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PG&E Letter DIL-03-007

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555-0001

Docket No. 72-26
Diablo Canyon Independent Spent Fuel Storage Installation
Supplemental Slope Stability Design Mitigation Features Information to Additional NRC Questions for the Diablo Canyon Independent Spent Fuel Storage Installation Application (TAC No. L23399)

Dear Commissioners and Staff:

By letter dated December 21, 2001, the Pacific Gas and Electric Company (PG&E) submitted an application to the U. S. Nuclear Regulatory Commission (NRC) for a 10 CFR 72 site-specific license to build and operate an independent spent fuel storage installation (ISFSI) at the Diablo Canyon Power Plant site. The application included a Safety Analysis Report, Environmental Report, and other required documents in accordance with 10 CFR 72.

By letter dated August 29, 2002, the NRC staff requested additional information needed to continue their review of the Diablo Canyon ISFSI License Application. PG&E submitted its response to the NRC staff by letter dated October 15, 2002 (PG&E Letter DIL-02-009). By letter dated March 27, 2003, PG&E submitted a supplemental response to additional NRC questions on slope stability (PG&E Letter DIL-03-004)

Enclosure 1 contains supplemental information to address additional NRC questions on slope stability design mitigation measures identified in a telephone call on April 9, 2003. Enclosure 2 is a report on rockfall analysis performed for the ISFSI.

NMSS01

If you have any questions regarding this response, please contact Mr. Terence Grebel at (805) 545-4160.

Sincerely,

Lawrence F. Womack
Vice President Nuclear Services

pns/4998
Enclosures
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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

In the Matter of PACIFIC GAS AND ELECTRIC COMPANY Diablo Canyon Independent Spent Fuel Storage Installation	Docket No. 72-26

AFFIDAVIT

Lawrence F. Womack, of lawful age, first being duly sworn upon oath states that he is Vice President, Nuclear Services of Pacific Gas and Electric Company; that he is familiar with the content thereof; that he has executed this supplemental slope stability response to additional NRC questions regarding the Diablo Canyon Independent Spent Fuel Storage Installation license application on behalf of said company with full power and authority to do so; and that the facts stated therein are true and correct to the best of his knowledge, information, and belief.

Lawrence F. Womack
Vice President Nuclear Services

Subscribed and sworn to before me this 6th day of May 2003.

Notary Public
State of California
County of San Francisco

ELIZABETH J. DIAMOND
COMM. #1352219
NOTARY PUBLIC-CALIFORNIA
SAN FRANCISCO COUNTY
My Comm. Expires May 16, 2006

PG&E Supplemental Information to NRC Additional Slope Stability Questions For Diablo Canyon Independent Spent Fuel Storage Installation (ISFSI) License Application

The following is supplemental information to that previously submitted in Request for Additional Information 4 under PG&E Letter DIL-03-004 on the rockfall size and impact load design basis. Detailed rockfall analysis, Rockfall Analysis, (WLA, 2003) is included as Enclosure 2 for reference.

Mitigation Design Basis

PG&E performed extensive field investigation to document the geology at the ISFSI site (GEO.DCPP.01.21), performed dynamic analysis to estimate potential rock mass movements along clay beds on the hill slope above ISFSI pads (GEO.DCPP.01.24 through GEO.DCPP.01.26), performed kinematic stability analysis for cut slopes (GEO.DCPP.01.22), and pseudo-static wedge analysis of the cut slopes (GEO.DCPP.01.23) to characterize the potential to generate rockfalls on the hill slope and cut slope in the vicinity of the ISFSI pads. It should be noted that these calculations have been previously submitted to the NRC.

These investigations showed that while small loose rocks (less than 2-foot in maximum dimension) can be found on the existing hill slope that could start to roll down the hill during strong ground shaking, these smaller size rocks do not carry large impact energy and thus do not control the design of the rock barrier based on rockfall analysis for various block sizes summarized in Tables 2 and 3 of Enclosure 2. Larger blocks that would control the design of the rock barrier are typically embedded in the rock mass. They are usually formed by rock discontinuities such as joints sets, bedding planes, and clay beds. Due to the interlocking of the tight discontinuities, these larger blocks are unlikely to dislodge during strong ground shaking under present conditions. However, if significant cumulative displacements occur during the strong shaking that would push the rock masses out of the slope along any weak discontinuities, then the calved/raveled rock blocks in the overthrust lip conceivably could detach from the rock mass along pre-existing steeply-inclined joints that sole out and daylight in the overthrust zone, or that exist immediately behind the overthrust lip. This overthrust portion of the rock and the rock immediately behind the overthrust could be free to move out the slope to form a rockfall hazard. These larger block rocks would control the rock barrier design.

