APPENDIX D: Workshop Summaries

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D.1.0 Introduction

In accordance with the Senior Seismic Hazard Analysis Committee (SSHAC) Level 3 implementation guidelines (U.S. NRC, 2012), three formal workshops (Workshops 1, 2 and 3) were performed for the Diablo Canyon SSC study. This Appendix provides a summary of each of these workshops, including the workshop agenda, list of participants, and summary of each of the presentations. The complete set of power point presentations provided by the speakers, as well as links to videos of the workshop proceedings, is provided on the PG&E website at www.pge.com/dcpp-ltsp. The tables accompanying this appendix appear at the end, under *Section D.6.0*. The overall list of SSC Resource and Proponent Experts that attended each of the three workshops is provided in Table D-1.

An important goal of a SSHAC Level 3 SSC study is to develop a "hazard-informed" SSC model. As such, at each of the workshops, the hazard analyst provided a sensitivity analysis to identify those parameters or issues of the SSC model that do or do not contribute significantly to ground motion hazard at the DCPP. At Workshop 1, the sensitivity analysis was performed using the then most current SSC and GMC model published by PG&E in the Shoreline fault study (PG&E, 2011). For Workshop 2, the sensitivity analysis explored various SSC parameters or concepts under consideration by the TI Team prior to development of the preliminary SSC model; the sensitivities were also performed using the GMC model from the Shoreline fault study (PG&E, 2011). For Workshop 3, the sensitivity analysis was performed using the preliminary SSC model and a GMC model that consisted of available NGA-West 2 GMPE relationships. A final sensitivity analysis using the final SSC model and a simplified form of the new SWUS GMC model (GeoPentech, 2015) is provided in *Chapter 14*.

Each workshop presentation describing the sensitivity analyses is available on the PG&E web site. Because of the importance of these sensitivity analyses, and for ease of reference, the power point presentations of the sensitivities are included as attachments to this appendix.

All the workshops were convened in San Luis Obispo, California, and were open to the public. A period of time was provided at the end of each day of each workshop for public or observer comments. Following each workshop, the PPRP provided written comments to the project sponsor, and the TI Team provided the PPRP with responses to the comments. This correspondence is included in the project files.

D.2.0 Workshop 1 – Hazard Significant Issues and Available Data

Workshop 1 lasted for three days between November 29 and December 1, 2011, and was attended by the PTI, the SSC TI Team and staff, the GMC TI Team and staff, the PPRP, the Database Manager, the Hazard Analysts, and the Resource Experts (REs). The SSC portion of the workshop included two full days. The third day of the workshop was a joint SSC/GMC session to discuss mutually important hazard significant issues and the relevant data to address those issues. Workshop participants that attended Workshop 1 are listed in Table D-2. An agenda for the workshop is provided in Table D-3.

The goal of Workshop 1 was to discuss issues significant to hazard, identify available data to address the significant issues, and identify gaps in data or knowledge that could be obtained through further investigations to reduce epistemic uncertainty related to the significant issues. REs were asked to discuss specific data sets and to assist in identifying available data to address significant issues. Legacy data from the prior LTSP studies were presented, if relevant to the current Diablo Canyon SSC project. Prior to the workshop, letters were sent to participating REs identifying directed topics and issues that they should be prepared to address at the meeting. The letters helped focus the workshop discussion on key issues related to a particular data set, including quality and resolution of data, expected use of data, uncertainty, or limitations in the data or interpretations. The REs were asked to present data in oral sessions and/or to participate in interactive discussion sessions with the TI Team and other REs. The presentations and following discussion informed the TI Team of the available data and evaluations and interpretations of the data. In addition, data needs identified during the course of Workshop 1 were compiled by the TI Team and considered in defining the scope of further studies.

Below, we summarize each of the SSC presentations. The GMC presentations are not discussed here but are available on the PG&E website.

D.2.1 Welcome/Introduction/Agenda – Kent Ferre

Representing PG&E as the Project Sponsor, Mr. Kent Ferre welcomed participants to the workshop and provided an overview of the workshop structure (SSC and GMC as separate parallel meetings with a one-day joint session). Mr. Ferre indicated that PG&E fully supported the use of the SSHAC Level 3 process to develop the SSC and GMC models for use in an updated PSHA for Diablo Canyon. Mr. Ferre briefly reviewed the workshop agenda

D.2.2 SSHAC and Workshop Rules – William Lettis

As the SSHAC SSC TI Lead, Dr. William Lettis provided an overview of the SSHAC Level 3 process for the workshop participants with specific reference to implementation guidance provided in NUREG 2117 (U.S. NRC, 2012). He discussed the objectives and goals of the SSHAC process, description of formal SSHAC participants and roles, description of the workshop process, and ground rules for conducting the workshop. Dr. Lettis provided an Organization Chart for the SSC project and clearly identified the specific roles and responsibilities of each of the project team members. The SSHAC training and review of workshop ground rules help ensure compliance with the SSHAC process and successful completion of the workshop. Dr. Lettis provided a more detailed review of the workshop agenda, and the process of presentation followed by discussion/questions from the TI Team.

As described by Dr. Lettis, the SSHAC Level 3 Objectives include:

1. Develop fully hazard-informed SSC and GMC models for update of the Diablo Canyon PSHA;

2. Provide increased regulatory assurance that the PSHA adequately captures uncertainties in data and scientific knowledge; and
3. Identify important data needs for reducing uncertainties in significant SSC and GMC model parameters

At the completion of each day's presentations, Dr. Lettis compiled a summary of key issues and data needs that arose from each presentation.

D.2.3 Project Background – Norm Abrahamson

As the SSHAC PTI, Dr. Norm Abrahamson provided an overview of the Diablo Canyon PSHA study and background information to bring the workshop participants to a common understanding of the status of studies performed to date at the DCPP. Dr. Abrahamson provided a review of unresolved technical issues from the 1991 LTSP study (PG&E, 1988; 1991) and US NRC Safety Evaluation Report (SSER 34), and the data collected to address these issues. He described the recently discovered Shoreline fault, the results provided in the 2011 Shoreline fault report (PG&E, 2011), and unresolved technical issues from the Shoreline fault study. Dr. Abrahamson briefly identified those technical issues of most significance to seismic hazard at Diablo Canyon.

D.2.4 Hazard Sensitivity – Katie Wooddell

Ms. Katie Wooddell presented a preliminary sensitivity analysis to identify those seismic source parameters that are most significant to seismic hazard at Diablo Canyon. For the preliminary sensitivity analysis, Ms. Wooddell used the then current SSC and GMC models for Diablo Canyon from the PG&E Shoreline Fault study (PG&E, 2011). Her presentation is provided as Attachment D-1. Ms. Wooddell examined the contribution to total hazard (annual frequency of exceedance [AFE]) from various fault sources, including the Hosgri fault, Los Osos fault, Shoreline fault and San Luis Bay fault, as well as more distant fault sources such as the San Andreas fault, Oceanic fault, West Huasna fault, Wilmar Avenue-Nipomo fault, Oceano-Pecho fault, Rinconada fault, Cambria fault, San Simeon fault, Casmalia fault, and Santa Lucia Bank fault. With the exception of the San Andreas fault that contributes ~2% of total hazard at long periods at the 10^{-4} hazard level, none of the more distant faults individually contributes >1% to hazard at the 10^{-4} level. Cumulatively (including the San Andreas fault), the more distant faults account for ~5% of total hazard at the 10^{-4} level for long periods. In terms of individual fault sources, the result shows that hazard at Diablo Canyon is controlled primarily by the Hosgri, San Luis Bay, Los Osos and Shoreline fault sources.

In addition, Ms. Wooddell examined the ranges in hazard results for the range in values of various input source parameters associated with the four nearby faults, including slip rate, fault dip/geometry, crustal thickness, and fault length (including joint ruptures). The resulting ranges in hazard results, or sensitivity to hazard uncertainty, are presented in "tornado" diagrams that rank the source parameters in order of "most significant" to "least significant" to hazard uncertainty at Diablo Canyon. As shown on the tornado diagrams (for PGA, T=0.2 sec, and T=2.0 sec) provided by Ms. Wooddell, the source parameters that are most significant to hazard uncertainty at Diablo Canyon are, in order of significance, slip rate on the Hosgri fault, location of the Hosgri fault (i.e., site-to-source distance), dip of the Hosgri fault, rupture length of the Hosgri fault, slip rate of the Shoreline fault, dip of the Los Osos fault, and slip rate of the Los Osos fault. Other source parameters, such as dip of the San Luis Bay fault, crustal/seismogenic thickness, and rupture length of the Shoreline, San Luis Bay and Los Osos faults do not contribute significantly to hazard uncertainty at Diablo Canyon.

D.2.5 Central Coast Seismic Network and Earthquake Catalog – Marcia McLaren

Ms. Marcia McLaren provided an overview of the PG&E Central Coast Seismic Network (CCSN), the current earthquake catalog from 1987 to present, and identified instrument/data gaps. Ms. McLaren also provided data on the distribution of earthquakes in the study area and historical focal mechanisms.

Ms. McLaren began by explaining the types of instruments used in the CCSN now consisting of acceleration and short period instruments (PG&E analog and digital; United States Geological Survey (USGS) instruments; broadband; and co-located), along with a subsequent comparison of analog and digital output data, demonstrating that digital data quality is superior, especially for collecting S-wave data. She discussed how instrument/data gaps exist west (offshore), north, and southeast of the DCPP. To address the offshore instrument/data gaps, PG&E is planning to implement the Ocean Bottom Seismometer (OBS) Project, consisting of installing temporary (4) and permanent (4) seismometers.

Following the description of the current CCSN and known data/instrumentation gaps, Ms. McLaren provided a summary of the PG&E earthquake catalog, history of data integration, and focal mechanisms observed throughout the study area. When all earthquake data from the study area (including 1D) were shown, Ms. McLaren indicated that more instrumentation in the Santa Maria Valley is needed. She noted that there is uncertainty in data collected from events of magnitude 3 and greater from the southern and offshore regions of the study area.

Ms. McLaren summarized the focal mechanism data for the study area provided in the 1988 PG&E Long Term Seismic Program (LTSP) Report, indicating that in the southern offshore Santa Maria Basin, the fault motions are primarily reverse and that focal mechanisms are more difficult to obtain. She presented figures displaying all events with their respective focal mechanisms and those grouped by similar focal mechanisms for the study area. These showed that for the San Simeon earthquake and aftershock areas, the primary motion was reverse, strike-slip, and oblique strike-slip, with a much lesser normal component.

Ms. McLaren concluded with the following points regarding the earthquake catalog and data quality:

1D Catalog Data Quality:

- Earthquake hypocenters are reasonably well located where station coverage is good (onshore), although absolute/relative location methods (tomoDD) improve resolution of earthquake patterns;
- Location uncertainties for onshore earthquakes approximately <1 km to 2 km (horizontal) and <1 km to ~4 km (depth);
- Location uncertainties for offshore earthquakes are inherently greater, ranging from < 1 km for the very near shore to ±5 km or more, farther offshore;
- Digital recordings from strong motion and short period sensors provide more on-scale seismograms for larger lower magnitudes; and
- Better S-wave data.

Focal Mechanism Data Quality:

- Good azimuthal station distribution (<180 degree) at varying distances and at least 15 P-wave first motions are keys for good focal mechanisms; and
- The OBS should improve offshore earthquake locations and focal mechanisms.

D.2.6 Central Coast Seismicity Locations – Jeanne Hardebeck

Dr. Jeanne Hardebeck discussed the CCSN locations, important network issues, and results of an assessment of the uncertainty of events occurring on the Shoreline fault. The four primary seismic network issues for earthquake location were listed as follows:

- Many stations are single-component, difficult to identify S-wave arrivals;
- Sparser station coverage outside of Parkfield and San Luis Obispo areas;
- One-sided station coverage for along-shore events (e.g., Hosgri and Shoreline faults); and
- No stations within a focal depth for earthquakes farther offshore.

Dr. Hardebeck provided a summary of the data types (phase and waveform) and location methods (catalog locations, 3D seismic velocity model from tomography, double-difference relocation; “hypoDD” code, and double-difference tomography; “tomoDD” code), and how each respective method can be used to locate or improve the relative and/or absolute earthquake locations. Dr. Hardebeck also noted that a comprehensive cross-correlation of the earthquake catalog for the study area was performed, the results of which were published in 2010 (Hardebeck, 2010). Support for the study performed by Dr. Hardebeck was provided under the PG&E LTSP/USGS CRADA program and are documented in unpublished reports.

Dr. Hardebeck performed a multi-step process to reassess earthquake locations with either tomoDD code, or a combination of 3D velocity and hypoDD methods. Results of the assessment show defined planar structures along the Hosgri, Shoreline, Estero Bay, and Rinconada faults. Analysis of the results for the Hosgri fault indicate that the onshore section (“San Simeon fault”) has planar seismicity beneath its surface trace, from 2-14 km depth, that deepens to the north. The area offshore Cayucos also has planar seismicity with similar depth ranges (4-10 km). Similar characteristics were also observed offshore of Point Buchon (planar seismicity beneath surface trace, 2-12 km depth); however, it likely deepens to the east. Dr. Hardebeck stated that locations along the southern Hosgri fault are poorly constrained. She showed the Shoreline fault as having planar seismicity, depth ranges from 2 km to 10-12 km, but deepening slightly to the north. She later stated that onshore seismicity in the Irish Hills is bounded by Shoreline and Los Osos faults, but the seismicity showed no clear dipping structures under Irish Hills.

The presentation concluded with a summary of Central Coast earthquake characteristics and location uncertainties:

- Hosgri fault: Planar seismicity beneath some sections of surface trace, in places down to 10-14 km depth. In the Point Buchon area, deeper events dip slightly to the east;
- Shoreline fault: Planar seismicity, down to 10-12 km depth;
- Irish Hills seismicity bounded by Shoreline and Los Osos faults. No clear dipping structures;
- Earthquake location uncertainty in the Point Buchon area estimated by average error of shot relocations: horizontal: 1.03 km; vertical: 0.91 km;
- The lower limit on earthquake location uncertainty in Point Buchon area estimated from synthetic catalogs. Average uncertainty: horizontal: 0.93 km; vertical: 0.93 km; and
- In the best case, planned OBS deployment will reduce uncertainty offshore of Point Buchon by 30-50%. Given the current low seismicity rate it may take some time to accumulate many new events.

D.2.7 Central Coast Focal Mechanisms – Jeanne Hardebeck

Dr. Hardebeck began with a reiteration of the seismic network issues that affect focal mechanism determination that include:

- One-sided station coverage for along-shore and off-shore faults, including the Hosgri and Shoreline faults;
- Sparser coverage outside of Parkfield and San Luis Obispo areas; and
- South of Oceano, the station coverage is too sparse, even for composite focal mechanisms.

Ms. Hardebeck provided a summary of the method that she developed for determining focal mechanisms called the Hardebeck & Shearer (HASH) method. The uncertainty was determined and plotted, and results of the uncertainty analysis show that along-shore/offshore events have more uncertainty (35 to greater than 45 degrees) and do not provide good enough data to determine fault orientation. There is good data in the onshore area however it is primarily located near San Simeon. Because of these uncertainties, Dr. Hardebeck primarily utilizes composite mechanisms that group data from events occurring along similar linear features, and utilize data with the lowest uncertainties. Using these composite data overlaid on known faults, Dr. Hardebeck demonstrated good correlation between composite mechanisms and fault orientations.

Dr. Hardebeck discussed how focal mechanisms can be compared to planar features using Optimal Anisotropic Dynamic Clustering (OADC). This method is reportedly more objective and assigns the simplest fault structure that fits the seismic data. She favored this method because it is truly objective, but cautioned that the method can identify horizontal planes that may not be true structures. Utilizing the OADC method, Ms. Hardebeck determined two fault structure scenarios using tomoDD and hypoDD, and combined them into one 3D model that shows a vertical Shoreline fault and a steeply east-dipping Hosgri fault.

The presentation concluded with a summary of the Central Coast focal mechanisms as follows:

- Due to station coverage limitations, well-constrained single-event focal mechanisms (quality A-C) are generally limited to onshore areas;
- Composite focal mechanisms for clusters of events are possible north of Oceano. South of Oceano, poor station coverage precludes even composite mechanisms;
- Composite focal mechanisms are in good agreement with orientations of known faults and planar structures illuminated by earthquake locations;
- While single-event mechanisms are poorly constrained along the Hosgri and Shoreline faults, the single-event first-motion polarities tend to agree with the respective fault orientations;
- Strike-slip mechanisms dominate along two NW-SE trends: (1) near the coast: Hosgri, San Simeon, Shoreline, faults and structures in Estero Bay, Point Buchon; and (2) inland: Rinconada and West Huasna faults; and
- Reverse mechanisms dominate between these two trends (Los Osos fault; San Simeon and Ragged Point earthquakes).

