United States Department of the Interior

GEOLOGICAL SURVEY
RESTON, VIRGINIA 22092

January 12, 1976

1-12-76

Mr. William P. Gammill
Chief, Site Analysis Branch
Division of Technical Review
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Bill:

Enclosed is a revised draft review of the Amendments 31, 32 and 34 of the FSAR for the Pacific Gas and Electric Company's Diablo Canyon site, Units 1 and 2, San Luis Obispo County, California, Docket Nos. 50-275 and 50-323. This review was prepared by Frank A. McKeown, who reviewed the geology, and James F. Devine, who reviewed the seismology. Mr. McKeown was assisted by Holly Wagner, David McCulloch, and Robert Yerkes; Mr. Devine was assisted by Robert Page and Wayne Thatcher.

Sincerely yours,

Fred N. Houser
Deputy Chief
Office of Environmental Geology

Enclosure

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Draft Review
F. A. McK[illegible]n (Geology)
J. F. Dev[illegible] (Seismology)
Diablo Canyon
FSAR Amendments 31, 32 and 34
January 12, 1976

PACIFIC GAS AND ELECTRIC COMPANY
DIABLO C[illegible] SITE, UNITS 1 AND 2
SAN LUIS OBISPO COUNTY, CALIFORNIA
AEC DOCKET NOS. 50-275 AND 50-323

Geology and Seismology

This is a review of the geological and seismological information contained in Amendments 31, 32, and 34 of the Final Safety Analysis Report (FSAR) for the Diablo Canyon nuclear power plant site. Amendment 37, containing important discussion of the g[illegible]nd response pertinent to seismicity, was received in early November and too late to be considered in this review. The amendments were prepared by the Pacific Gas and Electric Company (PG&E) in response to a request in a letter dated February 12, 1975, from the Nuclear Regulatory Commission (NRC) for certain additional information relevant to design basis earthquake issues, which have been the principal problems requiring additional earth sciences information and analyses. To support assertions in the FSAR through Amendments 11, 19 and 20, five requests for information (referred to as questions in the Amendments) were made.

2.17. Provide additional discussion and arguments for determining the maximum earthquake that can be expected on faults of various ranks within the San Andreas system. Relate the discussion to historic seismicity.

2.18. Provide additional documentation, including seismic reflection profiles, on the intersection of the Hosgri fault zone with the Transverse Range faults. Include geologic maps southward of those provided in the FSAR showing the structural relationships of the Transverse faults and structures having a northwest trend.

2.19. Provide additional documentation, including seismic profiles, on the northern reaches of the Hosgri fault zone. Include a fuller development of your views on the structural relationship of the Hosgri fault to the San Simeon fault.

2.20. Provide additional information on the location of the 1927 event, together with its probable mechanism. Discuss probable relationships of this event to the geologic structure in the region.

2.21. Provide your evaluation of the maximum credible earthquake on the Hosgri fault zone. Assuming this event occurs along the segment of the Hosgri fault zone nearest the site, evaluate its response spectrum at the site and compare it with the design response spectrum.

The response in the FSAR to the questions has provided considerable additional geologic and seismologic information and analyses. However, unambiguous answers to the questions have not been achieved. Many uncertainties in the data and interpretations still exist. Among the most important of these are: 1) the location and mechanism of the 1927 earthquake, 2) the exact relation of the Hosgri fault zone to faults in the Transverse Range system and the San Simeon fault, 3) the continuity of some faults, 4) the relative amounts of dip-slip and strike-slip movement on the Hosgri fault zone, 5) the sense of displacement on parts of the Hosgri zone, 6) identification and correlation of acoustical units, and 7) kinematic relations among different fault zones.

In addition to these uncertainties, some information shown on the profiles is not shown on the maps and vice versa, and some profile data are not included that are important to evaluate the extension or character of some faults. Because geologic maps developed from seismic

reflection profiles are based upon much interpretation that may differ among several interpreters, it was necessary for the purposes of our review to make independent interpretations of the seismic profiles. These independent interpretations are somewhat different than the interpretations presented in Amendments 31 and 32. The major differences are briefly described in appropriate sections of this review.

