UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
GENERAL ELECTRIC CO.	)	
	)	Docket No. 50-70
(Vallecitos Nuclear Center -	)	(Show Cause)
General Electric Test Reactor,	)	
Operating License No. TR-1)	)	

NRC STAFF'S PROPOSED FINDINGS OF FACT AND CONCLUSIONS OF LAW

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July 31, 1981

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In the Matter of GENERAL ELECTRIC CO. (Vallecitos Nuclear Center - General Electric Test Reactor, Operating License No. TR-1)	)	Docket No. 50-70 (Show Cause)

NRC STAFF'S PROPOSED FINDINGS OF FACT AND CONCLUSIONS OF LAW

I. INTRODUCTION

1. On October 27, 1977, the Acting Director, Office of Nuclear Reactor Regulation, issued an Order to Show Cause which provided that:

> 1. Pending further order by the Director Office of Nuclear Reactor Regulation, the General Electric Test Reactor (GETR) shall be placed and maintained safely in a cold shutdown condition;
>
> 2. The General Electric Company (GE or Licensee) show cause why the suspension of activities under Operating License No. TR-1 should not be continued.[1/]

2. The Order to Show Cause stated that "[t]he licensee may, within twenty days of the date of this order, file a written answer to this order under oath or affirmation. Within the same time, the licensee or any interested person may request a hearing."

1/ Noticed in the Federal Register on November 3, 1977 (42 Fed. Reg. 57573).

3. On November 11, 1977, the Licensee filed a timely response requesting approval to resume operations after completion of certain modifications proposed in the response, but did not request a hearing. On November 14, 1977, Friends of the Earth and Congressman Ronald V. Dellums requested a hearing and indicated their interest in participating in such a hearing.

4. In a Memorandum and Order dated February 13, 1978, the Commission, pursuant to Section 191 of the Atomic Energy Act of 1954, as amended (42 USC § 2241), delegated the authority to rule on the requests for a hearing and the authority to conduct any hearings that might ensue to an Atomic Safety and Licensing Board (Licensing Board or Board).

5. In its Memorandum and Order, the Commission revised the issues set forth in the Order to Show Cause in the event a hearing were held in the show cause proceeding as follows:

> (1) What the proper seismic and geologic design bases for the GETR facility should be;
>
> (2) Whether the design of GETR structures, systems and components important to safety requires modification considering the seismic design bases determined in issue (1) above, and, if so, whether any modification[s] can be made so that GETR structures, systems and components important to safety can remain functional in light of the design bases determined in issue (1) above;
>
> (3) Whether activities under Operating License No. TR-1 should continue to be suspended pending resolution of the foregoing.

6. The first prehearing conference in this proceeding was held on March 16, 1978. In its Order Following Conference, dated March 28, 1978, the Licensing Board admitted Friends of the Earth and Congressman Dellums as

parties in the proceeding, restated the issues to be determined, opened formal discovery, and directed that an evidentiary hearing be held at a future date, to begin in the vicinity of the GETR site.

7. On March 10, 1978, an untimely petition to be admitted as parties was filed jointly by Congressmen Phillip and John Burton. On March 15, 1978, an untimely petition to participate as a party in this proceeding was filed by Ms. Barbara Shockley. Based upon the consideration of the factors governing the granting of late-filed petitions set forth in 10 CFR § 2.714(a)(1) of the Commission's Regulations, the Staff and the Licensee did not object to the admission of the petitioners subject to their consolidation respectively with Congressman Dellums and Friends of the Earth. In an Order dated March 19, 1978, the Board admitted them as intervenors, with the Congressmen Phillip and John Burton consolidated for all purposes with Congressman Dellums, and Ms. Shockley consolidated for all purposes with Friends of the Earth. By joint motion dated April 16, 1981, Friends of the Earth and Congressman Dellums asked to consolidate their intervention. The Board granted their request.[2/]

8. A second prehearing conference in this proceeding was held on January 5, 1981. A subsequent conference call was held on January 21, 1981. In its Memorandum and Order following the conference and conference call, dated February 3, 1981, the Board established an 11-step schedule culminating in the commencement of evidentiary hearings on May 27, 1981. As part of the schedule, the Board set May 12, 1981 for the final prehearing conference.

