September 24, 2002

Mr. Harold B. Ray
Executive Vice President
Southern California Edison Company
San Onofre Nuclear Generating Station
P.O. Box 128
San Clemente, CA 92674-0128

SUBJECT: SAN ONOFRE NUCLEAR GENERATING STATION, UNITS 2 AND 3 - SEISMIC DESIGN BASIS ASSESSMENT (TAC NOS. MB2466 AND MB2467)

Dear Mr. Ray:

By letter dated August 2, 2001, the U.S. Nuclear Regulatory Commission (NRC) requested Southern California Edison (SCE) Company to discuss comments by Dr. Legg, concerning the seismic characteristics at the San Onofre Generating Station (SONGS) site. Of particular interest to the staff was Dr. Legg’s remarks stating that the major Oceanside detachment/thrust system underlies SONGS and that earthquakes could occur that may generate effects in excess of the level assumed in the design basis for the plant. Dr. Legg’s comments were provided in a petition filed by Ms. Patricia Borchmann on April 17, 2001. SCE responded to this request by letters dated September 21 and December 27, 2001.

The NRC staff has reviewed the licensee’s assessment of this seismic hazard increase contention. SCE conducted an extensive study using seismic source characterization, global positioning system (GPS) data, and probabilistic seismic hazard analysis. The purpose of the study was to determine whether the postulated blind thrust faults would have a significant effect on the seismic risk of SONGS. The SCE study was performed using the seismic hazard data from the seismic risk analysis for the SONGS Individual Plant Examination of External Events, completed in 1995, and the most recent seismic and GPS data in the vicinity of SONGS.

Using the new seismic hazard results, the SONGS core damage frequency increases from 4.27E-5/year to 4.57E-5/year and the large, early release frequency increases from 1.60E-6/year to 1.78E-6/yr. Since these increases are so small, SCE concludes that there are no seismic vulnerabilities at SONGS and that the postulated blind thrust faults do not appreciably change the seismic risk of SONGS.

The NRC staff reviewed the SONGS seismic hazard study and concludes that SCE has accurately modeled the potential hazards from the postulated blind thrust faults. The staff concludes that the design of the SONGS units, which is based on an assumed magnitude 7 earthquake occurring on the fault zone at a distance of 8 kilometers from the site, is adequate. This design event is larger than any earthquake known to have occurred on the fault zone. The NRC staff agrees that the evidence for larger earthquakes occurring on blind thrust faults in the vicinity of SONGS is highly inconclusive.

With the issuance of the enclosed Safety Evaluation (SE), the NRC staff considers the effort relating to TAC Nos. MB2466 and MB2467 complete. If you have any questions regarding this SE, please call Alan Wang at (301) 415-1445 or Bo Pham at (301) 415-8450.

Sincerely,

/RA/

Alan B. Wang, Project Manager, Section 2
Project Directorate IV
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Docket Nos. 50-361 and 50-362

Enclosure: Safety Evaluation

cc w/encl: See next page

With the issuance of the enclosed Safety Evaluation (SE), the NRC staff considers the effort relating to TAC Nos. MB2466 and MB2467 complete. If you have any questions regarding this SE, please call Alan Wang at (301) 415-1445 or Bo Pham at (301) 415-8450.

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Alan B. Wang, Project Manager, Section 2
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Office of Nuclear Reactor Regulation

Docket Nos. 50-361 and 50-362

Enclosure: Safety Evaluation

cc w/encl: See next page

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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

ASSESSMENT OF SAN ONOFRE NUCLEAR GENERATING STATION, UNITS 2 & 3

SEISMIC HAZARD STUDY OF POSTULATED BLIND THRUST FAULTS

SOUTHERN CALIFORNIA EDISON COMPANY

SAN DIEGO GAS AND ELECTRIC COMPANY

THE CITY OF RIVERSIDE, CALIFORNIA

THE CITY OF ANAHEIM, CALIFORNIA

SAN ONOFRE NUCLEAR GENERATING STATION, UNITS 2 AND 3

DOCKET NOS. 50-361 AND 50-362

1.0 INTRODUCTION

In response to concerns of increased seismic hazard in the area surrounding San Onofre Nuclear Generating Station (SONGS), Units 2 and 3 from postulated blind thrust faults in the vicinity of the site, Southern California Edison (SCE) has conducted an extensive study using seismic source characterization, global positioning system (GPS) data, and probabilistic seismic hazard analysis (PSHA). The purpose of the study was to determine whether the postulated blind thrust faults would have a significant effect on the seismic risk of SONGS. The SCE study was performed using the seismic hazard data from the seismic risk analysis for the SONGS Individual Plant Examination of External Events (IPEEE), completed in 1995, and the most recent seismic and GPS data in the vicinity of SONGS.