Although some changes in, and additions to, geologic and seismologic details have been made in Amendments 31, 32, and 34 compared with previous data in the FSAR, no major changes can be made in our conclusions that were stated in the review of the FSAR, and Amendments 11, 19, and 20, which was transmitted to the NRC from the Director of the United States Geological Survey by letter of January 28, 1975. The pertinent statement in our previous conclusions was as follows: "Earthquakes along the EBZ[1] presumably would not be as large as expected on the San Andreas fault, however, from the information presently at hand we can find no evidence that would preclude the occurrence of an earthquake as large as events characteristic of subparallel strike slip faults, which bound basins, such as the Santa Maria, in the San Andreas system and which do not transect structural provinces." The size of an earthquake on faults that bound basins was not specified in this conclusion. For reasons stated in subsequent

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[1] As defined in the FSAR, EBZ refers to the East Boundary fault zone, which is the Hosgri fault zone.

parts of this review, however, the magnitude of the design basis earthquake for the Diablo Canyon nuclear reactor site should be in the range of 7.0 to 7.5 and located on the Hosgri fault zone. This is based principally on the fact that the November 4, 1927, earthquake had a magnitude of 7.3 and that the best estimates of its location indicate that it could have occurred on the Hosgri fault.

Selected comments important to an evaluation of Amendments 31, 32, and 34 are outlined below.

Amendment 31

NRC Question 2.18

On figures 8 and 9 relative displacement on the Hosgri fault between Point Buchon and Point Sal is shown to be down on the east. On figure 10 relative displacement on the southern extension of the Hosgri fault south of Point Sal is down on the west, which is compatible with the argument that the Hosgri fault is the east boundary of a portion of the Santa Maria Basin. Changes in direction of relative movement, however, are very suggestive of lateral displacement, which may have occurrred after development of the basin and bounding faults.

On page 9, reference is made to fig. 11 as evidence that no scarp-forming seismic events have occurred on the southernmost part of the Hosgri fault since prior to the Wisconsinan stage of the Pleistocene. It is true that no offset of the ocean floor is evident on fig. 11. However, close inspection of fig. 11 shows offset of the post-Wisconsinan unconformity when sighting along it or placing a

straightedge along the mapped trace. Also, faulting of the post-Wisconsinan sediments cannot be precluded because a change in acoutical signature is evident across an upward projection of the fault shown in figure 11. The change in the acoustical signature of unit A2 across the fault is quite clear and may be evidence of lateral movement on the fault.

It is not clear from the profiles in figures 13a and 13b that the disturbed zones in them that are inferred to represent the West Hosgri fault are the same. At least three additional faults can be interpreted in the profile of figure 13b. Also a disturbed zone appears to be between stations 133 and 136 in the profile of line 13a. Kelez, Bartlett, and Polaris survey lines criss-cross this area and additional evidence from them to support or negate the suggested correlation of disturbed zones should be described.

An independent interpretation of the seismic profiles in the offshore area from about Point Sal to about five miles south of Point Arguello indicates that the Hosgri fault extends at least five miles south of Point Arguello and does not turn eastward as suggested in Amendment 31.

Although the Lompoc fault zone appears to have offset the sea floor, and may therefore be considered capable of movement again, its length of only about eight miles as inferred by the applicant appears to be incompatible with a magnitude 7.3 earthquake. An independent interpretation of the seismic profiles in the area of the Lompoc fault differs from that of the applicant in that it shows that the Lompoc

fault zone is about twenty miles long; the longest single fault in the zone is about fifteen miles in length. Furthermore, the displacement is interpreted to be dip slip or possibly oblique slip, rather than reverse slip as suggested by the applicant.

NRC Question 2.19

As noted in the previous section the sense of displacement on the southern part of the Hosgri fault is up on the west side, figure 1 (N), and therefore is not compatible with its being primarily related to basin development. However, an alternative interpretation suggests the displacement on the Hosgri fault in figure 1 to be down on the west.

Figure 1 (N) has three buried faults not shown on Plate I. This leads to questions concerning the interpretation of some of the data in the report.

Another instance of faults shown in profile but not on a map is seen from comparison of fig. 4 (N) and Plate I. The correlation of faults between Lines 16 and 12 (figs. 3 (N) and 4 (N)) is questionable. A profile along Line 14 would help. Also, an interpretation of Line 10 should be included.