The size of the calved/raveled rock blocks from the overthrust toe region would be controlled by the length of the overthrust lip (between 1 and 3 ft) based on the seismic displacement estimates from calculation GEO.DCPP.01.26, Revision 4 (submitted by PG&E Letter DIL-03-004, dated March 27, 2003), and the joint spacing in the rock mass, which would control the dimensions of the back side of the overthrust block and its lateral extent (averages between 1 and 3 ft as described in the SAR Section 2.6.5.2.2). Based on the calculated ranges of displacements and rock mass joint spacing, the most likely maximum rock block sizes that could be dislodged from the clay bed overthrust regions are between 1 and 3 ft in their maximum dimension. For conservative design purposes, a larger block whose maximum dimension is controlled by twice the typical joint spacing or block with maximum dimension of 6 ft was used. PG&E has taken a defense-in-depth approach for the rock barrier design. As such, an even more conservative block size with maximum dimension of 10 ft was used to check the kinetic energy this oversize block could have at the fence line, even though the size of the hypothetical block cannot be supported by geological evidence or the conservative estimate of the maximum overthrust distance of 3 ft documented in SAR Section 2.6.5.1.3.5.

Because the claybeds near the exposed slope face above the ISFSI pads are near horizontal, and the dominant northwest-to northeast-trend joint sets are steeply dipping, the shape of the intact overthrust rock block would take the form of an elongated triangular/rectangular block as shown in Figure 6 of Enclosure 2. The base of the cross section has a most probable maximum expected dimension of 3 feet or a more conservative larger block with maximum dimension of 6 ft as stated above. We conservatively assumed that the blocks take the form of rectangular shape and thus carry more mass and in turn more kinetic impact energy than triangular blocks with the same dimensions. Based on an average slope angle of 21 degrees, the height of the block would be 3 feet times tangent (21°) or 1.2 feet. The third dimension, measuring normal to the analytical cross section (or along elevation contours), is controlled by the joint spacing. Using maximum spacing of 3 feet to represent the third dimension, the volume of a rectangular slab is about 10.4 ft^3 or equivalent to a sphere with diameter of 2.7 ft. Using a similar approach, if the base of elongated rectangular block is 6 feet for the conservative block size, the corresponding sphere would have a diameter of 4.3 ft. Likewise, the oversized hypothetical block with maximum dimension of 10 ft and a 5 ft joint width of similar shape would correspond to an equivalent sphere with a diameter of 7.2 ft.

It should be pointed out that if the joint spacing is between 1 to 3 feet, then it would be relatively unlikely to have a rock overthrust of 6 feet or 10 feet without breaking up into multiple 3 feet or less blocks. Therefore, the most likely maximum rockfall blocks would have a base dimension of about 3 feet, which would correspond to a sphere of 2.7 feet in diameter.

Two state-of-practice computer programs were used in the rockfall hazard analysis (Section 4 of Enclosure 2). The primary program, RocFall, models the rocks as spheres. Although the equivalent sphere diameters of the three aforementioned block sizes are 2.7 ft, 4.3 ft, and 7.2 ft, a conservative assumption was used in the RocFall to model the blocks as spheres with 3 foot, 6 foot and 10 foot diameters. In addition, analyses were also performed for 1-foot spheres to evaluate impact potentials from smaller blocks

The secondary program, CRSP, models the blocks as cylindrical blocks, and the three aforementioned sizes of blocks were model as 3-ft-diameter by 3-ft-long, 3-ft-diameter by 6-ft-long, and 5-ft-diameter by 10-ft-long cylindrical blocks, for the realistic 3-ft block, conservative 6-ft block, and the hypothetical 10-ft block, respectively.