D.2.8 Geodetic Estimates of Crustal Deformation in the Central California Coast Region – Wayne Thatcher

Dr. Wayne Thatcher presented in lieu of Dr. Jessica Murray, who was unable to attend the workshop, and described ongoing geodetic monitoring in the central coastal region of California (Murray-Moraleda et al., 2011). Dr. Thatcher explained that the purpose of geodetic analysis is to better understand and quantify the distribution and partitioning of crustal strain in south-central coastal California. The current Central Coast study area consists of 55 stations including continuous, survey-mode, and semi-permanent GPS locations. Dr. Thatcher explained that the study area was a relatively “clean” area to investigate, being far enough from the San Andreas fault that the strain accumulations due to its movement are relatively small. Therefore, the effects of coastal faults can be studied more readily. Dr. Thatcher explained how Dr. Murray developed methods to correct for instrumental, seasonal, co-seismic and post-seismic offsets.

Dr. Thatcher concluded with the initial findings of the central California coast modeling:

- Little relative motion taken up on boundaries of proposed Oceanic block; its estimated Euler pole is consistent with that of the rest of the Salinian block; and

- No certain evidence found in additional model runs for compression (either N-NW or E-NE) within the Oceanic block, but more study is warranted.

D.2.9 Pacific-Sierra Nevada-Great Valley Plate Motion in Central California – Sarah Titus

Dr. Sarah Titus provided a review of the approaches and results from three studies on resolved plate motion in central California: Argus and Gordon (2001), the Berkeley Group (d'Alessio et al, 2005; Rolandone et al, 2008), and Titus et al (2011). Her review described the resolved pole of rotation of the Pacific Plate relative to the North American Plate for each study, the pole of rotation for the various velocity fields, and the resulting velocity field in central California. Dr. Titus provided a background of the tectonic setting along central California, consisting of the plate boundary and motion along the Pacific plate and the Sierra Nevada-Great Valley microplate (SNGV), and the slip behavior (from locked to creeping progressing northward) along the San Andreas fault that changes along strike.

Dr. Titus presented the predicted velocities and velocity trends in central California resulting from each of the three studies, dividing them into transects based on the behavior of the San Andreas fault (NW creeping, central creep, SE creep, locked). At the latitude of Diablo Canyon, the results of Argus and Gordon (2001) generally predict 39 mm/year fault- parallel and 3 mm/year fault-normal velocities, whereas the results of Rolandone et al. (2008), who corrected for the San Simeon and Parkfield events, show relatively higher fault-parallel velocities on the Pacific plate site. Updated results from Titus et al (2011) for the plate transect at the latitude of Diablo Canyon show:

- Fault-parallel motion: newest prediction is 37 mm/year (not 39 mm/year)
- Fault-normal motion: newest prediction is 5 mm/year.

D.2.10 Plate Boundary Motion: Implications for Regional Deformation in the Central Coast of California – Jeff Unruh

Dr. Jeff Unruh provided an analysis of how the observed plate motion rates described by Dr. Titus from the three plate motion models may be accommodated by faults in central California. Dr. Unruh described the evolution of the Pacific-North American plate boundary, which includes the intervening Sierra Nevada-Great Valley microplate, and how plate motion may be distributed on faults (including slip rate on the San Andreas fault and uncertainties in residual plate motions).

Dr. Unruh reiterated that the key plate boundary relevant to plate motion at Diablo Canyon is the Pacific Plate/Sierra Nevada-Great Valley microplate (SNGV) plate boundary, not the Pacific and North American Plate boundary. Dr. Unruh explained that the SNGV velocity is estimated to be about 13 mm/year to the northwest, with a motion that is not parallel to Pacific Plate, and from south to north the trend becomes more oblique (transpressional).

Dr. Unruh then discussed the implications of the uncertainty in slip rate of the San Andreas fault, with different vector scenarios showing that the uncertainty in slip rate causes significant differences in the amount of residual plate motion distributed elsewhere. He concluded with the following points:

- The San Andreas fault is the most significant single structure of the entire plate boundary—accommodating about 75% of total resolved plate motion;
- Relatively small uncertainty in the San Andreas fault slip rate translates into relatively significant uncertainties in direction and rate of residual motion;
- "Residual" plate boundary motion is oblique to both the resolved Pacific Plate/SNGV plate motion vector and to the San Andreas fault.
- Residual or "off-San Andreas fault" plate-boundary motion is directed more northerly than the Pacific/SNGV motion vector or the strike of the San Andreas fault; and
- Obliquity of residual motion gives rise to a component of "fault-normal" or "boundary-normal" transpressional deformation that is accommodated by mixed strike-slip and thrust faulting.
- Unless the Pacific/Sierran plate boundary model is wrong, or the San Andreas fault slip rate is grossly in error, the maximum unaccounted plate motion ranges are between approximately 3-7 mm/year. The range in maximum unaccounted plate motion was calculated from two scenarios that assume a San Andreas fault slip rate and account for the plate boundary slip rate and local faulting. The first scenario assumes a slip rate on the San Andreas fault of 28 mm/yr, which results in a residual of ~6.5 mm/yr of unaccounted plate motion distributed with a trend of N27°W. The second scenario assumes a slip rate on the San Andreas fault of 32 mm/yr, which results in a residual of ~3.5 mm/yr of unaccounted plate motion distributed with a trend of N12°W. Up to 3 mm/yr of the maximum unaccounted plate motion may be accommodated by the Kettleman Hills/Coalinga thrust fault system.
- The majority of remaining residual motion may be concentrated in Franciscan basement southwest of the Salinian Block along coastal California

D.2.11 DCPP LTSP/SSHAC GIS Database – Serkan Bozkurt

Mr. Serkan Bozkurt (Project Database manager) provided an overview of the SSHAC GIS Database and how it will be used in the SSHAC evaluation and model-building integration process, including:

- Data compilation, database design, maintenance and database backups;
- Performing various data conversions, adjustments, mosaics and re-processing LiDAR, multibeam, DEM, IFSAR, aerial/space imagery, geophysical data, historical maps, geologic maps, and seismic data sets;
- 2D, 3D and 4D data visualization to support the TI Team evaluation and integration process;
- Providing technical support for the TI Team;

- Providing spatial analysis support for the TI Team

D.2.12 Multibeam Echo Sounder Bathymetry for High Resolution Imaging of Seafloor Features: Requirements, Capabilities, Limitations & Innovations – Rikk Kvitek

Dr. Rikk Kvitek described the current status of multibeam bathymetric data along the central coast of California. He described the method of data acquisition, the significant improvement in data resolution in recent years (from 1997 to 2007), and limitations of collecting data in near-coastal shallow water or "white zone". The white zone occurs because conventional vessels are not able to access shallow water/rocky coastlines and LiDAR topographic data are of poor quality because of sediment disturbance, fog, etc. To address these data gaps in the white zone, Dr. Kvitek developed the "Kelpfly" approach, which consists of a modified wave runner mounted with multibeam instrumentation.

Dr. Kvitek concluded with a summary of mapping data gaps for the Diablo Canyon coastal region that included the following:

- Offshore high-resolution bathymetry greater than 3 nautical miles offshore;
- Hi-res mapping of the shelf break & slope north of Piedras Blancas
- Fill in the "white zone" along the coastal reach between Point Buchon and Point San Luis.

D.2.13 Offshore Paleo Marine Terrace Study – William Page

Dr. William Page described the results of a PG&E LTSP study using the recently acquired high-resolution multibeam echo sounder (MBES) data, supplemented by high resolution seismic reflection data, to map paleoshorelines in the shallow near-coastal region of Diablo Canyon (PG&E, 2011). Dr. Page presented the criteria used to identify and map the lateral extent of the paleoshorelines, and to estimate the age of the paleoshorelines in lieu of actual age data from each submerged platform. Based on the mapping criteria a "confidence" level was assigned to each mapped paleoshoreline. Results from the study show that paleoshorelines can be mapped and reasonably correlated on the informally named Santa Rosa shelf offshore of Point Buchon and the San Luis shelf offshore of Point San Luis, but that the submerged terrace sequence could not be correlated through an intervening area of poor data between the two shelves. Dr. Page concluded his presentation with a discussion of the uncertainties in mapping the offshore paleoshorelines and the "data gaps" in reducing these uncertainties to better constrain the mapping.

D.2.14 PG&E Geologic and Geomorphic Mapping, San Luis Range Region, LTSP Update Program – William Page

Dr. William Page provided an update of ongoing geologic and geomorphic mapping of the San Luis Range being performed as part of PG&E's LTSP program. A focus of the program was to provide "seamless" geologic and geomorphic mapping from the onshore to the offshore region in the Irish Hills area. To perform the mapping, PG&E collected

LiDAR data in the 2010 and 2011 and additional aerial photography at low tide in 2010. Dr. Page showed a number of examples of blended onshore/offshore data, and described the varying data quality from bare Earth, to vegetated ground, to heavy forested ground, to shallow water. Dr. Page presented several examples of the improved geologic mapping developed using the recently acquired data, and identified continuing "data gaps" in the white zone as described previously by Resource Expert Rikk Kvitek.

D.2.15 Gravity and magnetic Data: Status, Uncertainties and Gaps – Vicki Langenheim

Dr. Vicki Langenheim described the status of gravity and magnetic studies performed in the south central coastal California region with an emphasis on the available data and interpretations from the Irish Hills and adjacent coastal areas near Diablo Canyon (Langenheim et al, 2009, 2012). Dr. Langenheim described the data sets available and the uncertainties in measuring, processing, analyzing and modeling/interpreting the data. In general, the data quality and uncertainty are better onshore than offshore. Dr. Langenheim presented examples of an interpretation of each data set, including an isostatic gravity map reflecting density variation in the upper to middle crust that matched well with surficial geology and borehole data. Magnetic data were collected in the Diablo Canyon area by airplane, helicopter and boat. She provided an interpretation of the magnetic data across the offshore San Gregorio fault as an example of the type of analysis that can be performed using the magnetic data in the Diablo Canyon area.

Dr. Langenheim concluded her presentation by summarizing the gravity and magnetic data coverage in the Diablo Canyon area and data uncertainties:

Data Coverage

- Magnetic data coverage – Excellent.
- Gravity data coverage - Good for regional analyses; marine data could be improved.

Uncertainties/Areas of Interest

- More site-specific constraints on physical properties (density logs/borehole gravity);
- Sonic logs;
- Remnant magnetization; and
- Incorporation of new mapping and geophysical data.

D.2.16 Seismic Reflection Data – Overview – Stu Nishenko

Dr. Stu Nishenko provided a status report of the ongoing PG&E Central Coastal California Seismic Imaging Project (CCCSIP), as well as an update on the status of PG&E's legacy seismic reflection data. Dr. Nishenko described the key seismic source parameters of interest presented previously by the SSHAC Hazard Analyst, Katie Wooddell, and the CCCSIP activities to address these key parameters. Studies completed to date include 2D/3D seismic reflection data across the northern Shoreline fault offshore of Point Buchon and onshore seismic reflection data collected in the Irish Hills and Los Osos Valley. Dr. Nishenko described the data collection method, processing approach and status of interpretation (without providing the interpretation).

Following the descriptions of the two projects completed, Mr. Nishenko provided a summary of three projects that were planned or proposed through 2012:

- 3D Low-Energy Southern End of Shoreline fault Zone;
- 2D Low-Energy San Simeon-Hosgri Step Over; and
- 3D High-Energy Seismic Survey (HESS) (subsequently canceled due to permit restrictions).

For each study, Dr. Nishenko described the data acquisition process, the objective of the study, and current status of permitting, logistics and schedule. It was noted that if the studies proceed as planned, a large amount of new information will become available during completion of the SSHAC Level 3 SSC study, and that scheduling the interpretation of the data with completion of the SSHAC process will need to be resolved.

D.2.17 Deep, High-Energy Seismic Reflection and Refraction Data: Status and Gaps – Walter Mooney

Dr. Walter Mooney provided a primer on the tectonic setting and history of central coastal California, and showed data where the continental crust layering and Mohorovic discontinuity could be observed. He stated that a lot of data has been collected off of the California coast documenting oceanic crustal thickness of approximately 7 km and continental crustal thicknesses ranging from approximately 24 to 28 km. Dr. Mooney described the transportable EarthScope/USArray that is now providing higher resolution data. He presented a figure developed using P-wave velocities, further supporting the presence of thin coastal continental crust.

Dr. Mooney summarized the regional active-source deep seismic data, plotting well known transects on an index map. He primarily focused on the SJ-6 transect prepared by Western Geophysical in the early 1980s. This transect consisted of an onshore section (using Vibroseis trucks) and an offshore section that collected data by vessel. Dr. Mooney presented a figure displaying the transect data across the 35 km long/25 km to 30 km deep section, showing a crustal base near 20 km to 25 km deep, noting that flower structures are seen in much of the transect data, but he conceded that there is a lot of uncertainty.

Dr. Mooney compared cross-sections prepared using both the SJ-6 and PG&E Line 3 data. He explained that while there is good horizontal geometry, there is little resolution of vertical features. Dr. Mooney concluded by explaining three key data gaps:

- Much of the deep data is outdated;
- Inadequate resolution to image near-vertical structures, such as faults; and
- Targeted active-source seismic data would resolve key uncertainties in geologic and gravity/magnetic interpretations (e.g., fault geometry).

D.2.18 The Long Term Seismic Program, CDP Seismic Reflection and Associated Data Sets – Jan Rietman

Dr. Jan Rietman provided the history and background of the LTSP, detailed the equipment and data collection methods used during the various seismic reflection studies, identified geophysical data gaps, and provided a review of the seismic reflection Legacy Project. He stated that the offshore investigations concentrated on the Hosgri fault zone and other structures in the Eastern Offshore Santa Maria Basin and summarized the details of the cumulative LTSP data.

Mr. Reitman stated the total line length for the LTSP data set includes approximately 12,000 km of data, with the average line spacing north of Point San Luis being from 1 km (0 to 10 km offshore) to 10 km spacing (greater than 10 km offshore). South of Point San Luis, the line spacing ranged from 0.5 km to 3 km (survey area was 0 to 20 km offshore), and provided the details on six of the primary seismic reflection surveys performed in the eastern offshore Santa Maria Basin, including (1) GSI/Ogle Petroleum (1980), (2) Comap Alaska (1986), (3) Fairfield Industries (1979), (4) Western Geophysical (1974 to 1982), (5) Nekton (1983), and (6) Consolidated Geotechnical (1976). Dr. Rietman described the accuracy, resolution, and data formats of each of the surveys.

Mr. Reitman also described the supplemental offshore data sets used in LTSP followed by a description of these studies, which include:

- PG&E and EDGE deep crustal survey lines.
- 1972 to 1986 USGS and California State Lands Commission surveys.
- PG&E high-resolution surveys.
- Diver samples, cores, and wells.
- Well logs, biostratigraphic information, and velocity data.
- Maps of 3 unconformities tied into wells.
- Onshore CDP survey in Santa Maria Basin, (not discussed during presentation)

Mr. Reitman concluded by describing the Legacy Project, stating that its objective is to create an easily accessible database of all the geological, geophysical, and seismological data acquired and used in the LTSP assessment of seismic hazard at Diablo Canyon.

D.2.19 USGS Offshore, Low-Energy Seismic Reflection Data – Sam Johnson

Dr. Sam Johnson described the acquisition, processing and resolution of the recently acquired USGS high-resolution seismic reflection data, the data limitations, and three key data gaps. Profiles obtained from the study were presented, with the interpreted lithology/geometry shown to display a shallow structure and stratigraphy through a gentle 4° bend along 1600 m of the Hosgri fault. Profiles from Estero Bay were presented and key issues with data interpretation were pointed out, including seafloor reverberation that may result from the presence of a shallow/hard bottom and heave (vertical motion) of the data acquisition vessel.

Mr. Johnson noted 3 key data gaps that included:

- Multibeam mapping in Estero Bay.
- Multibeam mapping of the shelfbreak/upper slope areas and high-resolution seismic reflection mapping (as-needed).
- Earthquake history/recurrence data to answer the following questions:
    - Is there a Hosgri fault earthquake event stratigraphy preserved in intra-fault zone basins, in basins along scarps, or in adjacent submarine canyons/fans?
    - If present, can they be sampled (cored) and dated?

D.2.20 Low-Energy 2D/3D Seismic Data and Legacy Offshore Seismic Data Archive – Phil Hogan

Dr. Phil Hogan described the acquisition of the 2010 and 2011 offshore 2D and 3D low-energy seismic reflection data discussed earlier by Dr. Stu Nishenko, including the data quality, depth penetration, and resolution, development of the Legacy Data archive described previously by Dr. Jan Rietman, and plans for future data acquisition in late 2011 and 2012.