Although the straight coast line between Cambria and Point Estero suggests that the extension of the San Simeon fault is just offshore, data are lacking to prove this. None of the data presented in Amendment 31 preclude the San Simeon fault from intersecting the Hosgri fault offshore between Cambria and Point Estero. The two faults even as shown on Plate II (N) are less than 2.5 miles apart

and could very well be tectonically coupled to each other by an en echelon or anastomosing series of faults which is characteristic of faults in the coast ranges. Such coupling of the Hosgri and San Simeon faults is supported by interpretation of stratigraphic sections recently reported by Hall (1975). He infers that "---the San Simeon and Hosgri faults are part of the same system,---" and that 80 km or more of right slip has occurred along the system during the last 5 to 13 million years.

Figs. 7a (N) and 7b (N) are very puzzling. They show an inflection in the seafloor over the Hosgri fault, and a drastic change in the thickness and acoustical signature of unit A2, assuming A2' is correlative with A2. In addition to vertical displacement, lateral displacement, which is not mentioned, could be interpreted from these profiles. However, the basis for separating A2' from A3 is not apparent. Similarly it is not apparent why unit A', east of the fault, is terminated. It appears to continue to the east edge of these profiles.

On figure 11a (N) the A2 unit east of the fault at station 119 is correlated with the Monterey formation (p. 8, NRC Question 2.19, amend. 31), but the signature of the A2 unit west of this fault is completely different. This inferred lithologic change, as elsewhere, suggests lateral displacement.

NRC Question 2.20

On page 10 it is reasoned that both the Hosgri and West Hosgri faults can be eliminated as sources of the 1927 earthquake because neither the sea floor nor the post-Wisconsinan unconformity are offset in the epicentral area of the earthquake. This reasoning is not satisfactory because typically surface rupturing of a fault is discontinuous, and offset may not be detected if the displacement had a large lateral component. Furthermore, as stated on page 4 of this review, the base of post-Wisconsinan sediments is offset, and a fault in the sediments cannot be precluded in figure 11. The evidence, therefore, to eliminate the Hosgri fault as the source of the 1927 earthquake is inadequate. As previously stated, the length of the Lompoc fault shown by the applicant appears to be incompatible with the magnitude of the 1927 earthquake.

Figure 1 shows that segments of the Hosgri fault zone, the Lompoc fault, Purisima fault, and Lion's Head fault occur within the error circle of Gawthrop and error ellipse of Engdahl for the 1927 earthquake. However, all of the faults are outside of the area designated by Smith as the "inferred distribution of aftershock sequence of the 1927 earthquake." The 1927 earthquake, therefore, cannot be unequivocally located on any one of these faults. The Hosgri fault, however, is closer to the center of the estimate of error than the other faults and, therefore, must be considered as a possible fault on which to locate the earthquake.

Amendment 32

NRC Question 2.17

Although this section contains descriptions and explanations of

the "kinematics of structural behavior in the south-central California region---" contemporary seismic activity is not fully explained. Also, we do not agree with some statements given as fact. For example, on page 2 it is stated as fact that the 1927 M.7.3 earthquake occurred on the Lompoc fault. This is not fact but a highly controversial assumption. Item 2 on page 2 of this amendment indicates that the Lompoc and San Andreas are the only faults in the southern Coast Ranges that "reflect substantial late Quaternary surface deformation." As defined on page 3 of this amendment, "substantial" clearly includes the San Simeon fault, which as stated on page 7 of this review may be coupled with the Hosgri fault. The attempt to explain the large magnitude by using the logic that the Lompoc fault is in a transition zone between the Coast Ranges and Western Transverse Ranges applies to other faults in the zone including the southern part of the Hosgri fault.

