacement values were the basis for an analysis of post-earthquake gas pipeline pressure integrity using finite element pipe stress analysis. A challenge of the 2015 effort was that it included a wide range of fault activity rates, which varied from high slip rate faults (*e.g.*, Concord, Calaveras, Green Valley, and San Andreas faults) to low slip rate faults (<1 mm/yr) (*e.g.*, Clayton, Cordelia, and Pleasanton faults). The availability of site-specific data also varied considerably from very good (*e.g.*, nearby measurements of surface displacement from historic earthquakes) to little or no reliable information. These uncertainties were addressed through additional subsurface investigations, especially where reducing uncertainty had a clear impact on the engineering outcomes. In most cases the lack of site specific data (and/or the inability to collect more data) resulted in larger uncertainties and broader fault hazard zones. The keys to providing quality geologic information are to focus on (1) a transparent synthesis of geologic data (including a reasonable consideration of uncertainty) and (2) targeting field investigations to reduce uncertainty where new data may significantly impact the integrity assessments.

Risk Model for a System-Wide Dam Risk Reduction Program in Northern California

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