Since the SONGS IPEEE did not completely model both of the recently postulated blind thrust faults, two alternative source models were added to the original source model, used for the SONGS IPEEE. Each of these three source models were given a weight by SCE based primarily on seismic source characterization and GPS data. The resulting PSHA response spectrum, which incorporates the original and two new source models, is slightly higher than the 1995 SONGS IPEEE response spectrum in the low frequency range (below 1.5 Hz). SCE states that this slight increase in spectral acceleration in the low frequency range would only have a slight effect on the structural responses of the SONGS IPEEE buildings because these structures have natural frequencies of about 1.5 Hz and higher.

Using the new seismic hazard results, the SONGS core damage frequency (CDF) increases from 4.27E-5/year to 4.57E-5/year and the large early release frequency (LERF) increases from 1.60E-6/year to 1.78E-6/yr. Since these increases are so small, SCE concludes that there are no seismic vulnerabilities at SONGS and that the postulated blind thrust faults do not appreciably change the seismic risk of SONGS.

2.0 STAFF REVIEW

The SCE seismic hazard study uses (1) seismic source characterization, (2) GPS data evaluation, (3) seismic hazard analysis, and (4) seismic probabilistic risk analysis to determine whether the postulated blind thrust faults would have a significant effect on the seismic risk of SONGS. The NRC staff reviewed the information provided by SCE in each of these four sections to determine whether the seismic hazards from the postulated blind thrust faults in the vicinity of SONGS and the resulting seismic risk to the SONGS structures have been accurately characterized.

2.1 Seismic Source Characterization

Recent studies have shown that portions of the Miocene (24 to 5.3 million years before present) detachment fault systems in the inner California borderland have been reactivated as blind thrust faults in the current tectonic regime. Detachment faults are low-angle normal faults that form as a result of an extensional tectonic regime. The current tectonic regime in Southern California is transpressional, which means that the dominant right-lateral strike-slip motion between the Pacific and North American plates also has a component of compression. This component of compression has reactivated portions of the detachment fault systems as thrust faults. The extent to which the detachment fault systems have been reactivated as blind thrust faults is uncertain. A recent study [Rivero et al., 2000] has concluded that entire detachment systems have been reactivated as blind thrust faults, which implies that there is the potential for very large earthquakes (M 7.2 to 7.6) on these thrust faults.

The dominant relative motion between the Pacific and North American plates is right-lateral strike-slip centered along the San Andreas fault system and faults in the borderlands of southern and Baja California. The 1995 SONGS IPEEE characterized four major subparallel, northwest-trending, right-lateral strike-slip fault zones that occur in the offshore region of southern California and northern Baja California, Mexico. These four fault zones are:

- Newport-Inglewood/South Coast Offshore Zone of Deformation (SCOZD)/Rose Canyon (NI-SCOZD-RC)
- Palos Verdes-Coronado Bank-Agua Blanca
- San Diego Trough
- San Clemente-San Isidro

Since SCE did not fully consider the potential for earthquakes occurring on blind thrust faults near SONGS in its 1995 IPEEE, they have added two models to the original model. The postulated blind thrust faults that may pose a seismic risk for SONGS are (1) the San Joaquin Hills blind fault (SJBF) and (2) the Oceanside thrust fault.

The SJBF is 15 km, northwest along the coast, from SONGS. Rates of uplift of the San Joaquin Hills are 0.21 to 0.27 mm/yr, which suggests that the San Joaquin Hills anticline is actively growing. However, the uplift data and geomorphic analysis are not able to constrain the geometry of the SJBF. SCE models rupture lengths of 25 and 37 (km) units, on same line for the SJBF and determines fault slip rates based on the local uplift of the San Joaquin Hills minus the uniform coastal uplift of 0.1 to 0.17 mm/yr from Dana Point to San Diego.

The Oceanside detachment has been identified through interpretation of offshore seismic data; however, the geometry and location of the Oceanside detachment is not well known. Recent mapping by Rivero et al. (2000) extends the Oceanside detachment south from Laguna Beach to the United States and Mexico international border. The onshore eastward extent and dip of the Oceanside detachment beneath the coastline in the vicinity of SONGS has not been established since the detachment is not visible as a coherent reflector in the seismic data east of the outer shelf edge. In addition, the intersection of the Oceanside detachment and the offshore strike-slip NI-SCOZD-RC fault system is not seen in the seismic data. Reactivation of portions of the Oceanside detachment as thrust faults has been observed between San Mateo Point and Oceanside. On the other hand, Rivero et al. (2000) postulate that major portions of the Oceanside detachment have been reactivated as a thrust fault and that the fault extends onshore beneath SONGS. SCE uses two of the Rivero et al. (2000) models of the Oceanside thrust fault in its update of the 1995 IPEEE results.