Rockfall Analyses

A rockfall analysis for the hillslope above the ISFSI was performed. The potential hazard to the ISFSI from rockfall was evaluated using state-of-practice rockfall evaluation methods that include development of topographic cross sections along the rockfall paths, sensitivity analysis of key input parameters such as surface roughness and coefficient of restitution, evaluation of source rock characteristics, and iterative rockfall modeling using the Rocscience RocFall computer program which was selected as the preferred design analysis tool since its results agree closely with the Diablo Canyon slope field observations (Section 4.2 of Enclosure 2). It was validated by field testing and was developed in association with Dr. Hoek who is referenced in the Federal Highway Administration Standard FHWA SA-93-085 entitled "Rock Hazard Mitigation Methods". In addition, a secondary program, the Colorado Rockfall Simulation Program – CRSP was also used for a check of the RocFall program results. Although the RocFall analysis results were judged to be more applicable to the ISFSI site condition and the results are consistent with numerous seismic induced rockfall case history studies (Keefer, 1994), PG&E has taken a defense-in-depth approach, and decided that the more conservative results from either RocFall or CRSP will be used for design.

The computer programs allow the user to estimate the rockfall trajectory path, bounce height, velocity, and impact force at selected analysis points along the slope profile. This information is used to evaluate adequacy of the design for rockfall mitigation measures such as catchment benches or ditches, fences, or walls.

The inclination of the hillslope above the ISFSI pad and cutslope is relatively gentle, on the order of about 15 to 21°. Based on Keefer (1984), rockfalls and rockslides typically need to have a minimum slope about 40°, suggesting that the ISFSI hillslope is not particularly prone to rockfalls. No significant rockfalls have occurred on the hillslope since the borrow cut excavation was made in 1971 (SAR Section 2.6.1.12.2), further suggesting that the slope is not prone to rockfall and rockslide failures. In addition, the tower access road (shown in SAR Figure 2.6-1), above the ISFSI, forms benches in the slope profile that would serve to slow and arrest most rockfalls generated above the road.

Based on the site geologic investigations (GEO.DCPP.01.21), dolomite and sandstone rock blocks are moderately hard to hard, and relatively angular. Rockfall blocks therefore would be relatively hard and would tend to stay intact without significant breakage and disaggregation; however the angular shape of the blocks would tend to resist rolling. The slope surface between the potential clay bed slide mass rockfall source zones and the ISFSI pad is relatively rough, with a surface irregularity on the order of about 6 inches to 2 ft, and a thin cover of rock rubble. The surface irregularities serve to slow and arrest possible rockfalls, especially for angular blocks with relatively sharp corners and points. The surface irregularity has more influence on smaller blocks than larger blocks. For conservative design purposes, a surface irregularity of 6 inches was used in the analysis.

RocFall Analysis Results

Rockfall analyses, using the existing topographic cross sections, and the RocFall modeling program, show that rocks dislodged at the various clay bed slide mass toe regions tend to only roll a few tens of feet downhill before becoming arrested either on the slope, or on the tower access road benches above the ISFSI pad and cutslope as summarized in Table 1 (based on Table 2 of Enclosure 2). The modeled rock blocks roll over the ground surface without bounding, exhibit low translational and rotational velocities, and low impact forces. The results from the RocFall program indicates that rock blocks would not roll to the proposed rockfall fencing mitigation system. The results of the RocFall analysis agree with the field observation during excavation of the test trenches where rock with maximum dimension of 5 feet excavated from the trench were allowed to roll down the hillslope. The test block rolled for tens of yards and stopped at the mid-slope without continuously rolling down the slope. The RocFall analysis results also agree with the case history survey of seismic induced landslides by Keefer (1994). As discussed in PG&E Letter DIL-03-004, these analyses results suggest that the rockfall hazard to the ISFSI is very low, and should not require mitigation.

Table 1 - Summary of Rockfall Analysis Results

Block Description	Max Dimension of Rectangular Block (ft.)	Equivalent Sphere Dia. (ft.)	RocFall Analysis			CRSP Analysis		
			Sphere Dia. (ft.)	% of Blocks Reached Fence	Impact Kinetic Energy (ft.-tons)	Dimension (Dia x Length in ft.)	% of Blocks Reached Fence	90th Percentile Kinetic Energy (ft.-tons)
Realistic	3	2.7	3	0	0	3 x 3	100	28
Conservative	6	4.3	6	0	0	3 x 6	100	84
Hypothetical	10	7.2	10	0	0	5 x 10	0 to 37	294

CRSP Analysis Results

The most realistic geologic model for CRSP analysis relating to the maximum 3-foot sliding overthrust in the rock mass that exhibits a 3-foot joint spacing is represented by cylindrical blocks with 3-foot-diameter and 3 feet in length. CRSP analysis shows that 100% of the 1,000 randomly generated blocks of this size would reach the fence. The 75th and 90th percentile impact kinetic energy for these blocks ranges between 10 ft-tons to 25 ft-tons and 11 ft-tons to 28 ft-tons, respectively. Detailed analysis results can be found in Table 3 of Enclosure 2.