D.2.21 2011 DCPP Onshore Seismic Reflection Data Acquisition – Dan O'Connell

Dr. Dan O'Connell described the acquisition of the 2010 and 2011 onshore 2D and 3D low-energy seismic reflection data discussed earlier by Dr. Stu Nishenko, including the data quality, processing issues, depth penetration and resolution. The data were acquired in the Irish Hills and Los Osos Valley. The objective was to determine if structure is present and if resolution to 10 to 15 km depth could be obtained. Dr. O'Connell noted that implementation of the program was troublesome because of logistics associated with access and permitting on the different property types throughout the study area and the complex, highly reflective basement rocks. He described how Vibroseis trucks were not accessible at all locations, nor could they be permitted throughout the study area, because of issues with road damage. Therefore, the implementation strategy was to have both shallow and deep exploration components. Mr. O'Connell noted that the target is not to identify the vertical strike-slip faults, but to image some of the secondary features, flower structures, shallow deformation, etc. Dr. O'Connell pointed out that the high-resolution system allowed for real time monitoring and on the fly alteration of field techniques to collect the highest quality data.

D.2.22 PG&E Geologic and Geomorphic Mapping, San Luis Range, Long Term Seismic Program (LTSP) Update Program – William Page

Dr. William Page provided a geologic compilation map for the study area that includes numerous geologic, structural, and subsurface data. Examples of the resulting compilation map were presented for a larger study area at a scale of 1:200,000 and two smaller, more detailed study areas near Los Osos fault at a scale of 1;50,000, and along the fault for geomorphic and Quaternary deposit mapping at a scale of 1:12,000. Dr. Page provided slides that referenced each of the various source data, which included (1) Regional Geologic Source Maps, (2) Structural Data Sources, (3) Subsurface Data Sources, and (4) Air Photo Sources.

D.2.23 Geologic Mapping and Digital Compilation in San Luis Obispo County – Mark Wiegers

Mr. Mark Wiegers described the geologic mapping program by the California Geological Survey (CGS) in the San Luis Obispo area (Wiegers, 2009, 2010, 2011, 2013). Mr. Wiegers explained how the San Luis Obispo area quadrangles are completed and available electronically, but are still preliminary maps. He explained that the CGS is currently performing mapping in the Atascadero 7.5 minute Quadrangle and that the Arroyo Grande and Oceano Quadrangles will be performed next year (2012). Mr. Wiegers added that offshore mapping is being performed in collaboration with the California Seafloor Mapping Program that will be incorporated into the coastal mapping program.

D.2.24 Onshore Marine and Fluvial Terrace Database, South-Central California – Kathryn Hanson

Ms. Kathryn Hanson described the ongoing update to the PG&E LTSP marine terrace and fluvial terrace database. Ms. Hanson explained that the objective of the new mapping program is to further quantify rates and patterns of Quaternary deformation that can be used to evaluate alternative seismotectonic and kinematic models for the region; constrain the locations and geometries of faults and folds, and identify and characterize specific fault sources.

Ms. Hanson summarized the updated study areas and data that were added to the Quaternary database, which included:

- Field and office-based investigations;
- Marine and fluvial terrace mapping (Edna Valley near San Luis Obispo, Avila Beach Area, and Arroyo Grande Area);
- Refinement of maps using new DEMs (1-m LiDAR data and 2-m SLO InSAR data);
- Compilation of subsurface information (Tim Cleath, Cleath-Harris Geologists, Inc.); and
- Interpretation of offshore multibeam bathymetric and seismic profile data.

Ms. Hanson described the assumptions and uncertainties in the marine and fluvial terrace mapping:

- Resolution issues remain in estimating elevation of paleoshoreline angles; ±1-2 m variability modern shoreline; relief of platforms, exposure.

- Correlation and inferred ages of higher emergent marine terraces:
  - Assumption that high stripped surfaces are wave-cut platforms and that it is appropriate to correlate based on minimum SLAs
  - Assumption of constant uplift used to estimate ages and paleosea-levels for Q3 and Q4 terraces
  - Possible non-uniform gradient normal to coastline
  - Assumption of lateral correlations based on elevation spacing and apparent similarities in terrace width and cover deposits
  - Lack of direct age control for older terraces.
- Difficulties in mapping and correlating buried marine terraces.

D.2.25 LTSP Trenching Investigations – Tim Hall

Dr. Tim Hall discussed the PG&E LTSP paleoseismic trenching and fault mapping studies and current data set. Dr. Hall provided a figure showing the areas of investigation along the southern onshore portions of the San Simeon and the Los Osos fault, Edna, Wilmar Avenue, and San Miguelito, and San Luis Bay faults. He stated that the objectives of the studies were to locate faults and characterize their slip rate, recurrence interval, geometry, etc. Dr. Hall summarized the findings from each of the paleoseismic studies and provided the published references for each study, and, if not published, the data sets in the PG&E archival data. For each fault, Dr. Hall described the pertinent paleoseismic findings in terms of recency of fault activity (e.g., evidence for or against activity in the past 500,000 years), fault slip rate, timing and recurrence of past events, and fault geometry.

D.2.26 Los Osos Fault Data Compilation – John Baldwin

Mr. John Baldwin described the PG&E LTSP ongoing fault mapping along the Los Osos fault. Mr. Baldwin indicated that the purpose of the mapping was to reduce uncertainty in specific fault parameters, including: (1) location and activity of individual fault strands, (2) slip rate, (3) fault zone geometry, (4) segmentation, and (5) recommendations for future studies to refine the above. The fault mapping included the compilation of existing published and unpublished geologic and geomorphic map data, borehole, oil well and water well data, unpublished Alquist-Priolo trench data, and geophysical-seismic reflection and refraction data.

Mr. Baldwin summarized the Los Osos fault and recommendations for future studies. Key points included the following:

- Broad zone of deformation (flower structure vs. reverse faulting):
  - Geophysics (Estero Bay-1-2 km zone of faulting)
  - Cross Sections (Irish Hills, Lopez Reservoir)
- Multiple Quaternary active fault traces:
  - Steeply dipping
  - Secondary hanging wall deformation
  - Valleyward low-angle reverse faults (Holocene)

- Localized basins along Irish Hills and Lopez Reservoir segments
- Seismicity appears to support primarily reverse faulting
- Down-dip geometry is difficult to characterize with existing shallow information (need to combine "deep" geophysics, oil well and surficial mapping/trenching and consistent tectonic model)

D.2.27 SCEC Community Fault and Velocity Models … How They Might Contribute to the DCPP Seismic Hazard Assessment – Andreas Plesch

Dr. Andreas Plesch described the Southern California Earthquake Center Unified Structural Representation (SCEC USR) as a 3D description of crustal and upper mantle structure in California that integrates many forms of data and model results. Models and supporting datasets are evaluated and vetted by the SCEC community, and the USR serves a broad range of science and hazards assessment efforts, including strong ground motion prediction and PSHA. The USR was noted to consist of:

- Community Fault Models (CFM, CFM-R, SCFM); and
- Community Velocity Models (CVM, CVM-H).

Dr. Plesch described the basement structures in the DCPP study area. The basement surfaces in the CVM-H include displacements of major faults represented in the CFM. The CFM was defined to represent a 3D triangulated surface representation of active faults in California. The CFM integrates many types of data that constrain fault geometries, includes interpolated and extrapolated fault patches, and may result in alternative fault representations.

D.3.0 Workshop 2 – Alternative Models

Workshop 2 occurred over three days between November 6 and 8, 2012. The workshop was attended by the PTI, the TI Team and staff, the PPRP, the Database Manager, the Hazard Analysts, and Proponent Experts (PEs). In addition, several members of the SWUS GMC TI Team attended the workshop to assure that any potential interface issues were identified and addressed.

The primary goal of Workshop 2 was to use the PEs to explore the center, body, and range of alternative proponent models and interpretations for the SSC, with a focus on those parameters of the SSC model that are most significant to hazard. In addition, several of the PEs identified other alternative models or technical issues that were not captured in the SSC base case model, such as the concept of complex fault ruptures, linked fault ruptures, and non-Poisson earthquake recurrence. These alternative models or technical issues were identified during the workshop for future evaluation by the TI Team and were considered for integration, as appropriate, into the preliminary SSC model.

Workshop participants that attended Workshop 2 are provided in Table D-4. An agenda for the workshop is provided in Table D-5. Workshop 2 also was used to identify additional data gaps, data needs, and/or analyses that may be performed to further evaluate alternative models or key model parameters and uncertainties.

D.3.1 Welcome, Introduction, Workshop 2 Goals and SSHAC Training – Kent Ferre, Norm Abrahamson, William Lettis

Similar to Workshop 1, Mr. Kent Ferre as the Project Sponsor, Dr. Norm Abrahamson as the SSHAC PTI, and Dr. William Lettis as the SSHAC SSC TI Lead provided a series of presentations welcoming the workshop participants, describing the objective and goals of the workshop, and providing an overview of the SSHAC process, roles and responsibilities, and workshop ground rules. Dr. Lettis noted that in addition to the objective of exploring the range of alternative models and interpretations through Proponent Expert presentations and discussion, Workshop 2 also would include several Resource Expert presentations on new data collected since the completion of Workshop 1.

D.3.2 SSC Sensitivity Logic Tree – Steve Thompson

Dr. Steve Thompson of the TI Team provided an SSC framework logic tree to be used for sensitivity analyses. The SSC sensitivity logic tree described by Dr. Thompson completely replaces the Shoreline SSC logic tree/model that was used in the preliminary sensitivity analysis for Workshop 1. The intent of the SSC framework logic tree was to explore the sensitivity to seismic hazard of various alternative approaches for characterizing seismic sources. A particular focus of the sensitivity analysis was to explore the significance to hazard by various alternative models for the magnitude-frequency distribution (MFD) and recurrence models to incorporate uncertainty in earthquake time dependence. The updated sensitivity analyses were used in the TI Team evaluation process, and to continue focusing on those elements of the SSC model that are most significant to hazard (i.e., hazard informed evaluation).

D.3.3 Workshop 2 Sensitivity Analysis – Nick Gregor

Dr. Nick Gregor, Hazard Analyst for the SSC study, performed a suite of sensitivity analyses as requested by the TI Team using the SSC Sensitivity logic tree described previously by Dr. Thompson. For ease of reference, his presentation is provided as Attachment D-2. A primary focus of the sensitivity analysis was to explore the significance to hazard from modifying the shape of and distribution of moment in the characteristic Magnitude Frequency Distribution (MFD) model. The traditional “box-car” Characteristic MFD (Youngs and Coppersmith, 1985) was modified to include a normal distribution for the characteristic portion and the percent of total moment was varied between the exponential and characteristic portions of the MFD as specified in the SSC sensitivity logic tree. Additional sensitivity analyses were performed to evaluate uncertainty in the recurrence model by using half and two times the Poisson rate as a proxy for incorporating time dependent models and uncertainty in clustering. Many of the sensitivity analyses performed in Workshop 1 to explore the significance to hazard from uncertainty in slip rate and geometry of the Hosgri, Los Osos, San Luis Bay and Shoreline faults were repeated for Workshop 2 using updated information presented in

Workshop 1 and the subsequent TI Team evaluation of these data. The sensitivity analyses showed that uncertainty in the recurrence (time dependency) model is very significant to hazard (factor of 2), and that uncertainty in the MFD also is significant to hazard (factor of 1.5). Other hazard-significant sources of uncertainty include the slip rate on the Hosgri and Shoreline faults, and dip and location of the Hosgri fault.

D.3.4 Updated Resource Expert Presentations – Stu Nishenko and Scott Steinberg

Dr. Stu Nishenko and Mr. Scott Steinberg provided three presentations to update the TI Team on the ongoing AB1632-funded Central Coastal California Seismic Imaging Project (CCCSIP) studies (Nishenko), the ongoing PG&E LTSP studies (Steinberg), and the availability of these new data for the TI Team and the public (i.e., schedule for posting the new data to the PG&E website) (Steinberg). Dr. Nishenko indicated that due to permitting issues, the High-Energy Seismic Study (HESS) was not likely to proceed, but that other data acquisition activities were proceeding as planned, including the collection of Low-Energy Seismic Surveys (LESS) in the Estero Bay area across the Hosgri fault, the Point Sal area across the Hosgri fault, and in San Luis Obispo Bay across the southern projection of the Shoreline fault. Dr. Nishenko indicated that these data would be processed by Fugro Consultants Inc., and interpreted by the PG&E interpretation team led by Dr. Gary Greene, at which time the interpretations would be made available to the TI Team for their evaluation and integration into the SSC model.

Mr. Steinberg indicated that the ongoing LTSP studies included additional mapping along the Los Osos fault, additional mapping within the Irish Hills to support the onshore seismic reflection studies, additional mapping of the marine terraces using recently acquired LiDAR data, continuing update to the PG&E seismicity catalog, and support for several USGS CRADA studies, including funding for Dr. Jeanne Hardebeck, Dr. Sam Johnson and Dr. Jessica Murray. Mr. Steinberg indicated that information from these studies and from the ongoing CCCSIP studies would be made available on the PG&E website after they have been checked, as required, and initially interpreted by PG&E.

D.3.5 Marine Geology and Geomorphology of the Hosgri and Shoreline Faults – Sam Johnson

Dr. Sam Johnson provided a proponent interpretation of the multibeam bathymetry and shallow high-resolution seismic reflection data along the Hosgri fault from Estero Bay to directly south of San Luis Point, and for the Shoreline fault. Much of the information from the presentation is published in Johnson and Watt (2012). Dr. Johnson described the data as a Resource Expert at Workshop 1. He provided a map of the fault locations in the shallow subsurface (few tens of meters) to the surface, and indicated that the Hosgri fault is very well imaged. In his interpretation, the Hosgri fault links directly to the San Simeon fault and they are one and the same fault; he disagrees with the Hosgri-San Simeon fault "stepover" interpretation presented by PG&E in the LTSP study (PG&E, 1991). Although Dr. Johnson did not present any specific slip rate results, he suggested that there may be promising locations along the fault to perform this work (later confirmed by his study of the Estero Bay cross Hosgri slope (Johnson et al, 2014). Dr. Johnson offered several cautionary notes: (1) that observed vertical offsets or separation across the Hosgri fault are local features, and may in fact be transitory features. In this discussion, he described "side-wall rip out" structures first noted in publications by P. Mann. The side wall rip outs are transported laterally by the fault and give the appearance of having vertical separation; (2) horizontal slip rate on the Hosgri fault is likely to vary laterally along the Hosgri fault at fault intersections, such as the Los Osos fault (subtraction southward) and the Piedras Blancas structure (addition southward). Thus, it is difficult to simply use the observed onshore slip rate on the San Simeon fault to estimate slip rate on the offshore Hosgri fault near Diablo Canyon. (3) Dr. Johnson commented that it would be prudent to consider asymptotic branching relationships of the Los Osos, Shoreline, and Casmalia faults with the Hosgri fault for dynamic rupture modeling; (4) Dr. Johnson commented that he is not confident in the interpretation of and dating of offshore marine terrace surfaces. Considerable uncertainty exists in the location and amount of erosion that accompanied the last sea level rise.

D.3.6 Seismicity of the Hosgri and Shoreline Faults and the Irish Hills – Jeanne Hardebeck

Dr. Hardebeck used the OADC algorithm plus constraints from focal mechanism data to evaluate the location of seismicity lineaments along the Hosgri and Shoreline faults, within Estero Bay and within the Irish Hills (Hardebeck, 2013). She provided a description of the seismicity data and focal mechanisms as a Resource Expert at Workshop 1. Her proponent interpretation of these data using the OADC method provide constraints on the dip of the Hosgri fault ranging from 76 to 89 degrees to the east-northeast, and that a dip of 70 degrees would violate the data set. The Shoreline fault dips from 82 to 89 degrees to the southwest. Within her data constraints, both faults may be vertical. Dr. Hardebeck indicated that she would provide her, as yet, unpublished results to the TI Team for their evaluation, and she would show where the "up dip" projection of the OADC planes reach the sea floor surface. She cautioned against using the up dip projection as a reliable surface trace of the fault for calculating site-to-source distances. Dr. Hardebeck also presented OADC results showing two distinct seismicity lineaments in Estero bay, and indicated that these lineaments should be evaluated (reconciled/compared) with fault trends in Estero Bay identified by geologic data (she referred to Dr. Johnson's work) and to Geophysical data (she referred to Dr. Watt's work). Dr. Hardebeck also presented a variety of possible OADC lineaments within the Irish Hills area. She acknowledged that the lineaments are generally weak but that she believes the lineaments may be indicative of structure within the Irish Hills that the TI Team should consider in their evaluation. She recommended further evaluation of the seismicity data within the Irish Hills to see if planar seismicity lineaments can be defined through more objective (rather than subjective) analysis.