Amendment 34

NRC Question 2.21

The masimum credible earthquake of 6 1/4 - 6 1/2 on the Hosgri fault zone used in this section to derive peak site ground acceleration is unacceptable because as stated previously the 1927 earthquake with a magnitude of 7.3 cannot be precluded from having occurred on the Hosgri fault. Although we believe that the 1927 earthquake should be used to estimate the safe shutdown earthquake, fault length-magnitude relationships have also been considered. The uncertainties in these

relationships and the assumptions involved to use them are well known. Nevertheless we may consider that the Hosgri fault is about 90 miles (144 km) long, or even greater if it is coextensive with the San Simeon fault. The part of this total length that may rupture during an earthquake is highly conjectural, but we assume that one third of the fault will rupture, which is about 48 km. This assumed length is supported somewhat if the range in S-P times for the aftershocks of the 1927 earthquake are considered. The range in times calculates to about 45 km as shown by Engdahl (1975). The fault length-magnitude curve for strike-slip faults (Bonilla and Buchanan, 1970, fig. 3) shows magnitude 7 for a 45 km rupture. In our judgment it is prudent to consider this as a possible minimum magnitude exclusive of the consideration of the 1927 earthquake.

Conclusions

Although the FSAR includes a considerable amount of new information and analysis, the only change that can be made in the original conclusions transmitted to the NRC on January 28, 1975, is to be more specific in our estimate of the design basis earthquake. This is based upon the following facts and judgments.

1. The Hosgri fault zone is more than 90 miles long and may even tectonically coupled to the San Simeon fault as they are within 2.5 miles of each other and both form parts of the eastern boundary of the Santa Maria basin.

2. Marked changes in thickness and signature of acoustical units across the Hosgri fault zone in several profiles indicates evidence of lateral slip. This was noted in our review of January 28, 1975, but such changes are even more abundant in the profiles of Amendment 31. Right lateral movement is reported for the San Simeon fault. These data suggest that displacements on the Hosgri fault are related to the highly active San Andreas plate-boundary system.

3. The length of the Lompoc fault appears incompatible with the magnitude of the 1927 earthquake.

4. The Hosgri fault is closer to the center of the estimates of error of both Engdahl and Gawthrop than any other fault. It is therefore a possible source of the 1927 earthquake.

5. Equivocal evidence related to vertical displacement on the Hosgri fault in the epicentral area of the 1927 earthquake does not eliminate it as a source. Surface rupture is generally discontinuous, and if lateral slip occurred, it probably would not be detected. Offset of the base of post-Wisconsinan sediments and probable faulting of them is evidence of post-Pleistocene movement.

For the above reasons and discussions given in the review, we conclude that the 1927 earthquake could have occurred on the Hosgri fault and that a similar earthquake with a magnitude in the range of 7.0 - 7.5 could occur in the future anywhere along the Hosgri fault.

6. We repeat our opinion that, for sites within 10 km of the surface expression of a fault, the description of maximum earthquake ground motion or design motion by means of a single acceleration value and a standard response spectrum may not be an appropriate representation for design purposes.

Consequently, we feel that it is appropriate that we describe the Safe Shutdown earthquake for this site in terms of near-fault horizontal ground motion. The technique for such a description is presented in the Geological Survey Circular 672 entitled "Ground Motion Values for Use in the Seismic Design of the Trans-Alaska Pipeline System" (Ref. 4). It is our intention that the ground motion values as shown in Table 2 "Near-fault horizontal ground motion" of Ref. (4) for magnitude 7.0 and 7.5 be used as a description of the earthquake postulated to have the potential for occurring on the Hosgri fault at a point nearest to the Diablo Canyon site.

The conditions placed on these values as described in Ref. (4) p. 3-13 also apply in this case, e.g. "They characterize free-field ground motion,..." The design values of motion should be derived by modifying the ground motion values to implicitely allow for non-linear energy absorbing mechanisms in the vibratory response of the structure and their application to appropriate response spectra as specified in Ref. (4) p.p. 2 and 3 and appendix B.

It is intended, also, that this potential earthquake be considered in addition to all earthquakes considered previously by the applicant during the construction permit review process.

References Cited

Bonilla, M. G., and J. M. Buchanan (1970), Interim report on worldwide historic surface faulting: U. S. Geol. Survey, open file report no. 1611.

Engdahl, E. R. (1975), Teleseismic location of the 1927 Lompoc earthquake: TERA Technical Report, Berkeley, Calif.

Hall, C. A. (1975), San Simeon-Hosgri fault system, coastal California: Economic and environmental implications: Science, 190, p. 1291-12[illegible].

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