IPRP Report No. 2

Comments on PG&E's Enhanced Seismic Study Plans for Diablo Canyon Power Plant

Background

In 2006, the California legislature enacted Assembly Bill (AB) 1632, which was codified as Public Resources Code Section 25303. AB 1632 directed the California Energy Commission (CEC) to assess the potential vulnerability of California's largest baseload power plants, which includes Diablo Canyon Power Plant (DCPP), to a major disruption due to a major seismic event and other issues. In response to AB 1632, in November 2008 the CEC issued its findings and recommendations in its AB 1632 Report, which was part of its 2008 Integrated Energy Policy Report Update.

In Pacific gas and Electric Company's (PG&E) 2007 General Rate Case decision D.07-03-044, the California Public Utilities Commission (CPUC) directed PG&E to address and incorporate the recommendations from the AB 1632 Report into its feasibility study to extend the operating licenses of its Diablo Canyon Units 1 and 2 for an additional 20 years.

In November 2009, PG&E submitted its formal application with the Nuclear Regulatory Commission (NRC) to extend the licenses of DCPP Units 1 and 2. On January 15, 2010, PG&E filed A.10-01-014 with the CPUC for cost recovery of $16.73 million associated with the enhanced seismic studies recommended by the CEC's AB 1632 Report. In accordance with the CEC AB 1632 Report to improve the public health and safety in the vicinity of California's nuclear power plants, PG&E is planning on conducting 2-D and 3-D seismic studies and analyses at its Diablo Canyon Power Plant. PG&E plans to perform these studies for on-shore and off-shore areas by using enhanced 2-D and 3-D seismic reflection mapping and other advanced geophysical techniques to explore fault zones in the vicinity of DCPP, as recommended by the CEC AB 1632 Report.

IPRP Panel

CPUC Decision D.10-08-003, issued on August 16, 2010, established that the CPUC would convene its own Independent Peer Review Panel (IPRP) and invite the CEC, the California Geologic Survey (CGS), the California Coastal Commission (CCC), and the California Seismic Safety Commission (CSSC) to participate on the panel. Under the auspices of the CPUC, the IPRP is conducting an independent review of PG&E's seismic studies including independently reviewing and commenting on PG&E's study plan and the findings of the study, which are expected to be completed in 2013.

The IPRP convened its first meeting on August 31, 2010 at the CPUC in San Francisco. CPUC staff from Energy Division attended, as well as staff from the CEC, the California Coastal Commission, the California Geologic Survey, the California Seismic Safety Commission. At this meeting, PG&E gave a brief presentation on its proposed seismic survey study plans. The IPRP commented on PG&E's seismic study plans by issuing its IPRP Report No. 1 to PG&E on September 30, 2010.

PG&E provided updated briefings to the CPUC on the status of its enhanced seismic studies program on February 18, 2011 and May 3, 2011. At the May 3, 2011 presentation, PG&E indicated that on April 29, 2011 it had submitted to the California State Lands Commission its application for a geophysical permit to conduct high intensity off-shore seismic surveys. PG&E expected in May 2011 to submit its project scope to the San Luis Obispo County regarding on-shore seismic imaging. PG&E also expected to submit in May 2011 its application to the California State Lands Commission for permits for the Ocean Bottom Seismometers.

PG&E provided a copy of the technical portion of the application to the CA State Lands Commission for the high intensity off-shore seismic mapping that describes the project location, the 3-D seismic data acquisition target areas, and the proposed project activities for the off-shore and near-shore survey operations. PG&E also provided a copy of the project summary provided to the County of San Luis Obispo. Additionally, PG&E provided a copy of the technical portion of the permit application to the CA State Lands Commission for the Ocean Bottom Seismometers. All of this information was forwarded to the IPRP participants for their review.

PG&E's Seismic Study Plans for DCPP

On July 20, 2011, PG&E provided to the IPRP an updated status briefing on its seismic study plans and schedule. Following this meeting, PG&E provided to the IPRP, at its request, a memo report "Response to IPRP Request for Hazard Sensitivity for Targets for the DCPP Geophysical Surveys," that was prepared by the PG&E Geosciences Department and dated August 8, 2011.