D.3.7 Gravity and Magnetic Constraints for the Hosgri and Shoreline Faults – Janet Watt

Dr. Watt presented the results from her (and Dr. Langenheim's) proponent interpretation of gravity and magnetic data along the Hosgri and Shoreline faults. The gravity and magnetic data were presented by Dr. Langenheim as a Resource Expert at Workshop 1. Modeling of the magnetic data show that the Hosgri fault is vertical to steeply east dipping in the upper several kilometers of the crust. Modeling of the gravity data show that the Hosgri fault dips 70 to 85 degrees east to a depth of 3 kilometers. Consistency of these modeling results with the OADC modeling results presented by Dr. Hardebeck strongly support a near-vertical to steeply east dipping Hosgri fault. Dr. Watt also presented results of the gravity and magnetic modeling along the Shoreline fault. She interpreted that the Shoreline fault produces a strong signature along the coast from Point San Luis to offshore of Diablo Canyon, and suggested that some of the magnetic anomalies may in fact be offset by the fault. In their interpretation, it appears that the Shoreline fault may bend more northerly as it approaches the Hosgri fault. In questioning, Dr. Watt does not identify an offshore anomaly associated with the San Luis Bay fault although a clear magnetic low is observed along the projection. Dr. Watt indicated that further modeling would be required to evaluate the San Luis Bay fault and how the fault would look as a "blind" structure in the offshore.

D.3.8 Hosgri and Shoreline Fault Geometric Model – Hans AbramsonWard

Mr. AbramsonWard described results from the AB1632-funded CCCSIP Point Buchon study to evaluate the northern extent of the Shoreline fault and possible intersection with the Hosgri fault. Mr. AbramsonWard indicated that what was identified at the "Point Buchon fault" in the study is likely the northern continuation of the Shoreline fault. The fault appears to bend northward and asymptotically approach the Hosgri fault, and that at least one and possibly more locally confined small basins occur at or near the fault intersection. The basins contain late Pleistocene to Holocene sediment indicating active deformation. Mr. AbramsonWard indicated that it is difficult at this time to evaluate the northern end of the Hosgri fault due to the sparse available data (Dr. Johnson also acknowledged this uncertainty). Because of this uncertainty, both along the northern end of the Hosgri fault and elsewhere along the San Simeon, San Gregorio and San Andreas faults, Mr. AbramsonWard suggested that the TI Team consider "soft" segmentation boundaries along the Hosgri/San Simeon/San Gregorio fault system and San Andreas fault. These soft segmentation boundaries would stop ruptures some times and rupture through at other times.

D.3.9 Irish Hills and San Luis Range Fault Model – Doug Hamilton

Dr. Hamilton described evidence for recent/renewed late Pleistocene uplift of the Irish Hills, including what he interpreted to be recently incised drainages within the uplifted range. Dr. Hamilton's proponent tectonic model for elevating the range is displacement on a shallow-northeast dipping thrust fault that he calls the "San Luis Range fault".

Movement on the fault is the primary driver for uplift of the range. He presented his interpretation of seismicity data within the Irish Hills to support a low-angle northeast dipping thrust fault. From south to north, the fault would cross San Luis Obispo Bay, impinge (or intersect) at very shallow depth (within the upper 1 to 2 kilometers) with the Shoreline fault between Point San Luis and offshore of Diablo Canyon, and continue northward as the N40W/Point Buchon East fault across the offshore Islay shelf. He interprets the Shoreline fault as a relatively recent structure that truncates the westward continuation of the San Luis Bay fault. Dr. Hamilton considers the bedrock platform west of the Shoreline fault to have been primarily uplifted by the San Luis Range fault before the fault was recently truncated by the Shoreline fault. Dr. Hamilton also presented his interpretation of the "Diablo Cove fault". This fault is a localized structure identified in the original Diablo Canyon licensing and construction studies that extends beneath the Diablo Canyon site. Dr. Hamilton interprets that the fault may connect with and thus be reactivated by movement on either the Shoreline fault or the underlying San Luis Range thrust fault.

D.3.10 Seismicity of the Irish Hills and San Simeon Earthquake Epicentral Region – Marcia McLaren

Ms. McLaren described the distribution and patterns of pre- and post-San Simeon earthquake seismicity and compared these data to the observed microseismicity occurring within the Irish Hills as a "test" to see if patterns of microseismicity within the Irish Hills may express planar structures within the hills. In her proponent interpretation, the microseismicity within the Irish Hills do not constrain a preferred fault plane within the hills. She supported further evaluations by Dr. Hardebeck to assess the presence of planar seismicity lineaments within the Irish hills, and also suggested that the TI Team evaluate published studies by Hauksson on the use of and limitations of using microseismicity to define fault planes.

D.3.11 Geometric and Kinematic Alternatives for the Los Osos and San Luis Bay Faults – William Lettis

Dr. Lettis described alternative tectonic models to explain the observed patterns and styles of deformation in the Los Osos-Santa Maria domain, including alternating uplifted and subsiding tectonic blocks bordered by reverse and/or oblique slip faults. He presented two "end-member" models (1) NE-SW directed crustal shortening driven primarily by continued rotation of the Western transverse Ranges; and (2) transpressional deformation driven primarily by left-restraining transfer of slip from the San Andrea fault to the offshore Hosgri/San Simeon/San Gregorio fault system. These alternative proponent models will provide constraints on acceptable fault geometries and fault linkages. Dr. Lettis suggested that both tectonic processes (i.e., rotation of WTR and left restraining transfer of slip) may be occurring and superimposed on one another. He suggested that inversion of GPS data and focal mechanism data using both stress and strain algorithms may provide insights on the principal stress and strain orientations, both locally and regionally, from which to further evaluate these two "end member" alternative tectonic models.

D.3.12 Irish Hills Geologic Cross Section – Russ Graymer

Dr. Graymer compiled existing geologic data, borehole data, and potential field data to develop a proponent cross section across the Irish Hills that satisfies all the data to mid to lower crustal depths. For the deeper part of the cross section, Dr. Graymer indicated that the magnetic and gravity data provided constraints that are critical for any viable cross section. Dr. Graymer provided his preliminary cross section. He projected the distribution and geometry (i.e., structural data, strike, dip, and observed folds) of surface geology, supported by borehole data, into the subsurface using the constraints offered by magnetic and gravity data. Based on the cross section, Dr. Graymer recognizes two episodes of Cenozoic deformation, an early episode of normal faulting (transtensional? deformation) followed by a later episode of reverse faulting and crustal shortening (transpressional? deformation). He interprets that the Edna and San Miguelito faults played an important role in the earlier episode of deformation, and that the San Miguelito fault experienced continued activity in the later episode of deformation as evidenced by displacement of the Pliocene Squire Member of the Pismo Formation. He suggested that his cross section could be tested and/or improved with new mapping, seismic reflection data, comparison to the distribution of uplifted marine terraces, and by forward modeling.

D.3.13 Late Cenozoic Kinematic Model from Offset Geophysical Anomalies – Vicki Langenheim

Dr. Langenheim described the results of her recently published paper in Lithosphere that discusses long-term deformation rates on the Hosgri/San Simeon/San Gregorio fault system (Langenheim et al., 2012). She evaluated and developed a proponent correlation of gravity and magnetic anomalies along the fault system supported by the distribution of basement terranes as recognized by previous authors. She described several fundamental observations from her work: (1) gravity data show that the Hosgri fault ends to the south as mapped. An undisrupted gravity low extends across the southern projection of the fault, and does not favor a continuation of the fault to the south. Offset magnetic anomalies support 30 to 42 kilometers of long-term cumulative slip on the Hosgri fault over the past 10 to 12 million years from Point Buchon to the south. The implied long-term slip rate is higher than the present rate of strike slip on the Hosgri fault as recognized by earlier authors (e.g., Clark et al., 1984). But the 30 to 42 kilometers of cumulative slip is difficult to reconcile with shortening rates east of the Hosgri fault. Dr. Langenheim indicated that this observation is difficult to reconcile with current tectonic models.

D.3.14 Late Cenozoic kinematic Model for Transfer of Strain along the California Margin – Chris Sorlien

Dr. Sorlien described the results of his research in the southern offshore Santa Maria Basin. He suggests that slip on the southern Hosgri fault may step westward to the Southwest Channel-Ferrelo fault, which then continues southward into the Santa Barbara channel area. Dr. Sorlien also suggested that the TI Team consider alternative concepts (not yet a model) that some slip on the Hosgri fault may begin to step westward onto the Santa Lucia Bank fault in the northern and central offshore Santa Maria basin. No research has been performed to test this concept, but something is driving slip rate on the Santa Lucia Bank fault system.

D.3.15 Hosgri-San Simeon Fault Zone Geologic Slip Rate – Kathryn Hanson

Ms. Hanson described geologic constraints for Quaternary slip rate on the San Gregorio/San Simeon/ Hosgri fault system. Ms. Hanson based her presentation on her published proponent model of slip rate on the Hosgri fault (Hanson et al, 2004), updated with more current information. Based on unpublished ongoing studies near Seal Cove, the San Gregorio fault slip rate is approximately 3 to 4.5 mm/yr. The slip rate is based on detailed mapping of onshore marine terraces across the Frijoles trace of the San Gregorio fault, and is considered to be well constrained. To the south, the San Simeon fault has a slip rate of 0.7 to 2.6 mm/yr using the best constrained marine terrace mapping by Hanson and Lettis (1994). The upper and lower bound limits of 6 mm/yr to 0.5 mm/yr published by Hanson and Lettis are based on less well constrained marine terrace mapping, and are not considered reasonable for further assessment of the fault. Ms. Hanson recommended considering the time of onset and rate of shortening across the Piedras Blancas anticlinorium as a potential contribution (addition) to slip rate on the offshore Hosgri fault.

D.3.16 UCERF3 Deformation Model Approaches – Tim Dawson

Dr. Dawson described the approach used for building the UCERF3 fault models (Field et al., 2013), in general, and discussed some of the details and uncertainty in the model in the Diablo Canyon region specifically. He described how the fault models were used in subsequent fault deformation models, including geodetic data and block models. He cautioned against the direct use of the UCERF3 fault models or deformation models for site-specific use in a seismic hazard study.

D.3.17 Plate Margin Deformation and Kinematics from GPS Data – Chuck DeMets

Dr. DeMets presented the results from his PG&E LTSP funded analysis of plate motion rates along south-central coastal California west of the San Andreas fault (DeMets et al, 2012). In his proponent model, he concludes than unresolved plate motion that may occur off the California coast is approximately 3 mm/yr. He cautioned that there is uncertainty in the location of the Pacific plate boundary, and that he would prefer to analyze GPS data from several islands to further evaluate the unresolved rate of deformation. He suggested that the rate of deformation on the Hosgri fault may be reduced by up to 1.5 mm/yr based on his preliminary evaluation of the GPS data from the offshore islands. (Note: In subsequent analysis and in his published paper, the unresolved slip rate is reduced by 1.5 mm/yr and is approximately 1.5 to 2 mm/yr off the coast of central California (DeMets et al, 2014)).

D.3.18 Regional Deformation and Kinematics from GPS Data – Jessica Murray

Dr. Murray presented an update of her PG&E LTSP funded evaluation of GPS strain rates in south-central California with an emphasis on modeling strain rates west of the San Andreas fault. For her analysis, Dr. Murray divided the region into sub-blocks that are assumed to be bordered by active faults. She described the difficulty and uncertainty in attempting to use GPS data to model strain rates on closely spaced faults. She presented results from five different block models for the region (refer to figures on the PG&E web site for details of each model). Results from her proponent model generally show that up to 3 mm/yr of right-lateral shear may be occurring in the offshore coastal region, possibly on the Hosgri fault. In general, residuals in the region between the Hosgri fault and San Andreas fault show NE-SW directed crustal shortening.

D.3.19 NeoKinema Approach for Modeling Deformation – Peter Bird

Dr. Bird presented results of the UCERF3 NeoKinema model for south-central California west of the San Andreas fault. He did not perform new analyses or detailed modeling specifically for the Diablo Canyon area in preparation for the workshop. Results from his proponent model generally show up to 2 mm/yr of dextral shear on strike slip faults west of the San Andreas fault, including the Rinconada, West Huasna and Hosgri faults. He suggests in his presentation that about 1.2 mm/yr may be occurring on the Hosgri fault, but in discussion following his presentation, Dr. Bird cautioned that this result needs further evaluation. The NeoKinema model indicates that about 2 to 3 mm/yr of NE-SW directed shortening is occurring in the region between the Hosgri fault and the San Andreas fault. For further analysis of the GPS data, Dr. Bird recommended that the NeoKinema model be revised to include improved fault geometry/dips, test several different compilations of GPS data, test various Euler poles of rotation from various studies, and vary rigidity of the crust.

D.3.20 Offshore Evidence for Uplift Rate Boundaries – Hans AbramsonWard

Mr. AbramsonWard presented a proponent interpretation of the submerged offshore marine platforms that were described by Dr. William Page as a Resource Expert at Workshop 1. In his interpretation, Mr. AbramsonWard recognizes two offshore shelf areas, termed the San Luis shelf offshore of Point San Luis and the Santa Rosa shelf offshore of Point Buchon. The submerged paleostrandlines or shoreline angles within each shelf can be correlated laterally and define a unique block with consistent uplift rate. However, the paleostrandlines cannot be correlated between each shelf, suggesting that an as yet poorly defined uplift rate boundary exists between the two shelf areas. The uplift rate boundary occurs in a broad, generally west-northwest trending zone, of sparse data. The zone generally corresponds to the offshore projection of the San Luis Bay fault, and Mr. AbramsonWard suggested that continued slip on the fault may explain the uplift rate boundary. If so, the San Luis Bay fault would extend across and to the west of the Shoreline fault. The paleostrandlines locally cross the Shoreline fault without vertical separation within the resolution of the data, indicating that the Shoreline fault is not an uplift rate boundary (i.e., the Shoreline fault is primarily strike slip with little to no vertical separation).

D.3.21 Shoreline Fault Slip Rate Constraints – Steve Thompson

Dr. Thompson summarized the slip rate constraints developed for the Shoreline fault in the PG&E Shoreline fault report (PG&E, 2011), with updated information from ongoing studies. Slip rate estimates for the Shoreline fault were developed from observed seismicity rates (a minimum rate), by assuming that the San Luis Bay fault (Rattlesnake and Olson traces) merges with the Shoreline fault in the near shore and thus contributes to slip rate on the Shoreline fault offshore (also a minimum rate since the Shoreline fault extends south of the San Luis Bay fault intersection), and by using geomorphic expression of the fault trace relative to the better expressed geomorphology along the Hosgri fault as a proxy to estimate order of magnitude slip rate. Dr. Thompson reiterated the conclusion from the offshore paleostrandline study to conclude that the Shoreline fault does not have a discernible vertical component of slip within the resolution of the marine mapping data. Dr. Thompson reiterated the significant uncertainty associated with estimating slip rate on the Shoreline fault, and acknowledged that results from the ongoing AB1632 funded CCCSIP study in San Luis Obispo Bay will be important for reducing this uncertainty. In discussion following the presentation, Dr. Hardebeck emphasized that the use of microseismicity to estimate slip rate on the Shoreline fault is not a recommended approach.

D.3.22 Los Osos and San Luis Bay Fault Slip Rate Constraints – William Lettis

Dr. Lettis summarized the slip rate constraints developed for the Los Osos and San Luis Bay faults during the LTSP study (PG&E, 1988, 1991) and published in a series of papers by various authors in the early to mid-1990s. The slip rate for both faults relied heavily on the detailed mapping of marine terraces along the coast from Morro Bay on the north to San Luis Obispo Bay on the south described by Hanson et al. (1994). The flight of marine terraces provides excellent control on coastal uplift rate. The marine terrace sequence is truncated by the Los Osos fault at Morro Bay and separates the uplifted Irish Hills from an area of subsidence at Morro Bay. Similarly, the flight of marine terraces is offset by the San Luis Bay fault at two locations where the fault crosses the coastline. Dr. Lettis described how the observed vertical separation rate from the marine terrace data were converted to a fault slip rate using an assumed range of dip for the Los Osos and San Luis Bay faults.

D.3.23 Evidence Against Segmented Rupture Behavior – Jeanne Hardebeck

Dr. Hardebeck provided a proponent opinion against the use of fault segmentation to estimate future fault rupture lengths (and thus estimates of maximum or characteristic magnitudes). In her presentation, she explicitly defined a fault segment and multi-segment ruptures as specific predictions of future rupture endpoints. She critiqued PG&E's (2011) segmentation model for the Shoreline fault and lack of a linked Shoreline-Hosgri fault rupture as a plausible future earthquake rupture. She provided a series of historical examples where fault ruptures have violated previously identified fault segmentation points. Dr. Hardebeck indicated that in her opinion the UCERF3 Grand Inversion approach is "mature" and more objective in defining fault ruptures than the use of segmentation models (in discussion, Dr. Morgan Page concurred). She concluded that fault segmentation is not useful as a simplifying assumption for evaluating potential fault ruptures.