The impact kinetic energy in the rockfall analysis is correlated with the mass of the moving rock. A conservative design for the ISFSI rock barrier can be achieved by assuming a conservative, maximum rock size that conceivably could be released from the overthrust lip. For the ISFSI project, a conservative estimate of the upper bound block size was established by assuming the overthrust lip breaks off along joints in the rock mass that are twice the joint spacing. The resulting block was represented in the CRSP analysis as a cylindrical block with a 3-foot-diameter and 6 foot length. The CRSP analysis of these 6-foot-long cylindrical blocks shows that 99% to 100% of the blocks would reach the fence with the 75th percentile and 90th percentile impact kinetic energy ranging between 30 ft-tons to 81 ft-tons and 32 ft-tons to 84 ft-tons, respectively. The conservative estimate of the block size increased the mass of the sliding block by a factor of 2 and at the same time increased the impact kinetic energy by a factor of 3 to 4 as shown in Table 3 of Enclosure 2. Of the four analyses involving 2 cross sections each with two rockfall initiation points, the maximum 90th percentile impact energy for the 6-foot long block would be 84 ft-tons initiating from model 2b from Elevation 417 on Section I-I' as shown in Table 3 of Enclosure 2. The same 6-foot blocks rolling from other elevations or along other sections would be lower (35 ft-tons, 32 ft-tons, and 62 ft-tons) as can be seen from the same Table. Based on the conservatism built in the overthrust length calculation documented in GEO.DCPP.01.26, Revision 4, that requires detachment along joints at double the typical joint spacing distance to form the 6-foot block, the 84 ft-tons would be a conservative upper bound impact energy suitable for design at the ISFSI site, especially considering the RocFall analysis showed no rock blocks would reach the proposed fence location.

As part of a defense-in-depth approach taken for the rockfall barrier design, an extreme block size that is not supported by the geological evidence in terms of joint spacing, overthrust lip geometry, and past field performance was used in the CRSP analysis to evaluate the impact of this hypothetical rock block on the computed kinetic energy. The check analysis was performed using cylindrical blocks that measure 5 feet in diameter and 10 feet in length.

In sharp contrast to the analyses of 3-ft-diameter 3-ft long and 6-ft-long blocks that showed nearly 100% of the blocks reached the fence, three of the four analysis cases using the hypothetical large 5-ft-diameter and 10-ft long blocks showed less than 5% of the blocks would reach the fence. The only analytical case that showed more than 5% reaching the fence was obtained for Section A-A' with an initial rock seed point located at El 411. In this analysis, 37% of the 1,000 randomly generated 10-foot long blocks reached the fence with 90th percentile of the impact energy of 294 ft-tons. This energy is close to 11 times the energy delivered by the more realistic block of 3-ft-diameter and 3-ft-long block and about 4 times the kinetic energy delivered by the conservative block of 3-ft-diameter and 6-ft-long block.

In the three remaining analytical cases for the oversized hypothetical block, less than

5% of the 1,000 randomly generated rocks reached the fence. Section I-I with rock with a rockfall seed point at El. 369, resulted in 5% of the simulated rocks reaching the fence with the 90th percentile kinetic energy of 172 ft-ton. This impact kinetic energy is less then the 294 ft-ton discussed above and thus it does not impact the design. The next analytical case involved analysis of Section I-I with rock initiating from El. 417. In this analytical case, only 0.6% of the 1,000 randomly generated rocks reached the fence with 90th percentile kinetic energy of 437 ft-tons. Due to the limited number of blocks reaching the fence (6 out of 1000), the statistics analysis on 6 samples could potentially be strongly influenced by one or two sample results. In view of the very small percentage (0.6%) of hypothetical block sizes that have low likelihood of occurring in the field and that could reach the fence, it is concluded that the results from this analytical case should not govern the design. If the statistical sample was enlarged to include all oversize hypothetical rock blocks that would reach the fence from all four analysis cases, then the results would be expected to be dominated by the statistics of the 370 blocks and could potentially be even be lower because of the inclusion of 50 or so blocks with their corresponding 90th percentile kinetic energy of 172 ft-tons. The last case for the hypothetical 10-foot long cylindrical blocks analysis involves Section A-A with rocks initiating from El. 383. The results show none of the 10-foot cylindrical blocks would reach the fence in this analytical case.