While the briefing on July 20th focused on PG&E's recently completed studies of the Shoreline fault and studies currently being planned, the memo report related to the specific scientific questions to be answered by the planned studies. The memo report discusses the sensitivity of hazard analyses to alternative models that the planned studies may help to distinguish. These seismic studies are intended to refine estimates of potential earthquake ground shaking. The IPRP has not been informed of any plans for further analysis of secondary earthquake hazards, e.g., tsunami, fault rupture, liquefaction, or seismically induced landslides. Results of the sensitivity studies are shown for both deterministic and probabilistic hazard analyses. Generally, deterministic analyses are

sensitive to earthquake magnitude, while probabilistic analyses are sensitive to the rates of earthquakes. The analyses focus on earthquake shaking potential with a 0.2 second period. This short-period shaking "saturates"; it increases only slightly at magnitudes above about 7. Therefore, the comments below focus on the sensitivity of the probabilistic analyses. It should be noted that PG&E has not supplied the IPRP with the details of its probabilistic seismic hazard analysis, i.e., the detailed locations, magnitude, and rate of occurrence of earthquakes on each fault considered in the analysis. The IPRP comments below assume that the probabilistic analysis by PG&E is broadly similar to the probabilistic analysis underlying the National Seismic Hazard Maps.

- ✓ The IPRP requests an opportunity to review the probabilistic seismic hazard model being used by PG&E.

IPRP comments on the Hazard Sensitivity for the DCPP Geophysical Survey Targets

In the memo report, PG&E numbered the planned studies 2.1 to 2.10; this numbering scheme is retained in the IPRP comments below. The IPRP comments briefly summarize the goals of each of the studies as stated by PG&E and the IPRP's opinion of the potential for achieving those goals. The comments then describe the IPRP's current understanding of the relative importance of the goals and provide some recommendations for additional aspects of the studies to further refine our understanding of the potential seismic hazard at DCPP.

The IPRP notes that on-land seismic surveys, which are described in the July 20th briefing and in the memo report of August 8th, are identified in that memo as "not part of the IPRP tasks," apparently because they are "planned under separate funding". The IPRP is aware that funding for PG&E's Long-Term Seismic Program (LTSP) is authorized in its General Rate Cases (GRCs). However, CPUC Decision 10-08-003 summarizes the additional seismic studies for DCPP recommended by the California Energy Commission's November 2008 Report entitled "An Assessment of California's Nuclear Power Plants: AB 1632 Report" (AB 1632 Report). This decision, which granted funding for PG&E's planned seismic studies and established the IPRP, describes on-shore 2-D seismic surveys, offshore 3-D seismic surveys, and ocean bottom seismometers used to explore fault zones near DCPP. All of these studies are within the purview of the panel. Therefore, some or all of the on-shore seismic surveys that are within the LTSP, although funded by PG&E's GRC, would need to be reviewed by the IPRP.

2.1 Hosgri-San Simeon Step-Over

PG&E's 1988 LTSP report treated the Hosgri and San Simeon Faults as separate structures, with the distance between the two faults preventing any earthquakes from

rupturing both faults simultaneously. Since that study, several earthquakes have ruptured parts or all of two or more named faults (e. g., Landers, 1992; Hector Mine, 1999; Denali, 1999). As a result, seismic hazard models have increasingly considered the possibility of multi-segment or multi-fault earthquakes when the distance between faults is less than 5 km (following Wesnousky, 2008). The 2008 Uniform California Earthquake Rupture Forecast (UCERF2) by the Working Group on California Earthquake Probabilities (WGCEP, 2008) models the Hosgri and San Simeon as a single fault with nothing to prevent concurrent ruptures of all or parts of both faults. As noted in PG&E's memo report, the effect of greater fault length is higher maximum magnitude, but fewer earthquakes. In this case, the deterministic hazard analysis shows a slight increase in hazard if the faults rupture coseismically. The probabilistic seismic hazard analysis shows a typical result of increasing maximum magnitude; energy is used in fewer, larger earthquakes so the rate of occurrence of moderate magnitude earthquakes decreases and the overall hazard and consequential risk also decrease.