D.3.24 Segmentation: Requirements for Segmenting Faults; Evidence for Segmented Rupture Behavior – David Schwartz

Dr. Schwartz provided a counter-point proponent opinion in support of the use of fault segmentation to define future fault ruptures. Dr. Schwartz unequivocally stated that "Segmentation is real". Dr. Schwartz presented both static and dynamic criteria for defining segmentation points along faults, and used the Wasatch fault in Utah as an example of well-defined fault segmentation that is supported by paleoseismic evidence of past fault ruptures. He also used the Denali-Totschunda rupture to support the interpretation of fault segmentation along these faults. Dr. Schwartz emphasized the use of fault behavioral information such as fault slip rate and paleoseismic data to define fault segments, and to a lesser degree the use of fault geometry constraints such as fault stepovers, fault intersections and fault bends. He recommended that consideration of uncertainty in the location of the segmentation points, and to relax the segmentation point to allow some ruptures to link as multi-segment ruptures. In discussion, Dr. Morgan Page endorsed the use of slip rate changes along fault strike as a constraint to fault ruptures and that the Grand Inversion identifies these locations.

D.3.25 Characterizing Faults and Rupture Lengths for Hazard Analysis – Craig dePolo

Dr. dePolo provided a proponent opinion on the use of fault segmentation to evaluate the potential for defining future fault ruptures. He stressed/endorsed the use of the primary or "core" fault segment approach for defining fault ruptures rather than details of the segmentation endpoints. He suggested examining various fault length scales relative to rupture lengths as a means to estimate future fault rupture lengths, and referenced the work by Biasi and Wesnousky. He recommended that the TI Team consider using various fault rupture scenarios, and to consider both single segment ruptures and multi-segment ruptures. If possible, the rupture model should be supported by paleoseismic data.

D.3.26 Rupture Length Considerations – Glenn Biasi

Dr. Biasi presented empirical data from past fault rupture end points compiled by Wesnousky (2008) and updated in the UCERF3 appendices. These empirical data show that 75% of ruptures have at least one end point at a previously defined fault segment boundary, and 33% of ruptures have both end points that coincide with segmentation boundaries. Although not implemented as a rupture constraint in UCERF3, Dr. Biasi believes that it could be used to check the UCERF3 results and could be added as a constraint in future UCERF models. In discussion, Dr. Morgan Page suggested that it could be used as an “improbability” constraint. Dr. Biasi indicated that the data show fault segments may link in ruptures up to a stepover width of 5 kilometers. He suggests that the 5-kilometer-width may scale with crustal thickness. The data also show that strike slip faults do not jump from fault to fault very often (18%), but when they do they generally jump from strike slip to strike slip faults and less frequently from strike slip to reverse faults. Dr. Biasi indicated that “stress matters”; fault segments may anticipate multi-segment ruptures depending on the accumulated stress.

D.3.27 Recurrence Rate Discussion – Norm Abrahamson, Tom Rockwell, Dave Jackson

Dr. Abrahamson, Dr. Rockwell and Dr. Jackson gave three back-to-back-to-back proponent opinions on recurrence models. Dr. Abrahamson noted that considerable uncertainty exists in current recurrence models and that uncertainty should be incorporated now such that we will be within the bounds of this uncertainty as further research is performed (i.e., can reject various hypotheses later based on data). Thus, Dr. Abrahamson recommended incorporating additional uncertainty beyond the traditional Poisson recurrence distribution by considering non-Poissonian recurrence models (e.g., Brownian Passage Time or other renewal models). Dr. Rockwell presented paleoseismic data for southern California faults (and also Turkey) showing that the coefficient of variation (CV) for recurrent fault displacement is 0.4 to 0.7 (Rockwell and Klinger, 2013). In discussion, Dr. Biasi also described a low CV for the Alpine fault. Rockwell indicated that such a low CV would support some form of time dependence in earthquake recurrence that should be incorporated in the SSC recurrence model. Dr. Jackson offered a rebuttal proponent opinion “the curse of retrospective confirmation and its applicability to future application”. Dr. Jackson strongly supports the Poisson model and suggests that we should “always give randomness its respect”.

D.3.28 Magnitude PDF for Fault Ruptures – Morgan Page

Dr. Page provided results from various analyses performed as part of the UCERF3 study. She provided evidence both for and against characteristic fault behavior, and indicated that the UCERF3 group favored an exponential GR model for earthquake magnitude (Page et al, 2011). However, results from the UCERF3 Grand Inversion could not fit the state wide fault model using an exponential model; i.e., if the exponential model is correct, we need a 20 to 30% increase in seismicity rate statewide or we need to use a lower *b* value than the current seismicity rate indicates. Dr. Page indicated that multi-fault ruptures were required in the UCERF3 models to reduce the “bulge” in magnitude-frequency distribution results in the *M* 6-7 range.

D.3.29 Magnitude PDF for Fault Ruptures – Norm Abrahamson

Dr. Abrahamson described the results from slip-at-a-point data now published by Hecker et al (2013) that suggest relatively low CV for displacements at a point along a fault. These data suggest that fault behavior deviates from a GR relation at high magnitudes, and better fit the Youngs and Coppersmith (1985) characteristic model. Dr. Abrahamson recommends that paleoseismologists carefully evaluate bias in their observations and to be objective. In discussion, Dr. Dave Jackson suggests that site effects are unduly influencing the low CV observations (i.e., this is a near-surface and not a seismogenic phenomenon).

D.3.30 Stochastic Model for Fault Ruptures – Dave Jackson

Dr. Jackson presented a proponent opinion on the nucleation and location of large earthquakes. Although “big earthquakes prefer faults, some occur off of known faults”. He encouraged the TI Team to embrace the concept that large earthquakes may nucleate off of a known fault and propagate onto a fault.

D.3.31 Magnitude Scaling Relations – Bruce Shaw

Dr. Shaw reviewed the magnitude scaling relations used in UCERF3. The Shaw (2009) relation considers saturation of fault width effect and assumed a constant stress drop. He considers his relation appropriate for both strike slip and dip slip faults. He recommends that the TI Team consider including additional epistemic uncertainty; for example, the Ellsworth B relation should not be excluded in his view. Dr. Abrahamson noted that, in his view, the Ellsworth B relation was not valid to use as it does not represent a good fit to the data at lower magnitudes (including around *M* 6, important to DCPP hazard), and viable models must defensibly describe the mean and its uncertainty. Dr. Shaw expressed the view that uncertainty in seismogenic width should be considered.

D.3.32 Magnitude Scaling Relations – Tom Hanks

Dr. Hanks presented his proponent opinion of magnitude scaling relations. He noted that slip data suggest better behavior at longer lengths and large magnitudes (x3) and more variability at shorter lengths and smaller magnitudes (x10). Dr. Hanks recommends that the TI Team not use the Ellsworth B relation for magnitudes in the *M* 5 to 7 range. Dr. Hanks suggested the TI Team review the study performed by Dr. Mark Stirling for the GEMS project (Stirling et al., 2013). Dr. Hanks proposed a “Diablo” model of 1.25 logA+3.3, for A >537 km^2, which was later published as Hanks and Bakun (2014). In discussion, Dr. Dave Jackson suggested that the TI Team consider the scaling relation developed by Y. Kagan for global events *M* >7, where the linear fit is between length and the cube root of seismic moment.

D.4.0 Workshop 3 – Preliminary Model and Hazard Feedback

Workshop 3 occurred over three days between March 25 and 27, 2014. The workshop was attended by the PTI, the TI Team and technical staff, the PPRP, the Database Manager, the Hazard Analysts, and selected REs and PEs. Similar to Workshop 2, several members of the SWUS GMC TI Team attended the workshop to assure that any potential interface issues were identified and addressed.

The primary goal of Workshop 3 was for the TI Team to present the preliminary SSC model to the PPRP, to receive feedback from the PPRP on the model, and to receive feedback from the Hazard Analysts on the hazard sensitivity results. In addition, the first day of the workshop included presentations from selected REs and PEs on data or analyses performed following Workshop 2. Workshop participants that attended Workshop 3 are provided in Table D-6. An agenda for the workshop is provided in Table D-7.

During Workshop 3, the TI Team presented the preliminary SSC model to the PPRP and selected REs and PEs. Unlike during Workshops 1 and 2, members of the PPRP were active participants in Workshop 3 to fully query the model parameters, level of documentation, uncertainty, and rationale in developing the model. Thus the workshop provided an opportunity for the PPRP to review and challenge the TI team's evaluations and the technical justifications used to develop the structure of the SSC logic trees and weights on branches of the logic trees (e.g., whether any significant interpretations are missing, how the TI Team has integrated the alternative models and data uncertainties into a single SSC). In addition, the REs and PEs were invited to provide comments following the discussion between the TI Team and PPRP. The TI Team used this feedback in developing the final version of the SSC logic trees.

D.4.1 Welcome, Introduction and SSHAC Training – Kent Ferre, Norm Abrahamson, William Lettis

Similar to Workshops 1 and 2, Mr. Kent Ferre as the Project Sponsor, Dr. Norm Abrahamson as the SSHAC PTI, and Dr. William Lettis as the SSHAC SSC TI Lead welcomed the project participants and workshop attendees, and described the objectives and goals of Workshop 3. In the spirit of a "hazard informed" study, Dr. Abrahamson emphasized to the TI Team and to the audience "don't sacrifice things that matter for things that are interesting." Dr. Lettis reviewed the SSHAC process and provided SSHAC training to the project participants. Dr. Lettis emphasized the roles and responsibilities of each of the SSHAC participants, and that Workshop 3 is focused on the TI Team presenting the Preliminary SSC model to the PPRP, and for the PPRP to actively engage in discussion and questioning of the TI Team to ensure that all the available data and alternative proponent models have been considered and evaluated by the TI Team and integrated into the preliminary model, as appropriate (as opposed to Workshops 1 and 2 where the PPRP acted primarily as observers and not as active participants). Dr. Lettis also indicated that a number of ongoing projects, primarily the AB1632 funded offshore and onshore studies, were reaching conclusion and that the workshop would include several Proponent Expert presentations from the results of these studies.

D.4.2 Overview of the Preliminary SSC Model – Steve Thompson

Dr. Thompson provided an overview of the entire Preliminary SSC model by reviewing each element of the logic tree and providing a specific example from the model to illustrate each element of the logic tree. Because of interest by the PPRP, an unintended consequence of this approach was to respond to many questions regarding the model prior to presentation of the details of the model. Comments/questions/concerns from the PPRP included:

- Please defend the seismogenic depth for reverse faults.
- Please defend the existence of lateral tear faults or lateral ramps between thrust/reverse faults.
- Clarify which elements of the model are faults versus axial surfaces.
- Please clarify epistemic uncertainty versus aleatory variability in your model. “Degree of belief” is an epistemic uncertainty.
- Please document the TI Team approach for allocating slip rate to rupture sources vis a vis the UCERF3 approach for allocating slip rate.
- Please evaluate free air gravity to assess/test the sense of vergence on the NE and SW vergent fault models.
- Please consider adequate complexity in developing the multi-fault rupture sources.

Dr. Thompson responded to these comments/questions from the PPRP, as well as referred to future presentations for additional detail. However, many of these comments provided insight to the TI Team for improving the clarity and documentation of the model, in particular the differentiation of aleatory and epistemic uncertainty in the model.

D.4.3 Hazard Sensitivity feedback on the Preliminary SSC Model – Nick Gregor

Dr. Gregor, the SSHAC Hazard Analyst, provided hazard sensitivity feedback to the TI Team on elements of the preliminary SSC model. The presentation provided by Dr. Gregor is provided as Attachment D-3 for ease of reference. The sensitivity analysis was performed with the preliminary SSC logic tree but using available NGA-West 2 GMPE relationships (the SWUS GMPE model was not available at that time) and an assumed shear wave velocity at the site of Vs30m = 760 m/s. Results of the sensitivity analysis were presented in terms of ratios of change in ground motion (as opposed to ratios of change in hazard as presented at Workshops 1 and 2). Dr. Gregor described the sensitivity analyses that were performed, and presented the hazard results, magnitude deaggregation plots, and tornado diagrams at PGA, 1 Hz and 5 Hz showing relative significance to ground motion for each of the SSC model elements. Results from the sensitivity analysis show that uncertainty in recurrence (time dependency model) is the largest and most significant contributor to ground motion, followed by slip rate on the Hosgri fault, selection of the Characteristic and Maximum magnitude (larger magnitudes generally lead to lower hazard and ground motion), slip rate on the Shoreline fault, and selection of the tectonic fault model (the Southwest vergent model leads to highest hazard and ground motion).

The PPRP provided many comments on the sensitivity analysis and recommendations to explore additional questions with further sensitivity analyses. The TI Team recorded these requests for further consideration, and to perform additional sensitivity analyses during development of the final SSC model.

D.4.4 Tectonic Setting/Strain Regime of South Central California – John Caskey

Dr. Caskey provided the TI Team assessment of the tectonic setting of south-central coastal California. Dr. Caskey described the alternative models of either NE-SW directed crustal shortening versus transpressional right lateral shear in the region. He described the evolution of the plate margin, from subduction of the Farallon plate during the Cretaceous to approximately 22 to 24 million years ago and then replaced by right-lateral transform faulting from 22 Ma to the present. He described how the transform margin matured and reorganized over time and the change in resolved slip rate and plate orientation along coastal California during the Miocene leading to the contemporary tectonic setting. He presented a model for southward decreasing right lateral slip rate on the San Gregorio/San Simeon/ Hosgri fault system in the contemporary tectonic setting.

The PPRP requested additional clarification and documentation on the location and seismogenic potential of the subducted (and abandoned) slab beneath the coastal margin of California. The PPRP noted that the subducted slab may have a different rheology and shear modulus than the overlying crust and, if the Hosgri fault or other faults penetrate the slab, may effect calculations of moment rate and magnitude. The PPRP requested that the TI Team consider all available data showing the location of the slab (referred to Howie, Meltzer, Miller, etc.) and to carefully evaluate whether the slab is disrupted by crustal faults, if possible.

D.4.5 Updated Stress/Strain Analysis – Nora Lewandowski

Ms. Lewandowski provided a Proponent Expert interpretation of the stress and strain field in the Irish Hills and surrounding region based on analysis of updated GPS data and focal mechanism data. She evaluated the resulting stress/strain field to assess the predicted sense of slip on observed faults and modeled fault geometries. The sense of predicted slip should fall within the allowed slip uncertainty in the Outward vergent, Southwest vergent and Northeast vergent models. Results from the inversion of GPS and focal mechanism data are generally consistent and show a N10-20°E principal stress and strain axis, with both dextral (horizontal plane) distributed shear and transpressional shear (with crustal shortening). Ms. Lewandowski indicated that she would not favor one sense of strain over another given the limited data available, and that strain within and bordering the Irish Hills may be heterogeneous.

The PPRP suggested that the TI Team consider the uncertainty and limitations in the data and results, especially when evaluating the possible range in slip orientation (fault rake) in the model.

D.4.6 Location and Dip of the Hosgri Fault – Hans AbramsonWard

Mr. AbramsonWard described the TI Team assessment of the potential range in dip for the Hosgri fault. He presented various seismicity cross sections and reviewed the results from the gravity and magnetic studies provided by Proponent Experts Dr. Langenheim and Dr. Watt and seismic reflection data provided by Dr. Johnson and from the AB1632 CCCSIP studies. Mr. AbramsonWard described the preliminary SSC model for the Hosgri fault showing that the range of dip on the Hosgri fault may range from 90 degrees (vertical) to 85 NE to 75 NE. Each dip is uniquely associated in the SSC model to one of the three Irish Hills fault models (OV, NE, SW), although Mr. AbramsonWard stressed that by “association” the TI Team does not mean to imply “correlation”. In reality, any of the three Hosgri fault dips may occur with any of the three Irish Hills fault models.

The PPRP provided the following comments:

- The seismicity cross sections show that some seismicity is occurring below a depth of 12 kilometers. Please document the TI Team assessment of a 12-kilometer thick seismogenic crust.
- Please define and document strike slip, reverse slip, or oblique slip by fault rake, by horizontal to vertical ratio, by fault dip, etc., because this assessment is required for the GMPE model.
- Please consider decoupling the Hosgri dip from unique association with one of the Irish Hills fault models. Allow all three Hosgri dips to occur with all three fault models. Consider what parts if any may be correlated.