9. Subsequent to the Board's Order of February 3, 1981, the Staff, Licensee and Intervenors conferred informally in an effort to arrive at stip-

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2/ As part of the Notice of Hearing dated May 1, 1981 (46 Fed. Reg. 25576 (May 7, 1981).

ulations. On May 11, 1981 a Stipulation signed by counsel for each of the parties was submitted to the Board for its consideration. In the Stipulation, the parties agreed that a final prehearing conference need not be held. In addition, GE stated its intention not to present an affirmative case on issue 3. Eighteen statements of fact were agreed to. A schedule was presented for the appearance of witnesses, cross-examiantion, and filing of proposed findings of fact and conclusions of law. The Board decided not to hold a final prehearing conference, but rather to discuss the status of the proceeding by means of a conference call among members of the Board and counsel for each of the parties.

10. On May 13, 1981 a conference call was held to discuss the Stipulation dated May 11, 1981. Representatives of each of the parties and Administrative Judges Foreman and Grossman participated in the conference call. The Board issued its Order Summarizing Conference Call dated May 14, 1981, in which the Board approved and adopted the Stipulation. The Board also deferred any ruling on the Intervenors' request that the Board accept the qualifications of Glenn Barlow as an expert witness for the Joint Intervenors, except to decide that Mr. Barlow would be permitted to present his full testimony either as admitted expert testimony or as an offer of proof. A supplemental stipulation was also reached by the parties, the results of which were sent to the Board in a letter from Staff Counsel dated May 22, 1981.

11. A "Notice of Hearing" was published on May 7, 1981.[3/] The hearing commenced in Livermore, California on May 27, 1981. Oral limited appearance

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3/ See note 2, <u>supra</u>. The notice provided that the hearings would commence in Livermore, California, on May 27, 1981, and then continue on June 1, 1981 in San Francisco, California until completion.

statements from members of the public were received on that day. Tr. 187-224. The evidentiary phase of the hearing also, commenced on May 27, 1981, continuing through May 29, 1981 in Livermore. The Hearing reconvened in San Francisco, California on June 1, 1981, with additional limited appearance statements received on that day. Tr. 731-67. The evidentiary phase began again on June 1, 1981 and proceeded to conclusion on June 10, 1981. The record was kept open until June 26, 1981 for corrections and other housekeeping chores.[4/] The evidence in the record, contained in a transcript of 2306 pages, includes the prefiled written testimony and oral testimony of witnesses for the Staff, the Licensee, and Joint Intervenors. The evidentiary record includes documentary exhibits offered and received into evidence as indicated in Appendix A hereto.

II. FINDINGS OF FACT

12. Our findings of fact parallel the first two issues set forth by the Commission in its Memorandum and Order of February 13, 1978. The third issue in the Memorandum and Order, whether activities under the GETR operating license should continue to be suspended pending resolution of the first two issues, was not litigated in the hearing, as the Licensee stipulated that it did not presently intend to seek authority for interim operation pursuant to the third issue. Stip. para. 1. The first portion of our findings deals with the proper geologic and seismic design bases for

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[4/] The Staff and the Licensee made timely submittals of their transcript corrections. Intervenors also made a timely submittal, indicating that they had no corrections to the transcript. By Board Order dated June 29, 1981, those transcript corrections were approved and the record in the proceeding as constituted containing those corrections was closed.

the GETR. This issue in turn breaks down into subissues concerning geology, seismology, and earthquake engineering. The second issue involves the adequacy of the design of the GETR structures, systems, and components important to safety in light of the design bases determined in connection with issue one. These findings are set forth below.[5/]