At the briefing on July 20th, PG&E presented preliminary results of seismic surveys of the Hosgri-San Simeon step-over. Previous surveys have shown that there are faults within the step-over zone, but there is not a direct connection between the Hosgri and San Simeon faults. Data from future surveys with smaller spacing between survey lines will allow for a better estimate of how direct is the connection between the Hosgri and San Simeon faults. It is likely that a better model, intermediate between the 1988 LTSP "hard segmentation" and the 2008 UCERF "direct connection" model will be possible once these surveys show the extent of faulting and the existence of any connections between faults within the step-over zone. Since the "direct connection" model significantly reduces the probabilistic seismic hazard at Diablo Canyon, it is important to know how much weight to give that model in the analysis.

- ✓ The IPRP agrees that more closely spaced seismic surveys within the step-over zone will allow better resolution of the faulting and enable better estimates of the potential for ruptures involving both the Hosgri and San Simeon faults.

2.2 Hosgri – Shoreline Intersection

Questions regarding the Hosgri-Shoreline fault intersection are similar to those regarding the Hosgri-San Simeon step-over. If the intersection is a hard "segment boundary", then earthquakes do not rupture through it and more, smaller earthquakes are required to use up the available energy. The nature of the intersection has been a focus of recent studies because the Shoreline fault was recently discovered. A deterministic analysis does show that a larger magnitude earthquake rupturing both the Shoreline and Hosgri faults results in higher hazard and consequential risk at Diablo Canyon than earthquakes on the Shoreline or Hosgri faults alone. In probabilistic seismic hazard analysis, however, fewer, larger earthquakes result in lower long-term hazard and consequential risk as described above.

It is important to know if there is a "direct connection" between the Shoreline fault and the Hosgri fault not because such a connection would raise the potential hazard and consequential risk at Diablo Canyon but because it would lower them.

PG&E has put extensive effort into planning for a high-energy 3-D seismic survey focusing on the connection between the Hosgri and Shoreline faults. The 3-D surveys have the potential to provide information to show whether the Hosgri and other faults could act together. Those studies have only a moderate chance of showing the faults at seismogenic depths because of the chaotic structure and lack of sharp seismic velocity contrasts in the Franciscan complex bedrock around the faults.

- ✓ The plans described by PG&E appear to be well conceived and have as good a chance as currently feasible of providing data on the intersection of the Hosgri and Shoreline faults.

2.3 Hosgri Slip Rate

Fault slip rate, the amount of displacement on a fault over time, can be used to calculate the amount of energy available to be released as earthquakes over time. Since slip rate controls the amount of energy that is available to produce earthquakes on a fault, it is a key parameter in probabilistic seismic hazard analysis. When this key parameter is poorly constrained, as it is for the Hosgri fault, the resulting seismic hazard analysis is very uncertain. Studies to better understand the slip rate on the Hosgri fault could include GPS surveys including seafloor GPS stations west of the Hosgri fault and very high resolution seismic surveys of young geologic features (such as channels eroded during ice-age low sea level). Although PG&E has identified the slip rate on the Hosgri fault as one of the uncertainties with the most effect on hazard analysis, PG&E has not presented specific plans to investigate it.

- ✓ The IPRP recommends further studies to decrease the uncertainty in the seismic hazard at Diablo Canyon by better constraining the slip rate on the Hosgri fault.