The NRC staff finds that SCE has adequately considered the postulated blind thrust faults in its seismic source characterization. Both the San Joaquin Hills blind fault and the Oceanside detachment have been incorporated into the earlier 1995 IPEEE to develop a new IPEEE result. SCE has used two of the models postulated by Rivero et al. (2000) for the Oceanside detachment, which assumes that the entire detachment fault has been reactivated as a blind thrust fault. These two models also assume that the Oceanside thrust fault extends onshore beneath SONGS and extends through the major offshore NI-SCOZD-RC fault system.

2.2 <u>GPS Data Evaluation</u>

SCE used recorded tectonic ground displacement rates from GPS stations in southern California to determine whether the model postulated by Rivero et al. (2000) for the Oceanside detachment is feasible. In order for the entire Oceanside detachment to be reactivated as a blind thrust fault, there needs to be at least a measurable amount of tectonic ground displacement perpendicular to the dominant N41°W right-lateral shear motion between the Pacific and North America plates. SCE examined the displacement rates at selected GPS stations in southern California in order to determine if there is a sufficient loading or driving force for the postulated Oceanside blind thrust fault. The results of the SCE study show that:

- There may be some compressive strain occurring between some coastal areas near the SONGS site and Catalina Island. However, the reported error ellipses associated with these sites are large enough that the compressive component may well be within the uncertainties, and, in any case, the small compressive strain that may be occurring between the coastal area and Catalina Island is considered inadequate to load or drive the postulated Oceanside blind thrust (OBT).

- In the region of the SONGS site, the absence of significant GPS relative displacement rates in the direction perpendicular to the major strike-slip faults (NI-SCOZD-RC fault system) in the region makes it difficult to postulate significant active thrust faults in the region.

The NRC staff finds that SCE has adequately examined the southern California GPS data to determine whether sufficient driving forces exist to reactivate the entire Oceanside detachment as a blind thrust fault. SCE chose a station located offshore on Catalina Island (behind the

Oceanside fault) and other stations located onshore in order to accurately evaluate the tectonic ground displacements in the region. Three of the five GPS stations selected by SCE have been recording displacements for over a five-year period. The results of the GPS study, performed by SCE, show that the major tectonic displacements, in the region surrounding SONGS, are along the major strike slip faults in southern California. As a result, the possibility of active blind thrust faults in the vicinity of SONGS, which would require significant displacement perpendicular to the major strike-slip faults, is questionable.

2.3 Seismic Hazard Analysis

SCE used its seismic source characterization to develop two additional source models, which incorporate the postulated blind thrust faults in the region surrounding SONGS. Using its seismic source characterization as well as the results of the GPS study, SCE assigned weights to each of the three seismic source models. These three seismic source models were then used in a PSHA to develop new hazard curves for SONGS.

Model 1 assumes that the NI-SCOZD-RC is an active strike-slip fault zone that truncates and displaces the Oceanside detachment. The Oceanside detachment is not considered to be an active seismic source and the San Joaquin Hills blind fault is modeled as an active fault that merges with the NI-SCOZD-RC fault zone at depth.

Model 2 assumes both independent strike-slip and blind thrust faults in the region surrounding SONGS. This model includes an active OBT as well as the Newport Inglewood (NI) strike-slip fault to the north and the Rose Canyon (RC) strike-slip fault to the south. The South Coast Offshore Zone of Deformation (SCOZD) strike-slip fault is not included in Model 2.

Model 3 assumes the OBT and the SCOZD-RC represent strain partitioning in the upper crust above an oblique fault plant at depth. In this model the thrust and strike-slip fault merge into a single structure, an oblique fault, at depth. The slip on the oblique fault at depth would partition into thrust and strike-slip motion on the shallow faults.

The weights given by SCE to these three models are as follows:

- Model 1 = 0.70
- Model 2 = 0.25
- Model 3 = 0.05

SCE states that,

> The Oceanside detachment appears viable as an east-northeast-dipping basement/cover contact in the inner California borderland in the vicinity of SONGS, but there is no direct evidence that clearly demonstrates the activity and seismogenic capability of the OBT as postulated by Rivero et al. (2000). Evidence presented by Rivero et al. (2000) regarding the level of activity, slip rate, and seismogenic potential of the OBT as a source of future large magnitude earthquakes is inconclusive.

> A much stronger case is made in support of the model (model 1) that characterizes the SCOZD as part of a through-going strike-slip fault zone. Primarily, geodetic data show that strain in the southern California inner borderland is characterized by north-northwest directed shear subparallel to the overall North America/Pacific plate motion. Little or no convergence across the inner borderland normal to the plate boundary in the vicinity of SONGS is indicated. In particular, the lack of significant convergence in the regional signal to the east of the OBT suggests there is not a regional “driving” force that would reactivate large seismogenic thrust.