D.4.7 Slip Rate of the Hosgri Fault at Estero Bay, a Proponent Model – Hans AbramsonWard

Mr. AbramsonWard presented his analysis of AB1632 LESS results across the Hosgri fault in Estero Bay. At this location, the Hosgri fault appears to displace a deeply buried stream channel. In his interpretation, the channel is displaced laterally 450 to 1650 meters with a best estimate of 1250 meters. The horizontal to vertical ratio of slip is approximately 6 to 8/1 horizontal to vertical. The age of the channel is estimated to be 800 ka to 1.7 Ma based on an assumed constant sedimentation rate constrained by sea level unconformities. These interpretations yield a right lateral slip rate of 1.3 mm/yr with a range of 0.5 to 2.1 mm/yr.

The PPRP suggested that the TI Team consider the uncertainty in the channel correlation and the age estimate to assure that we capture the CBR of slip rate at this location. The PPRP also cautioned that the TI Team evaluate its “degree of belief” in the results from this study.

D.4.8 Slip Rate of the Hosgri Fault Near Point Sal, a Proponent Model – Phil Hogan

Dr. Hogan presented his team's analysis of AB1632 LESS results across the Hosgri fault directly offshore of Point Sal (south of the intersection with the Casmalia fault). Dr. Hogan recognizes three distinct stratigraphic unconformities (top Miocene, Early-Late Pliocene, Top Neogene), and two younger unconformities called H10 (15-20 ka) and H30 (130-140 ka). He recognizes a suite of erosional channels that cross the Hosgri fault, labeled A through F. Only channel F crosses the entire Hosgri fault zone (two prominent traces at this location). Channel F is displaced 450 to 600 meters with a preferred displacement of 500 to 550 meters. The age of the channel is estimated from the stratigraphic unconformities as 130 to 140 ka (best estimate) with a minimum age of 15 to 20 ka and maximum age of 625 ka. These interpretations yield a right lateral slip rate of 1.46 to 1.61 mm/yr with a range of 0.72 to 4.35 mm/yr.

The PPRP reiterated their comment that the TI Team consider the uncertainty in the channel correlation and the age estimate to assure that we capture the CBR of slip rate at this location. The PPRP also cautioned that the TI Team evaluate its "degree of belief" in the results from this study. The PPRP commented that "a lot" of information is available at the Point Sal site, including further evaluation of the location and geometry of the Channel F thalweg, use of the channel margin as an additional piercing point, and comparison of the Channel F offset with the partial Channel A and B offsets for consistency.

D.4.9 Slip Rate Cumulative Distribution Function for the Hosgri Fault – Steve Thompson

Dr. Thompson presented the TI Team approach for capturing the CBR of slip rate for the Hosgri fault through development of a cumulative distribution function (CDF) of slip rate. He described the use of slip rate data from the marine terraces at San Simeon, from the Estero bay "shoreface" by Dr. Sam Johnson (Johnson et al., 2014; Proponent presentation given at a Working Meeting of the TI Team), the Estero Bay channel offset and the Point Sal channel offset. Dr. Thompson indicated that a much more careful review of the uncertainty in Dr. Johnson's Estero Bay offset is needed.

The PPRP commented that further assessment of the Estero Bay "shoreface" offset is needed. Although the age of the feature appears to be well constrained, the amount of displacement appears to be very poorly constrained. Further analysis is needed to understand the "noise" in the offset data, how the top and bottom of the feature were defined, how slope processes were considered (e.g., slumping, erosion and re-deposition). The PPRP also requested documentation of how the regional GPS data were used to constrain slip rate on the fault – only as a constraint or as corroboration? Or can the data be used as direct input to the slip rate CDF. The PPRP also requested that the TI Team consider proximity of slip rate sites to Diablo Canyon, and to consider the addition or subtraction of fault slip rate from intersecting faults, in particular the Los Osos fault. In other words, the TI Team may consider developing a fully integrated slip rate estimate along the Hosgri fault constrained by the “slip rate sites” but informed by slip rate estimates on intersecting or branching faults and by the regional GPS data.

D.4.10 Rupture Model and Earthquake Rate for the Hosgri Fault – Steve Thompson and Glenn Biasi

Dr. Thompson and Dr. Biasi presented the preliminary SSC rupture source model and deformation rate model. The rupture source model describes how the various characterized fault sources, in terms of their geometry and slip rate, may link together into rupture sources. Splay ruptures, complex ruptures and linked ruptures were defined and described. A distinct suite of rupture sources is defined for each fault geometry model. Dr. Biasi described how slip rate from the fault sources is allocated to the rupture sources, such that when all the rupture sources occur, the slip rate on individual fault sources is preserved. Dr. Biasi noted that although it appears that each individual rupture source is given a unique percent of slip rate, when all three rupture models are considered, the uncertainty in rupture source geometry and slip rate is constrained.

The PPRP offered a number of comments regarding the rupture source model and the slip rate allocation model (termed the deformation rate model):

- The nomenclature is somewhat confusing, and the PPRP recommends that the TI Team carefully describe, define and document the model terminology.
- The PPRP noted that the percent allocation of slip rate to individual rupture sources gives the appearance of precision that is not real. The PPRP recommends that the TI Team very carefully document what is meant/intended by the allocation of percent slip rate, and to carefully maintain “bookkeeping” for transparency.
- The PPRP recommends that the TI Team compare the rupture source model and rupture participation rates to the UCERF3 participation rates to help inform the TI Team in development of the final SSC model (they noted that this is for information only; the participation rates between the two models do not need to match).
- The PPRP recommends that the TI Team carefully document the assessment of characteristic and maximum magnitude assigned to each rupture source, and why certain rupture sources are treated using a characteristic MFD and others are characterized by an Mmax MFD.

D.4.11 Earthquake Rate Model – Katie Wooddell/Norm Abrahamson

Dr. Abrahamson presented the current status of development of the “WAACY” model (Wooddell and Abrahamson, 2013; Wooddell et al, in preparation), and described the elements of the model and why the model was created. The WAACY model is a modification of the Youngs and Coppersmith (1985) characteristic model, and includes a “tail” to incorporate earthquake magnitudes larger than the characteristic magnitude up to a maximum magnitude. The purpose for this revision to the characteristic model is to incorporate the concept of linked fault ruptures in the UCERF3 model that lead to large maximum magnitudes. "Knobs" in the model that must be defined by the TI Team are the tail offset, the tail slope, the maximum magnitude, and the amount of moment that would be distributed to the lower magnitude exponential portion, the characteristic magnitude portion, and the upper magnitude tail portion (Subsequent to Workshop 3, the WAACY model was refined to eliminate many of these "knobs" and to use a more prescribed approach for developing the PDF shape. See *Chapter 10* and Appendix G describing the WAACY model).

The PPRP commented that this is a new, as yet unpublished, model, and questions whether it is ready for use in the SSC model. They expressed concern that some parts of the model have not yet been defined or documented that it produces acceptable results. The PPRP recommended performing a full sensitivity analysis on each of the logic tree nodes (or knobs) that contribute to development of the WAACY magnitude PDF.

D.4.12 Comparison of SSC Model to UCERF3 Model – Thompson

Presentation not given due to time constraints

D.4.13 AB1632 ONSIP Results Proponent Model – Stu Nishenko and Dan O'Connell

Dr. O'Connell presented a Resource Expert status update of the AB1632 funded ONSIP program, the processing of data completed, depth range of penetration and interpretable data, and resolution uncertainty of the various data sets. He expressed that during the interpretation of the seismic reflection data, the interpreter should exercise caution when projecting oil well data onto the seismic profiles. Interpreters should focus on the well-constrained portions of the reflection and tomographic imaging in areas with consistent source and receiver coverage. He emphasized that the seismic data reflect acoustic reflections and not necessarily geologic features.

Because this was a Resource Expert interpretation, the PPRP did not provide comments.

D.4.14 AB1632 ONSIP Results Proponent Model – Jeff Unruh

Dr. Unruh presented a Proponent Expert interpretation of the ONSIP data presented by Dr. O'Connell. Dr. Unruh (and the interpretation team) interpreted all of the seismic reflection data collected by the ONSIP program integrated with surface geologic mapping and borehole/oil well data. Lithologic units recognized at the surface were projected to depth on the seismic reflection lines using geologic attitudes (strike and dip of bedding) observed anticlines and synclines, and observed fault locations. In general, all the seismic lines show a primary Pismo syncline with inner fault graben structures. The faults originated as normal or transtensional structures and accommodated growth of the syncline (e.g., syn-depositional growth panels are recognized on the hanging wall of many normal faults). Many of the inner graben faults are currently "blind" and do not reach the ground surface. Two distinct traces of the Edna fault are recognized and the faults project farther to the west-northwest as buried "blind" faults than previously recognized. Many of the faults, including the Edna fault and San Miguelito fault have been re-activated as reverse faults as shown by anticlines in the hanging wall, post development of the Pismo Syncline. Several of the geophysical lines that cross the surface trace of the Los Osos fault show a fault in the subsurface dipping approximately 60 to 75 degrees to the southwest, although the data quality are very poor and other interpretations may be possible. However, several well-preserved reflectors show that a shallow southwest dipping (less than 30 to 45 degrees) is not permissible. The San Luis Bay fault dips steeply 60 to 75 degrees to the northeast. The San Miguelito fault is located in the hanging wall of the fault and appears to be passively uplifted and possibly rotated by movement on the San Luis Bay fault. The interpretation team is in the process of integrating all of the seismic interpretations to develop crustal cross sections to a depth of 10 to 12 kilometers. The deep crustal sections will incorporate gravity data to further constrain fault geometries and thicknesses of various stratigraphic units. The team plans to perform forward modeling of the interpretations to test their validity.

Because this is a Proponent Expert presentation, the PPRP did not have any comment.

D.4.15 Implications of ONSIP Results to SSC Model – William Lettis

Presentation not given due to time constraints

D.4.16 Microseismicity Analysis of Irish Hills – Jeanne Hardebeck

Dr. Hardebeck provided a Proponent Expert interpretation of seismicity lineaments within the Irish Hills. She described the resolution uncertainty of hypocenters (less than 1 kilometer) and the methodology used to identify possible seismicity planes within the Irish Hills. Her intent is to provide an objective analysis of the data rather than the subjective interpretation of seismicity lineaments that has been provided in the past. She uses the OADC algorithm, modified to reject results showing horizontal or sub-horizontal planes. The algorithm identifies seismicity planes where seismicity may occur within 2 kilometers of the resolved plane. As a test, the method resolved both the Hosgri and Shoreline fault as two steeply dipping planes. In the Estero Bay area directly north of the Irish Hills, the method identifies two distinct north-northwest trending planes that project south toward the Irish Hills. Within the Irish Hills, the method identifies several dipping seismicity planes, both southwest and northeast dipping planes. Following her presentation, Dr. Hardebeck indicated that she will release her unpublished results for the TI Team to independently evaluate. The TI Team noted that many if not all the seismicity planes within the Irish Hills are not as well defined and have greater uncertainty than the seismicity planes recognized in Estero Bay. Dr. Hardebeck generally agreed but felt that the identified planes within the Irish Hills are real.

Because the presentation was a Proponent Expert interpretation, the PPRP did not have any comment.

D.4.17 AB1632 LESS Results for Shoreline Fault Proponent Model – Gary Greene

Dr. Greene provided a Proponent Expert interpretation of the AB1632 funded LESS results across the Shoreline fault in San Luis Obispo Bay. Dr. Greene reviewed the objectives of the study – to identify the southern extent of the Shoreline fault and to evaluate slip rate on the fault. Results from the study show that the Shoreline fault extends to the southern end of the LESS 3D seismic survey. Interpretation of data south of the survey led the interpretation team to extend the fault to the southern end of San Luis Bay and onshore to an intersection with the Casmalia fault. Nine sets of piercing points were identified to assess slip rate on the fault. Most of the piecing points are channels, and two of the piecing points are interpreted paleosea-level strandlines. The best estimate of offset from the paleostrandline is 10 meters. The age of the strandline is estimated to be 155 to 180 ka. These interpretations yield a best estimate right-lateral slip rate of 0.06 mm/yr, with a range of 0.01 to 0.51 mm/yr depending on the age assigned to the strandline. Other piercing points include both channel thalwegs and channel margins. In particular, channel A is offset 30 to 40 meters. The age of the channel is estimated to be 250 ka based on sea level correlations of unconformities above the channel. These interpretations yield a best estimate right lateral slip rate of 0.16 mm/yr with a range of 0 (channel may not be offset within limits of resolution) to 0.24 mm/yr. Channels F and I are not offset within the limit of resolution of the data (up to 6 meters).

Because this is a Proponent Expert presentation, the PPRP did not have any comment.

D.4.18 Slip Rate Cumulative Distribution Function for the Shoreline Fault – Steve Thompson

Similar to the Hosgri fault, Dr. Thompson presented a CDF plot to capture the uncertainty in slip rate on the Shoreline fault. This CDF will be modified based on results from the LESS 3D survey presented by Dr. Greene and the TI Team's independent assessment of the 3D data.

D.4.19 Overview of SSC Tectonic Fault Model – William Lettis and Glenn Biasi

Presentation not given due to time constraints.

D.4.20 SSC Tectonic Fault Models – Hans AbramsonWard

Mr. AbramsonWard provided the TI Team's tectonic fault models used in the preliminary SSC model. Three fault models were developed to explain faults observed within and bordering the Irish Hills and the greater San Luis Range. These models include the Outward vergent model, the Southwest vergent model and the Northeast vergent model. Mr. AbramsonWard described each of the overall models, the fault geometries and slip rates within each model, and the fundamental differences between each model that are intended to capture the CBR of fault geometry and slip rate. Each model satisfies fundamental geologic observations, such as the surface location of faults, uplift rate boundaries identified by the marine terrace data, and known fault slip rates and sense of slip. The three models also expresses the uncertainty in tectonic setting, both transpressional deformation (OV vergent model) and NE-SW directed deformation (SW and NE vergent models).

Following the presentation, the PPRP provided a number of comments:

- Evaluate the memorial terrace near Morro Bay as a possible constraint for location of the Los Osos fault.
- Document the northern extent of the San Miguelito fault.
- Evaluate/explain the origin of the Morro Bay basin in the SW vergent model.
- Evaluate how uplift is occurring west of the Shoreline fault, and how this uplift can be accommodated in the models.
- For the NE vergent model, consider the Los Osos fault as a backthrust off of the slab with the Hosgri fault as a “backstop”.
- The PPRP noted that the OV vergent model is transpressional and does not require a detachment at depth. However, the NE and SW vergent models reflect crustal shortening and will require a detachment at depth.
- The PPRP suggests that the TI Team consider that the San Luis Bay fault may cross cut the Shoreline fault. Cross cutting active faults occur in nature, and the PPRP noted the El Major fault rupture in 2010 that cross cut the 1892 event.
- The PPRP asked the TI Team to consider the “center” of the CBR. The PPRP felt that the range of the CBR was captured in the model.
- The PPRP suggested that the TI Team perform another sensitivity analysis on the depth of the seismogenic crust to confirm that it is not a significant parameter as noted in previous sensitivity analyses.

D.4.21 Overview of SSC Deformation Model – Steve Thompson

Dr. Thompson presented the TI Team interpretation of the deformation or slip rate model used in the SSC model. Dr. Thompson described the allocation of slip rate to the various rupture sources in greater detail than provided in the previous presentation by Dr. Biasi.

The PPRP generally appreciated and accepted the approach of allocating fault slip rate to fault rupture sources as long as the bookkeeping is transparent and the TI Team has a clear understanding of aleatory variability in rupture sources (e.g., all ruptures occur with a frequency) versus epistemic uncertainty in slip rate. The PPRP reiterated that the TI Team may have captured the range of uncertainty, but that the “center” and “body” of the uncertainty requires further evaluation and documentation. The TI Team has not adequately defined the center and body of uncertainty. The PPRP suggests that the TI Team consider that elements from each model may represent the “center” or best estimate of the distribution and not just one model in its entirety.

D.4.22 SSC Deformation Models – Steve Thompson

Dr. Thompson described the TI Team's path forward to complete the Deformation model used in the final SSC model. The TI Team will:

- Independently evaluate the results from the AB1632 funded LESS 3D surveys for the Shoreline and Hosgri faults to obtain estimates of slip rate
- Evaluate whether dip slip rates on other faults in the Southwest Boundary Zone (e.g., Pecho, Oceano, Wilmar Avenue faults) should be "added" to the strike slip rate on the Shoreline fault, assuming different efficiencies (initially considered a range of 50 to 100%).
- Consider using seismicity rate on the Hosgri fault and other faults to evaluate the exponential portion of the magnitude PDF.
- Carefully document how the strike slip component of slip rate is constrained in the Outward vergent model.
- Evaluate if the quantitative analysis to develop the fault slip rate CDF gives the appearance of greater precision/accuracy than is real.
- Evaluate whether a branch should be added to the slip rate logic tree that is informed by the analysis but uses additional geologic judgment, degree of belief, consistency with geodetic data, etc.
- Consider additional constraints from the revised stress/strain analysis presented by Ms. Lewandowski.