2.4 Hosgri Dip

In the LTSP seismic hazard model and in the UCERF, the Hosgri fault is treated essentially as a vertical fault. Early work on the Hosgri fault suggested that it may dip to the east, toward Diablo Canyon. More recent work by Hardebeck (2010) shows that seismicity on the fault essentially follows a vertical plane. The high-energy 3-D seismic survey, which will focus on the intersection of the Shoreline and Hosgri faults, may also help define the geometry of the Hosgri fault at depth. If the seismic survey shows a vertical fault plane at depth, it would confirm Hardebeck's interpretation of the seismicity. As discussed above, the 3-D surveys have, at best, a moderate chance of showing the faults at seismogenic

depths due to the chaotic structure and lack of sharp seismic velocity contrasts in the Franciscan complex bedrock around the faults.

- ✓ The plans described by PG&E appear to have as good a chance as currently feasible of providing data on the dip the Hosgri fault near the intersection of the Shoreline and the Hosgri faults.

2.5 Shoreline Fault Segmentation

For its initial seismic hazard analysis including the Shoreline fault, PG&E divided the fault into three segments and considered earthquakes that ruptured one, two, or three of the segments. A 3-D seismic survey of the Shoreline fault is unlikely to provide further information to improve the segmentation model or distinguish between segmented and unsegmented models. Details of the magnitude and frequency of earthquakes included in the model can be important. Realistic unsegmented models will consider the possibility of earthquakes of any magnitude up to the maximum possible for the area of the fault. Generally, however, a larger maximum magnitude reduces the rate of occurrence of all earthquakes in a probabilistic seismic hazard analysis and results in lower hazard and consequential risk. In the case of the Shoreline fault, PG&E reports that the effect of segmentation on the hazard analysis is small.

- ✓ The plans described by PG&E appear to have as good a chance as currently feasible of providing data on the orientation and continuity of the Shoreline fault at depth.

2.6 Shoreline Fault Slip Rate

As described above, fault slip rate controls the amount of energy that is available to produce earthquakes on a fault. Although this key parameter is estimated in PG&E's Shoreline fault report, the IPRP has not yet completed its review of that report. Pending completion of the review, the IPRP considers the slip rate for the Shoreline fault to be poorly constrained. Studies to better constrain the slip rate on the Shoreline fault could include GPS surveys including seafloor GPS stations southwest of the Shoreline fault and very high resolution seismic surveys of young geologic features (such as channels eroded during ice-age low sea level). In the briefing of July 20th, PG&E showed one such sea level low-stand channel that is notably complex where it crosses the fault.

- ✓ The IPRP recommends further studies to decrease the uncertainty in the seismic hazard at Diablo Canyon by better constraining the slip rate on the Shoreline fault.

2.7 Southeast End of Shoreline Fault

Initial mapping of the Shoreline fault shows the fault extending southeast of Diablo Canyon into the shallow waters west of Oceano. There, the surface traces of the fault are covered

by recent marine sediments. Seismic surveys could locate and delineate further strands of the Shoreline fault to the southeast, and possibly show connections with other faults already mapped on-land, e.g., the Oceano fault. Although PG&E reports that the effect of extending the fault to the southeast on the hazard analysis is small, the IPRP notes that if the zone does connect with faults on-land, then studies of fault slip rate or earthquake recurrence on any on-land connecting fault may be relevant to the Shoreline fault.

- ✓ The plans described by PG&E appear to have as good a chance as currently feasible of providing data on the orientation and continuity of the southeast end of the Shoreline fault. The IPRP recommends that a secondary focus of these studies should be to constrain any potential connections to faults on-shore.

2.8 Los Osos Fault Dip

The Los Osos fault, which crops out on the north side of the Irish Hills, dips to the south beneath the hills. The current PG&E seismic hazard model estimates the dip of the fault plane to range from 45 to 75 degrees. Shallower dips result in the fault projecting closer to the Diablo Canyon Power Plant and present significantly higher hazard. At the briefing on July 20th, PG&E presented general plans for on-land seismic surveys across the Irish Hills using both vibroseis and accelerated weight drop trucks. These surveys appear to be designed to cover as much of the Irish Hills as possible using existing roads. The IPRP notes that the target of this investigation is the Los Osos fault, but other faults with other orientations have been mapped or postulated beneath the Irish Hills.