Based on the CRSP analysis, the following conclusions are reached:

1. For a realistic block size that can be reasonably expected at the ISFSI site, it was modeled as 3-ft-diameter and 3-ft-long cylindrical block in CRSP. The analysis showed that nearly 100% of the 1,000 randomly generated blocks would reach the fence with the 90th percentile kinetic energy delivered at the fence of 28 ft-tons.

2. For a more conservative block size modeled as 3-ft-diameter and 6-ft-long cylindrical block in CRSP, the analysis showed that nearly 100% of the 1,000 randomly generated blocks would also reach the fence with the 90th percentile kinetic energy delivered at the fence of 84 ft-tons.

3. To adopt a defense-in-depth approach for the rock barrier design, a hypothetical oversize block was modeled in CRSP as a 5-ft-diameter and 10-ft long cylindrical block. The analysis showed that the percent of blocks reaching the fence is significantly reduced with this increase in block size. In three of the four analysis cases, the analysis shows less than 5% of the blocks would reach the fence. Although the trend of reducing percentage of blocks reaching the fence for this size block is consistent and important, performing statistical analysis on the kinetic energy for the individual analysis case which has very few blocks reaching the fence could be misleading. The fourth analytical case using the large hypothetical block showed 37% of the 1,000 randomly generated blocks would reach the fence. Statistic analysis for the 370 or so blocks would be meaningful and the 90th percentile kinetic energy delivered at the fence is 294 ft-tons.

Accordingly, the kinetic energy of 294 ft-tons was selected for the rock fence design using a hypothetic 5-ft diameter by 10-ft-long cylindrical block with volume of 196 ft^3 that has mass close to 10 times the mass of the more realistic model of 3-ft-diameter by 3-ft-long cylindrical block (with volume of 21 ft^3), or close to 20 times the mass of a 3-ft elongated rectangular block (with volume 10 ft^3) that PG&E considers the most probable block size that can be reasonably expected at the site.

A defense-in-depth design approach was adopted and an ISFSI slope hazard mitigation system will be designed that incorporates several protection elements. The rockfall fencing impact design criteria was developed using the CRSP program, which gives very conservative results based on the Diablo Canyon slope field observations. Design criteria of 295 ft-tons will be used for the maximum impact loading which envelopes both the RocFall and CRSP analyses results.

Mitigation Features

The following elements comprise the rockfall mitigation system for the ISFSI.

- The existing 10- to 12-ft wide tower access road provides a very effective catchment bench for possible rockfall released above the road. The road bench will be maintained and periodically cleared to maintain its effectiveness as a rockfall catchment bench.

- A 2- to 6 ft-wide, 1-ft deep drainage ditch will be constructed at the top of the cutslope. This ditch would help catch small rockfall blocks generated on the slope above the cutslope.

- A rockfall barrier fence will be constructed at the top of the ISFSI cut that will be designed to absorb and dissipate the energy from possible rockfall generated on the slope above. The design criteria and supporting bases for the rockfall barrier fence are described above.

- The cutslope includes a 25-ft wide mid-slope horizontal bench. The significant width of the bench should effectively catch any rocks released from the upper part of the cutslope (above the bench), and also provides a wide buffer zone to accommodate the calculated 1- to 2-ft of displacement for the slide mass models No. 3b (SAR Figure 2.6-49) that toes-out in the vicinity of the bench location.

- The ISFSI pad is setback from the toe of the cutslope a distance of 41 ft. This setback provides a significant buffer zone to catch any possible rockfall from the lower part of the cutslope, and provides a substantial separation between the pad and zone of possible deformation at the toe-of-slope daylight of slide mass model No. 3a and 3c (SAR Figure 2.6-49).

The rockfall barrier fence to be constructed at the top of the ISFSI cutslope will be a commercially available, rockfall fence system specifically designed for the possible site loading conditions. An example rockfall fence system under consideration is the Geobrugg rockfall fence system that has been installed at numerous locations throughout the United States, and locally along Highway 1 by Caltrans (See Enclosure 2, Attachments E and F). PG&E's rockfall analysis suggests that the Geobrugg Very High Impact fence (design load of 295 ft-tons) would be suitable for the ISFSI installation. Therefore, a fence height on the order of about 8 ft should provide a substantial margin of safety against all possible rockfall block sizes and forces.

A copy of the rockfall analyses, Rockfall Analysis, is provided as Enclosure 2.