D.4.23 Overview of SSC Rupture and Earthquake Rate Model – Steve Thompson

Dr. Thompson presented an overview of the TI Team assessment of the earthquake rate model including magnitude scaling relations, and the use of Characteristic and Maximum Magnitudes in the model. Dr. Thompson described the TI Team approach for defining Characteristic and Maximum magnitudes for each rupture source and the selection of magnitude PDF. The model is intended to develop a complete fault participation rate for the fault section closest to Diablo Canyon and is progressively less complete for fault sections farther from the site. Other fault sections farther from the site may have less complete participation rates because this does not contribute to hazard at the site. The model is based on the most complete and current slip rate data, and thus will be a more complete model than the UCERF3 model (i.e., the SSC MFD will likely be different than the UCERF3 MFD)

The PPRP provided several comments:

- Evaluate the sensitivity to hazard whether a fault is a Characteristic magnitude source or a Maximum magnitude source.
- Carefully document the assessment process leading to the assignment of a rupture source to one of the two categories. Define the criteria used in the assessment process.

- Carefully document epistemic versus aleatory uncertainty in the earthquake rate model.
- Carefully design and compare the SSC model results to the UCERF3 model results for fault participation rates for all fault sections for all possible rupture sources. Explain the differences between the two results (PPRP agrees that the SSC model will be more complete than the UCERF3 model and does not necessarily require a change if different).
- Suggest performing a sensitivity analysis to evaluate the significance of the GR portion of the Maximum magnitude MFD.
- Document how slip rate allocated to individual rupture sources will sum to the actual fault slip rate.

D.4.24 SSC Rupture and Rate Models for Outward Vergent, Southwest Vergent and Northeast Vergent Models – Hans AbramsonWard

Mr. AbramsonWard described the TI Team assessment of the earthquake rate model for each of the three Irish Hills fault models, including combinations with the Hosgri fault models. Mr. AbramsonWard described that the seismogenic depth for the three Irish Hills fault models is fixed at 12 kilometers, and presented seismicity data to support this assessment. He also indicated that the Hosgri fault models allow ruptures to both 12 kilometers and 15 kilometers (locally penetrating the slab).

The PPRP provided several comments on the deformation models:

- The PPRP reiterated that the definitions of various terms need to be defined and used consistently – fault source, rupture source, simple rupture, complex rupture, splay rupture, linked rupture, etc.
- Provide additional documentation of the 15 kilometer depth of the Hosgri fault. Is this significant?
- The PPRP suggested that the TI Team consider that the Shoreline fault may be confined to the hanging wall of an underlying reverse fault that is responsible for uplift of the offshore platform west of the Shoreline fault.
- Evaluate the new slip rate data from the LESS survey to provide constraints on possible rupture sources.

D.4.25 SSC Recurrence Model – Glenn Biasi

Dr. Biasi provided a status update of the SSC TI Team's assessment of the recurrence (time dependency) model. The TI Team determined that additional uncertainty needed to be added to the Poisson recurrence model to capture time dependency of fault behavior. Dr. Biasi presented his analysis of an approach to develop an equivalent Poisson rate (EPR) that captures this uncertainty. His initial analysis examined the lognormal time dependent model. In his opinion, the lognormal renewal model is adequate to evaluate the EPR. Dr. Biasi described empirical data for fault CVs in California, the lower the CV the more periodic the time dependent behavior of the fault. California faults generally show a low CV with a mode of 0.6 and a range of 0.4 to 0.8. Such a time dependent model will indicate a minimum upper EPR of 1.5 to 1.8 the Poisson rate. The EPR model will be given significant weight in the SSC model but not full weight. It is the TI Team's assessment, at the time of the workshop, that the Poisson model cannot be rejected given the current state of knowledge, and thus will be given a low weight in the model.

The PPRP provided several comments:

- Has the TI Team considered other renewal models than the lognormal, such BPT model? The PPRP indicated that for the recently completed Hanford analysis, the lognormal and BPT renewal models led to different EPRs.
- Has the TI Team considered whether the low CVs consistent with low slip rate faults such as those in the Diablo Canyon area?
- If low slip rate faults have long recurrence intervals of >7000 years, the use of an EPR compared to traditional Poisson model is likely not worth the effort (same results).
- The PPRP suggests that the TI Team re-consider using a Poisson model with a low weight in the SSC model. If the TI Team fundamentally believes that the CBR of the TDI is that faults follow a renewal earthquake process, then the Poisson model can be rejected.
- The PPRP suggests that the TI Team need not define the "process" for why a fault follows a non-Poisson recurrence model. The non-Poisson renewal process is real regardless of process (time dependence, clustering, etc.).
- PPRP suggests that the TI Team consider using a simple three branch logic tree with an EPR for the range of CV values, and not a more complex logic tree with several EPRs for each CV.
- PPRP suggests that the TI Team consider whether the non-Poisson behavior is a correlated parameter between faults or rupture sources or a fault-specific behavior that is not correlated.
- The PPRP suggests that when the EPR analysis is complete, that the TI Team perform sensitivity analysis and present the results to the PPRP at a Working Meeting.

D.4.26 San Andreas and Other Fault Sources – Steve Thompson

Dr. Thompson described how the San Andreas and "other" regional faults in the 200-mile plant site radius are incorporated into the model. For the San Andreas fault sections closest to the site, the TI Team decided to use the rupture participation rates from the UCERF3 model, rather than developing a new MFD for the fault. For other regional faults, the TI Team decided to adopt the UCERF3 model for incorporation into the SSC model, because sensitivity analyses have shown that these other faults do not contribute significantly to hazard or ground motion. Dr. Thompson also presented the TI Team approach for developing the background seismic source.

The PPRP generally concurred with the TI Team approach; but emphasized that the SSC model must account for the occurrence of the 1927 Lompoc earthquake.

D.4.27 Background Seismic Sources – Nick Gregor

Dr. Gregor presented a sensitivity analysis for the background source model described by Dr. Thompson. The background source uses the seismicity data and rates determined from the PG&E 2014 seismicity catalog and the UCERF2 seismicity catalog (See Appendix F). Results from the sensitivity analysis shows that the background seismicity rate would have to be at least three times greater than observed to begin to contribute to 1% of the hazard at all frequencies.

The PPRP generally concurred that the background seismicity zones will not contribute significantly to hazard, but suggested that the TI Team carefully document how the seismicity rates were smoothed over the background zone.

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D.6.0 Tables

Table D-1. Resource and Proponent Experts for the Diablo Canyon SSHAC Level 3 SSC Study

Workshop #	Individual (Listed Alphabetically)	Affiliation
2,3	Norm Abrahamson	PG&E
2, 3	Hans AbramsonWard	Lettis Consultants International, Inc.
1	John Baldwin	Lettis Consultants International, Inc.
2, 3	Glenn Biasi	University of Nevada, Reno
2	Peter Bird	UCLA
2	Chuck DeMets	University of Wisconsin–Madison
2	Craig dePolo	Nevada Bureau of Mines and Geology
3	Gary Greene	Moss Landing Marine Laboratories
1, 2	Tim Hall	Consultant
2	Doug Hamilton	Consultant
2	Tom Hanks	USGS, Menlo Park
1, 2	Kathryn Hanson	AMEC Environment & Infrastructure
1, 2, 3	Jeanne Hardebeck	USGS, Menlo Park
1, 2, 3	Phil Hogan	Fugro Consultants, Inc.
2	David Jackson	UCLA
1, 2	Sam Johnson	USGS, Menlo Park
1	Rikk Kvitek	Cal State Monterey Bay
1, 2	Vicki Langenheim	USGS, Menlo Park
2	William Lettis	Lettis Consultants International, Inc.
3	Nora Lewandowski	Lettis Consultants International, Inc.
1	Marcia McLaren	PG&E
1	Walter Mooney	USGS, Menlo Park
1, 3	Dan O'Connell	Fugro Consultants, Inc.
1	Nate Onderdonk	Cal State Fullerton
2	Morgan Page	USGS, Pasadena
1	William Page	PG&E
1	Andreas Plesch	Harvard University
1, 2	Jan Rietman	Fugro Consultants, Inc.
2	David Schwartz	USGS, Menlo Park
2	Bruce Shaw	Lamont-Doherty Earth Observatory
2	Christopher Sorlien	UC Santa Barbara

Workshop #	Individual (Listed Alphabetically)	Affiliation
1	Wayne Thatcher	USGS, Menlo Park
2	Stephen Thompson	Lettis Consultants International, Inc.
1	Sarah Titus	Carleton College
1,2, 3	Jeff Unruh	Lettis Consultants International, Inc.
1	Janet Watt	USGS, Santa Cruz
2	Steve Wesnousky	University of Nevada, Reno
1	Mark Wiegers	California Geological Survey

Table D-2. SSC Workshop 1, List of Participants

Group or Role	Individual	Affiliation
PPRP	Kevin Coppersmith	Coppersmith Consulting, Inc.
	Steve Day (*)	San Diego State University
	Neal Driscoll	Scripps / UCSD
	Brian Chiou (*)	Consultant
	Ken Campbell (*)	Consultant
	Tom Rockwell	San Diego State University
Project Sponsor PG&E	Kent Ferre	PG&E
Project Management - Utilities	Richard Klimczak	PG&E
	William R. Horstman	PG&E
Project Technical Integrator	Norman A. Abrahamson	PG&E
Hazard Analysts	Nick Gregor	Nick Gregor Consulting
	Katie Wooddell	PG&E
Technical Integrator Team	William Lettis	Lettis Consultants International, Inc.
	John Caskey	San Francisco State University
	William Page	PG&E
	Scott Steinberg	PG&E
	Stephen Thompson	Lettis Consultants International, Inc.
Technical Integrator Support	Hans AbramsonWard	Lettis Consultants International, Inc.
	Gary Greene	Moss Landing Marine Laboratories
	Kathryn Hanson	AMEC Environment & Infrastructure
	Marcia McLaren	PG&E
	Stuart Nishenko	PG&E
	Daniel O’Connell	Fugro Consultants, Inc.
Database Manager	Serkan Bozkurt	Lettis Consultants International, Inc.
SSC Resource Experts	Jeanne Hardebeck	U.S. Geological Survey, Menlo Park
	Wayne Thatcher	U.S. Geological Survey, Menlo Park
	Sarah Titus	Carleton College
	Rikk Kvitek	CSU Monterey Bay
	Vicki Langenheim	U.S. Geological Survey, Menlo Park
	Janet Watt	U.S. Geological Survey, Santa Cruz
	Walter Mooney	U.S. Geological Survey, Menlo Park
	Jan Rietman	Consultant
	Sam Johnson	U.S. Geological Survey, Santa Cruz
	Phil Hogan	Fugro Consultants, Inc.
	Dan O’Connell	Fugro Consultants, Inc.
	Mark Wiegers	California Geological Survey
	Tim Hall	Consultant
	John Baldwin	Lettis Consultants International, Inc.
	Andreas Plesch	Harvard University
Regulatory Observers	John Stamatakos	Center for Nuclear Waste
	Annie Kammerer	U.S. NRC
	Casey Weaver	California Energy Commission
	Chris J. Wills	California Geological Survey
	Rui Chen	California Geological Survey

Group or Role	Individual	Affiliation
	Tim Dawson	California Geological Survey
	Gordon Seitz	California Geological Survey
GMC Resource Experts and Other Observers	Alexander Bykovtsev	RANS
	Alexis Lavine	AMEC Environment & Infrastructure
	Andy Lutz	Lettis Consultants International, Inc.
	Keith Knudsen	U.S. Geological Survey, Menlo Park
	Bob Youngs (*)	AMEC Environment & Infrastructure
	Dan Larkin	CalPoly
	Dan Lloyd	Landsite, Inc.
	David Hafemeister	Self
	Doug Hamilton	Consultant
	Erik Layman	Layman Energy Associates
	Gresh Eckrich	Fugro
	George Murray	SCE/SONGS
	J. Strickland	PG&E
	Hans Poschman	Senator Blakeslee
	Jane Swanson	SLOMFP
	Jeff Snyder	Senator Blakeslee
	Jeff Unruh	LCI
	Jennifer Donahue (*)	Geosyntec
	Jennifer Nevius	Geosyntec
	Jenny Watson-Lamprey	JWL
	John Barneich	GeoPentech
	John McCabe	CUESTA Community Programs
	Jonathan Bray (*)	UCB
	Justin Hollenback	Univ. of California, Berkeley
	Justin Martos	CalPoly
	Ken Thompson	Avila Valley Advisory Council
	Lindsay Fowler	Self
	Linda Al-Atik (*)	
	Liz Apfelberg	MFP
	Lloyd Cluff	Consultant
	Mark Tebbets	CalPoly
	Michael Burall	Invisible Software
	Otto Schmidt	SLO Resident
	Pam Racouillat	Self
	Paul Somerville (*)	URS
	Phil Hogan	Fugro
	Ralph Archuleta (*)	UCSB
	Robb Moss	CalPoly
	Robert Darragh (*)	Pacific Engineering and Analysis
	Ronnie Kamai (*)	PEER
	Sherry Lewis	MFP
	Tim Cleath	Cleath-Harris Geologists
	Timothy Ancheta (*)	PEER

Group or Role	Individual	Affiliation
	Tom Cuddy	Pacific Gas and Electric Company
	Tom Freeman	GeoPentech
	Yousef Bozorgnia (*)	PEER/Univ. of California, Berkeley
	Adrian Rodriguez-Marek	Virginia Tech
	Ruth Harris (*)	U.S. Geological Survey, Menlo Park
	Rob Graves (*)	U.S. Geological Survey, Pasadena
	Walt Silva (*)	PEA

(*) GMC TI Team or Resource Expert

Table D-3. SSC Workshop 1, Final Agenda

Day 1 (Combined morning session) - Tuesday, November 29, 2011		
Time	**Topic**	**Presenter**
9:00	Welcome/Introduction/Review Agenda *Structure of workshop (SSC & GMC separate)*	K. Ferre
9:15	SSHAC and Workshop Rules	W. Lettis
10:00	Project Background	N. Abrahamson
10:40	Break	
11:00	Hazard sensitivity	K. Wooddell
12:00	Lunch	
Day 1 (Afternoon SSC session)		
1:00	SSC Session 1 (Seismicity and GPS) - objectives	W. Lettis
1:15	Central coast seismic networks and earthquake catalogs	M. McLaren
1:45	Central coast seismicity locations	J. Hardebeck
2:15	Central coast focal mechanisms	J. Hardebeck
2:45	Break	
3:00	Geodetic estimates of crustal deformation in the Central California Coast Region	W. Thatcher
3:30	PAC-SN Great Valley plate motion in central California	S. Titus
4:00	Plate boundary motion: implications for regional deformation in the central coast of California	J. Unruh
4:30	Summary of Day 1	W. Lettis (moderator)
5:00	Comments from observers	
5:30	Adjourn	
6:00	Public science questions	N. Abrahamson

Table D-3. SSC Workshop 1, Final Agenda (cont.)

Day 2 (SSC session) - Wednesday, November 30, 2011		
Time	**Topic**	**Presenter**
8:30	SSC Session 2 (GIS and Geophysics) objectives	W. Lettis
8:45	DCPP LTSP/SSHAC GIS Database	S. Bozkurt
9:15	Multibeam Echo Sounder bathymetry for high resolution imaging of seafloor features: requirements, capabilities, limitations & innovations	R. Kvitek
9:45	Offshore paleo marine terraces	W. Page
10:15	Break	
10:30	PG&E geologic and geomorphic mapping, San Luis Range Region, LTSP Update Program	W. Page
11:00	Gravity and magnetic data: status, uncertainties and gaps	V. Langenheim
11:30	Discussion	W. Lettis (moderator)
12:00	Lunch	
1:00	SSC session 3 (seismic-reflection) objectives	W. Lettis
1:15	Seismic-reflection data – overview	S. Nishenko
1:45	Deep, high-energy seismic reflection and refraction data: status and gaps	W. Mooney
2:15	The Long Term Seismic Program, CDP seismic reflection and associated data sets	J. Rietman
2:45	Break	
3:00	USGS offshore, low-energy seismic-reflection data	S. Johnson
3:30	Low-energy 2D/3D seismic data and legacy offshore seismic data archive	P. Hogan
4:00	2011 DCPP onshore seismic reflection data acquisition	D. O'Connell
4:30	Summary of Day 2	W. Lettis (moderator)
5:00	Comments from observers	
5:30	Adjourn	
6:00	Public science questions	N. Abrahamson

Table D-3. SSC Workshop 1, Final Agenda (cont.)