- ✓ The current plans for on-land seismic surveys appear to be adequate to image reverse faults beneath the hills. The IPRP will be interested in reviewing the results that show the Los Osos fault, but also any other geologic structure or structures beneath the hills.

2.9 Los Osos Sense of Slip and 2.10 Los Osos Slip Rate

The description of the sense of slip on the Los Osos fault in PG&E's memo report of August 8th shows the importance of PG&E's developing a comprehensive tectonic model of the Irish Hills. The planned on-land seismic surveys of the Irish Hills appear to take advantage of the available roads for survey locations to develop cross-sections that should result in a fault model describing the location and orientation of the major faults beneath the hills and, ideally, the rate and sense of slip on each of the faults. The sense of slip and slip rate on the Los Osos fault can each have a significant impact on estimated seismic hazard and consequential risk at Diablo Canyon.

- ✓ The IPRP believes that a broader goal of the on-land seismic surveys should be for PG&E to develop a tectonic model of the Irish Hills that includes defining the

locations and slip rates on all faults beneath the hills that can be checked against rates of uplift and surface deformation.

IPRP Authority and Review Process

In 2006, AB 1632 (Blakeslee) was enacted requiring the California Energy Commission (CEC) to conduct a comprehensive study of the seismic vulnerability of Diablo Canyon and directed the CEC to perform subsequent updates in the IEPR as new data or new understanding of potential seismic hazards emerge. In 2008, the CEC published its AB 1632 Report, which recommended that PG&E complete several seismic studies including that PG&E should use three-dimensional geophysical reflection mapping and other advanced techniques to explore fault zones near Diablo Canyon. The California Public Utilities Commission in 2009 and 2010 directed PG&E to complete the advanced seismic studies recommended in the CEC's AB 1632 Report and have an Independent Peer Review Panel review these seismic studies (CPUC letter to PG&E on June 25, 2009 and CPUC Decision 10-08-003).

The IPRP expects that:

- PG&E will provide its study plans and draft completed study findings to the IPRP for review. These include studies summarized in CPUC Decision 10-08-003 including off-shore, on-shore, and ocean bottom studies, and seismic studies recommended in the AB 1632 Report.
- The IPRP, coordinated by the California Geological Survey (CGS), will review and provide comments on PG&E's study plans. The goal will be, if possible, to provide comments within 30 days of receipt.
- The IPRP, coordinated by the CGS, will review and provide comments on PG&E's draft completed study findings to the CPUC. The goal will be to provide comments as promptly as possible.
- PG&E will review and, if possible, within 30 days incorporate the IPRP's recommendations and comments in PG&E's revised study plans and revised completed study findings and prepare for the IPRP a "Response to Comments"for the IPRP to document scientifically why PG&E accepted or rejected the IPRP's comments.
- PG&E and the IPRP will participate in quarterly meetings/briefings to review the status of PG&E's seismic studies, any changes in the study plans, and any preliminary study findings.
- PG&E and the IPRP will prepare a master schedule incorporating the major milestones for the IPRP's review process and will include these milestones in

PG&E's monthly progress reports and schedule to the NRC and the Atomic Safety and Licensing Board.

- The CPUC and CEC will address any major scientific or technical issues that have not been resolved informally between the IPRP and PG&E. CPUC Decision 10-08-003 states that, "Should a dispute arise it should be resolved informally but if that is not attainable the Commission has authority to halt the associated rate recovery." In addition, the CEC may report on any seismic issues and updates through its IEPR process. However, we anticipate that any major scientific or technical issue that may arise can be addressed and resolved informally.

The quarterly briefings/meetings mentioned above will allow PG&E to report on its progress and help facilitate a productive informal exchange of scientific viewpoints. The IPRP would like to schedule another briefing in October.

IPRP membership:

California Geological Survey

California Coastal Commission

California Emergency Management Agency

California Energy Commission

California Seismic Safety Commission

California Public Utilities Commission