SCE gives a very low weight to Model 3 since there is little empirical evidence to suggest that oblique slip with the ratio of strike-slip to dip-slip suggested by the available data for the OBT would occur on a fault plane dipping between 14° to 24°.

Using the three models as input to a PSHA, SCE developed new seismic hazard curves for SONGS. These seismic hazard curves were then used to derive a uniform hazard spectrum (UHS). The resulting UHS, which incorporates the original and two new source models, is slightly higher than the 1995 SONGS IPEEE UHS in the low frequency range (below 1.5 Hz). SCE states that this slight increase in spectral acceleration in the low frequency range would only have a slight effect on the structural responses of the SONGS IPEEE buildings because these structures have natural frequencies of about 1.5 Hz and higher.

The slight increase in spectral acceleration for low frequencies is primarily due to SCE’s inclusion of source directivity effects for each of the models. Rupture directivity effects at a given site are expected from earthquakes that have rupture faults near the site and affect ground motions in a frequency range lower than 1 Hz. SCE used the method developed by Abrahamson (2000) to incorporate the rupture directivity effect into the PSHA.

In addition to rupture directivity effects, SCE also incorporated fling into the PSHA. Fling is defined as the ground motion at a site caused by permanent slip (i.e., tectonic deformation) that accompanies earthquake shaking. The effects of fling increase the SCE response spectral values by less than 2 percent at 0.5 Hz and about 1 percent at 1 Hz. Response spectral values at frequencies above 1 Hz are not affected by fling.

The NRC staff finds that SCE has given adequate weight to the potential for active blind thrust faults in the region surrounding SONGS. The GPS data shows that the dominant strain in the southern California inner borderland is characterized by north-northwest directed shear subparallel to the overall North America/Pacific plate motion. The NRC staff concurs with the conclusion made by SCE that the absence of significant relative displacement rates in the direction perpendicular to the major strike-slip faults (NI-SCOZD-RC fault system) in the vicinity of SONGS makes it difficult to postulate significant active thrust faults in the region. Therefore, Model 1 is correctly given the dominant weight. The NRC staff also concludes that SCE has used the latest attenuation relationships and has included both rupture directivity and fling effects into its PSHA in order to accurately model the seismic hazard at SONGS.

2.4 Seismic Probabilistic Risk Analysis

SCE updated its seismic probabilistic risk analysis (PRA) using the new PSHA results as input. The seismic PRA focused on the potential increase in core damage and large early release risk due to the postulated blind thrusts. Using the new seismic hazard results, the SONGS CDF increases from 4.27E-5/year to 4.57E-5/year and the LERF increases from 1.60E-6/year to 1.78E-6/yr. Since these increases are so small, SCE concludes that there are no seismic vulnerabilities at SONGS and that the postulated blind thrust faults do not appreciably change the seismic risk of SONGS.

The NRC staff concurs with SCE's conclusion that the increase in CDF and LERF are very small and subsequently, the postulated blind thrust faults do not appreciably change the seismic risk of SONGS.

3.0 CONCLUSION

The NRC staff has reviewed the SONGS seismic hazard study and concludes that SCE has accurately modeled the potential hazards from the postulated blind thrust faults. SCE added two additional models to incorporate the potential for active blind thrust faults in the vicinity of SONGS. Following its seismic source characterization and analysis of GPS data, SCE gave Model 1, used in the 1995 IPEEE, a weight of 0.7 and the other two models a combined weight of 0.3. The two new models consider the OBT fault to be a potential seismogenic source. These two additional models were included with the original model in an update of the PSHA for SONGS. The PSHA for SONGS also included the latest attenuation models and included source directivity and fling. The resulting hazard curves from the PSHA were used by SCE to update its seismic PRA. Both the increase in CDF and LERF are minimal.

The NRC staff concludes that the design of the SONGS units, which is based on an assumed magnitude 7 earthquakes occurring on the NI-SCOZD-RC fault zone at a distance of 8 kilometers from the site, is adequate. This design event is larger than any earthquake known to have occurred on the NI-SCOZD-RC fault zone. The evidence for larger earthquakes occurring on blind thrust faults in the vicinity of SONGS is inconclusive.

4.0 REFERENCES

Abrahamson, N.A. (2000), Effects of Rupture Directivity on Probabilistic Seismic Hazard Analysis, Proc. Of the 6th International Conference on Seismic Zonation, Palm Springs, CA, Nov. 2000.

Rivero, C., Shaw, J.H., and Mueller, K., (2000), Oceanside and Thirtymile Bank Blind Thrusts: Implications for Earthquake Hazard in Coastal Southern California, Geology, V.28, p.891-894.

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Date: September 24, 2002