Day 3 (SSC morning session) - Thursday, December 1, 2011		
Time	**Topic**	**Presenter**
8:30	SSC Session 4 (Geology) Objectives	W. Lettis
8:45	PG&E geologic and geomorphic mapping, San Luis Range Region – LTSP update program	W. Page
9:15	Geologic mapping and digital compilation in San Luis Obispo County	M. Wiegers
9:45	Onshore marine and fluvial terrace database, south-central California	K. Hanson
10:15	Break	
10:30	LTSP trenching investigation	T. Hall
11:00	Los Osos fault data compilation	J. Baldwin
11:30	SCEC Community Fault and Velocity Models	A. Plesch
12:00	Lunch	
Day 3 (Combined afternoon session)		
1:00	Summary of GMC Hazard Significant Issues and Data Needed to Resolve Them	N. Abrahamson
2:00	Discussion of GMC Data Needs	
2:30	Break	
2:45	Summary of SSC Hazard Significant Issues and Data Needed to Resolve Them	W. Lettis
3:30	Discussion of SSC Data Needs	
4:00	Discussion of SSC and GMC Interface Issues	
5:00	Comments from observers	
5:30	Adjourn	

Table D-4. SSC Workshop 2, List of Participants

Group or Role	Individual	Affiliation
PPRP	Kevin Coppersmith	Coppersmith Consulting, Inc.
	Steve Day	San Diego State University
	Neal Driscoll	Scripps/UCSD
	Tom Rockwell	San Diego State University
Project Sponsor PG&E	Kent Ferre	PG&E
Project Management – Utilities	Richard Klimczak	PG&E
	William R. Horstman	PG&E
	Nozar Jahangir	PG&E
Project Technical Integrator	Norman A. Abrahamson	PG&E
Hazard Analysts	Nick Gregor	Nick Gregor Consulting
	Katie Wooddell	PG&E
Technical Integrator Team	William Lettis	Lettis Consultants International, Inc.
	John Caskey	San Francisco State University
	Hans AbramsonWard	Lettis Consultants International, Inc.
	Scott Steinberg	PG&E
	Stephen Thompson	Lettis Consultants International, Inc.
Technical Integrator Support	William Page	PG&E
	Gary Greene	Moss Landing Marine Laboratories
	Kathryn Hanson	AMEC Environment & Infrastructure
	Marcia McLaren	PG&E
	Stuart Nishenko	PG&E
	Daniel O'Connell	Fugro Consultants, Inc.
Database Manager	Serkan Bozkurt	Lettis Consultants International, Inc.
Resource and Proponent Experts	Jeanne Hardebeck	U.S. Geological Survey, Menlo Park
	Victoria Langenheim	U.S. Geological Survey, Menlo Park
	Jan Rietman	Consultant
	Sam Johnson	U.S. Geological Survey, Menlo Park
	Chuck DeMets	UW-Madison
	Bruce Shaw	Lamont Doherty Earth Observatory, Columbia U.
	Phil Hogan	Fugro Consultants, Inc.
	Christopher Sorlien	UC Santa Barbara
	Peter Bird	UCLA
	Tim Hall	Consultant
	Craig dePolo	Nevada Bureau of Mines and Geology, Reno
	Morgan Page	U.S. Geological Survey, Pasadena
	Tom Hanks	U.S. Geological Survey, Menlo Park
	David Jackson	UCLA
	Glenn Biasi	University of Nevada, Reno
	Doug Hamilton	Consultant
	Steve Wesnousky	University of Nevada, Reno
	Jeff Unruh	Lettis Consultants International, Inc.
	Phil Hogan	Fugro Consultants, Inc.

Group or Role	Individual	Affiliation
	David Schwartz	U.S. Geological Survey, Menlo Park
	Tim Dawson	California Geological Survey
	Russell Graymer	U.S. Geological Survey, Menlo Park
	Janet Watt	U.S. Geological Survey, Menlo Park
	John Baldwin	Lettis Consultants International, Inc.
	Jessica Murray	U.S. Geological Survey, Menlo Park
Regulatory Observers	John Stamatakos	Center for Nuclear Waste
	Christie Hale	US Nuclear Regulatory Commission
	Annie Kammerer	US Nuclear Regulatory Commission
	Rasool Anooshehpoor	US Nuclear Regulatory Commission
	Jon Ake	US Nuclear Regulatory Commission
	William Maier	US Nuclear Regulatory Commission
	Mark Johnson	California Coastal Commission
	Joan Walter	California Energy Commission
	Casey Weaver	California Energy Commission
	Gordon Seitz	California Geological Survey
	Robert Anderson	California Seismic Safety Commission
Other Observers	Andy Lutz	Lettis Consultants International, Inc.
	Brian Gray	Lettis Consultants International, Inc.
	Bryce Pfeifle	Cleath-Harris Geologists
	Christopher Slack	AMEC
	David Weisman	A4NR
	David Williams	Cleath-Harris Geologists
	Helene Carton	LDEO, Columbia University
	Jane Swanson	SLOMFP
	Jeremy Chandler	Lettis Consultants International, Inc.
	Jennifer Donahue	Geosyntec
	John Geesman	Dickson Geesman
	Sam Blakeslee	California State Senate
	Linda Seeley	SLO Mothers for Peace
	Megan Stanton	Pacific Gas and Electric Company
	Nora Lewandowski	Lettis Consultants International, Inc.
	Philippe Renault	Swiss Nuclear
	Robert Budnitz	Diablo Canyon Independent Safety Committee
	Ross Hartleb	Lettis Consultants International, Inc.
	Scott Lindvall	Lettis Consultants International, Inc.
	Sherry Lewis	Mothers for Peace
	Tim Cleath	Cleath-Harris Geologists

Table D-5. SSC Workshop 2, Final Agenda

Day 1, Monday November 6th, 2012		
Time	**Topic**	**Presenter**
8:00	Welcome: Introduction	K. Ferre
8:15	Workshop 2 Goals	N. Abrahamson
8:30	SSHAC Training	W. Lettis
8:50	SSC Sensitivity Logic Tree	S. Thompson
9:15	SSC Sensitivity Results	N. Gregor
9:30	Discussion	
9:45	Break	
10:00	New Data Acquisition (NDA): AB1632-Funded Projects	S. Nishenko
10:30	NDA: LTSP-funded projects	S. Steinberg
10:45	NDA: Data availability	S. Steinberg
11:00	Discussion	
11:15	SSC1: Marine geology and geomorphology of the Hosgri and Shoreline faults	S. Johnson
12:00	Lunch	
13:00	SSC 2: Seismicity of the Hosgri and Shoreline faults and Irish Hills	J. Hardebeck
13:30	SSC 3: Gravity and magnetic constraints for the Hosgri and Shoreline faults	J. Watt
14:00	SSC 4: Hosgri and Shoreline fault geometric model	H. AbramsonWard
14:30	Discussion	
15:00	Break	
15:15	SSC 5: Irish Hills and San Luis Range fault model	D. Hamilton
15:45	SSC 6: Seismicity of the Irish Hills and San Simeon earthquake epicentral region	M. McLaren
16:15	SSC 7: Geometric and kinematic alternatives for the Los Osos and San Luis Bay faults	W. Lettis
16:45	Discussion	
17:15	Day 1 Summary	H. AbramsonWard
17:30	Comments from observers	
17:45	Adjourn	
18:00	Public science questions	N. Abrahamson

Table D-5. SSC Workshop 2, Final Agenda (cont.)

Day 2, Tuesday November 7th, 2012		
Time	**Topic**	**Presenter**
8:00	Welcome: Introduction to Day 2	W. Lettis
8:15	SSC 8: Irish Hills geologic cross section	R. Graymer
8:45	SSC 9: Late Cenozoic kinematic model from offset geophysical anomalies	V. Langenheim
9:15	SSC 10: Late Cenozoic kinematic model for transfer of strain along the California margin	C. Sorlien
9:45	Discussion	
10:15	Break	
10:30	SSC 11: Hosgri-San Simeon fault zone geologic slip rate	K. Hanson
11:00	SSC 12: UCERF3 Deformation model approaches	T. Dawson
11:30	Discussion	
12:00	Lunch	
13:00	SSC 13: Plate margin deformation and kinematics from GPS data	C. DeMets
13:30	SSC 14: Regional deformation and kinematics from GPS data	J. Murray
14:00	SSC 15: NeoKinema approach for modeling deformation	P. Bird
14:30	Discussion	
15:00	Break	
15:15	SSC 16: Offshore evidence for uplift rate boundaries	H. AbramsonWard
15:45	SSC 17: Shoreline fault slip rate constraints	S. Thompson
16:15	SSC 18: Los Osos and San Luis Bay fault slip rate constraints	W. Lettis
16:45	Discussion	
17:15	Day 2 summary	W. Lettis
17:30	Comments from observers	
17:45	Adjourn	
18:00	Public science questions	N. Abrahamson

Table D-5. SSC Workshop 2, Final Agenda (cont.)

Day 3, Wednesday November 8th, 2012		
Time	**Topic**	**Presenter**
8:00	Welcome: Introduction to Day 2	W. Lettis
8:10	Magnitude-Frequency Sensitivity	N. Gregor
8:15	SSC 19: Evidence against segmented rupture behavior	J. Hardebeck
8:45	SSC 20: Segmentation: requirements for segmenting faults; evidence for segmented rupture behavior	D. Schwartz
9:15	SSC 21: Characterizing faults and rupture length for hazard analysis	C. dePolo
9:45	Break	
10:00	SSC 22: Rupture length considerations	G. Biasi
10:30	Discussion	
11:00	SSC 23: Recurrence Rate Discussion	N. Abrahamson, T. Rockwell, D. Jackson
11:30	Discussion	
12:00	Lunch	
13:00	SSC 24: Magnitude PDF for fault ruptures	M. Page
13:30	SSC 25: Magnitude PDF for fault ruptures	N. Abrahamson
14:00	SSC 26: Stochastic model for fault ruptures	D. Jackson
14:30	Discussion	
15:00	Break	
15:15	SSC 27: Magnitude Scaling Relations	B. Shaw
15:45	SSC 28: Magnitude Scaling Relations	T. Hanks
16:15	Discussion	
16:30	Day 3 Summary	S. Thompson
17:45	Concluding remarks, observer comments, and adjourn	W. Lettis

Table D-6. SSC Workshop 3, List of Participants

Group or Role	Individual	Affiliation
PPRP	Kevin Coppersmith	Coppersmith Consulting, Inc.
	Steve Day	San Diego State University
	Neal Driscoll	Scripps / UCSD
	Tom Rockwell	San Diego State University
Project Sponsor PG&E	Kent Ferre	PG&E
Project Management - Utilities	Richard Klimczak	PG&E
	William R. Horstman	PG&E
	Nozar Jahangir	PG&E
Project Technical Integrator	Norman A. Abrahamson	PG&E
Hazard Analyst	Nick Gregor	Nick Gregor Consulting
Technical Integrator Team	William Lettis	Lettis Consultants International, Inc.
	John Caskey	San Francisco State University
	Glenn Biasi	University of Nevada, Reno
	Hans AbramsonWard	Lettis Consultants International, Inc.
	Stephen Thompson	Lettis Consultants International, Inc.
Technical Integrator Support	Kathryn Hanson	AMEC Environment & Infrastructure
	Marcia McLaren	PG&E
	Stuart Nishenko	PG&E
Database Manager	Serkan Bozkurt	Lettis Consultants International, Inc.
Resource and Proponent Experts	Jeanne Hardebeck	U.S. Geological Survey, Menlo Park
	Gary Greene	Moss Landing Marine Laboratories
	Phil Hogan	Fugro Consultants, Inc.
	Nora Lewandowski	Lettis Consultants International, Inc.
	Daniel O'Connell	Fugro Consultants, Inc.
	Jeff Unruh	Lettis Consultants International, Inc.
Regulatory Observers	John Stamatakos	Center for Nuclear Waste
	Chris Wills	California Geological Survey
	Meralis Plaza-Toledo	US Nuclear Regulatory Commission
	Joseph Giacinto	US Nuclear Regulatory Commission
	Mark Johnson	California Coastal Commission
	Casey Weaver	California Energy Commission
	Robert Anderson	California Seismic Safety Commission

Table C-6. SSC Workshop 3, List of Participants (continued)

Group or Role	Individual	Affiliation
Other Observers	John McCabe	Cuesta College
	Jan Rietman	Consultant
	Doug Hamilton	Consultant
	David Schwartz	U.S. Geological Survey, Menlo Park
	Tim Dawson	California Geological Survey
	Gordon Seitz	California Geological Survey
	Rochelle Becker	A4NR
	David Weisman	A4NR
	Justin Hollenback	PEER
	John Geesman	A4NR
	Aileen Chea	SFSU
	Matt Huebner	Lettis Consultants International, Inc.
	Alex Remar	Lettis Consultants International, Inc.
	Robert Givler	Lettis Consultants International, Inc.
	Robert Budnitz	Diablo Canyon Independent Safety Committee
	Alex Steely	UC Santa Cruz
	Ferman Wardell	Diablo Canyon Independent Safety Committee
	Jim Ostovani	Self
	Carola DiAlessandro	GeoPentech
	Julian Lozos	Stanford University
	Keith Knudsen	US Geological Survey
	Ken Thompson	AVAC
	Chris Madugo	Oregon State University
	Tom Cuddy	PG&E
	Colin Rigley	New Times
	Sherry Lewis	Mothers for Peace
	Tim Cleath	Cleath-Harris Geologists

Table D-7. SSC Workshop 3, Final Agenda

Day 1, Tuesday March 25th, 2014		
Time	**Topic**	**Presenter**
8:00	Welcome: Introduction	K. Ferre
8:15	PTI Comments	N. Abrahamson
8:30	SSHAC Training	W. Lettis
9:00	SSC Model Overview	S. Thompson
9:45	Discussion	
10:00	Break	
10:15	Hazard sensitivity	N. Gregor
11:00	Discussion	S. Nishenko
11:15	Tectonic setting/strain regime of south-central California	J. Caskey
11:30	Updated Stress/Strain analysis	N. Lewandowski (PE)
11:45	Discussion	
12:00	Lunch	
13:00	Hosgri fault location and dip	H. AbramsonWard
13:30	Hosgri fault slip rate	H. AbramsonWard (PE)
14:00	Hosgri fault slip rate near Point Sal	P. Hogan (PE)
14:30	Hosgri fault source slip rate CDF	S. Thompson
15:00	Break	
15:15	Hosgri Rupture Model	S. Thompson
15:30	Hosgri Earthquake Rate Model	G. Biasi
16:00	Magnitude PDF Model	N. Abrahamson (PE)
16:30	Day 1 Discussion	W. Lettis
17:00	Comments from observers	
17:15	Adjourn	
17:30	Public science questions	N. Abrahamson

(PE) = Proponent Expert
(RE) = Resource Expert

Table D-7. SSC Workshop 3, Final Agenda (cont.)

Day 2, Wednesday March 26th, 2014		
Time	**Topic**	**Presenter**
8:00	Training	W. Lettis
8:15	AB1632 ONSIP results	D. O'Connell (RE)
9:00	Discussion	
9:15	AB1632 ONSIP results	J. Unruh (PE)
9:45	Discussion	
10:00	Break	
10:15	Microseismicity Analysis of Irish Hills	J. Hardebeck (PE)
11:00	Discussion	
11:15	Preliminary results of 3D LESS study on Shoreline fault zone	G. Greene (PE)
11:45	Discussion	
12:00	Lunch	
13:00	Overview of Tectonic Fault Models	W. Lettis / G. Biasi
13:30	Fault Models: Outward Vergent, Southwest Vergent, and Northeast Vergent Models	H. AbramsonWard
14:15	Discussion	
14:30	Break	
14:45	Deformation Models	S. Thompson
16:15	Discussion	
16:30	Day 2 Discussion	W. Lettis
17:00	Comments from observers	
17:15	Adjourn	
17:40	Public science questions	N. Abrahamson

(PE) = Proponent Expert
(RE) = Resource Expert

Table D-7. SSC Workshop 3, Final Agenda (cont.)

Day 3, Thursday March 27th, 2012		
Time	**Topic**	**Presenter**
8:00	Training	W. Lettis
8:15	Overview of Rupture and Earthquake Rate Models	S. Thompson
8:45	Discussion	
9:00	Rupture and Rate Models: Outward Vergent, Southwest Vergent, and Northeast Vergent Models	H. AbramsonWard
10:15	Discussion	
10:30	Break	
10:45	Recurrence Models: Approach and Results	G. Biasi
11:30	Discussion	
12:00	Lunch	
13:00	Recurrence Model Discussion	S. Thompson
13:30	San Andreas and Other Fault Sources	S. Thompson
14:00	Discussion	
14:15	Break	
14:30	Background Seismic Sources	N. Gregor
15:00	Day 3 Discussion	W. Lettis
16:00	Observer Comments	
16:15	Adjourn	
16:30	Public science questions	N. Abrahamson