A: ISSUE ONE: WHAT THE PROPER GEOLOGIC AND SEISMIC DESIGN BASES FOR THE GETR FACILITY SHOULD BE

13. The Licensee's geology review was performed primarily by Earth Sciences Associates (ESA), represented at the hearing by Mr. Richard Harding of Earth Sciences Associates, with additional input from Dr. Richard Jahns, and Mr. Richard Meehan. Lic. Ex. 1. The Licensee's seismology review was conducted by Dr. Robert Kovach and Dr. Charles Richter. Lic. Ex. 21. The probability analysis was performed by Dr. John Reed of Engineering Decision Analysis, Inc. (EDAC). Lic. Ex. 1. The Intervenors did not offer a qualified

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[5/] Citations to oral testimony in the transcript give the last name of the witness or witnesses whose testimony is being cited, immediately following the transcript page or pages. Examples are: Tr. 1500 (Jones), Tr. 1500-05 (Jones, Adams). Citations to prepared written testimony give the last name of the witness or witnesses, the page of the transcript immediately preceding the prepared testimony, and the page or pages of the prepared testimony to which reference is made. Examples are: Jones, ff. Tr. 1500, at 5 and Jones and Adams, ff. Tr. 1600, at 10-12. Citations to exhibits designate the party who introduced the exhibit, the number of the exhibit, and the page or pages to which reference is made. Examples: Staff Ex. 1 and Lic. Ex. 2 at 10-12. Citations to the Stipulation, dated May 7, 1981, indicate the lettered statements of fact included in section "B" of that Stipulation. An example is: Stip. para. 2.a. Finally, citations to proposed findings are as follows: to "Licensee's Proposed Findings of Fact and Conclusions of Law," dated July 6, 1981, indicated as Lic. Findings, followed by the referenced finding number; "Intervenors' Proposed Findings of Fact and Conclusions of Law," dated July 23, 1981, are indicated as Int. Findings, followed by the numbered finding being referenced.

witness on the geology or seismology issues[6/] but presented Dr. David Brillinger on the probability issue.

14. The Staff geology review was conducted by Dr. Robert Jackson and Dr. Philip Justus. Because of the complex technical questions that exist at the GETR in the area of geology and seismology, the Staff solicited the assistance of the U.S. Geological Survey (USGS). Justus and Jackson, ff. 996, at 6. The role of the USGS was to provide geologic input into the Staff's review of the GETR site area. Although the USGS formed conclusions regarding the Verona fault and its characteristics, it did not develop a design value surface offset beneath the GETR. Morris, Brabb, and Herd, ff. 996. at 5. The USGS did review the regional seismicity, and sponsored the Staff conclusions regarding the appropriate design value to associate with the maximum vibratory ground motion to be expected at the GETR site from earthquakes on the Calaveras and Verona faults. Devine, ff. 996, at 3; Ellsworth, ff. 996.

15. In order to obtain another view on the problem independent of both G.E. and the U.S. Geological Survey, the Staff obtained the service of Dr. David Slemmons, one of the world's leading experts in earthquake fault evaluations. He was requested to reach his conclusions independently and to provide those views to the Staff. Justus and Jackson, ff. 996. at 6, 7. His testimony speaks to his conclusions and the bases for them. Slemmons, ff. 996.

6/ The Intervenors sought to introduce testimony from James Glenn Barlow on various subject. As a consequence of Mr. Barlow's lack of formal training in the relevant subject areas, however, the Board refused to admit Mr. Barlow's testimony. Tr. 900. The Board did permit the Intervenors to make an offer of proof of Mr. Barlow's testimony. Id. Upon review of the record, the board reaffirms its ruling that Mr. Barlow's testimony should not be received in evidence. Consequently, the Board disregards those findings of fact claimed by the Intervenors which are based on the proposed oral and written testimony of Mr. Barlow. See, Int. Findings 22-27 and 75-102.

16. In addition, as a result of a submittal of a probability study by the Licensee and requests by the Advisory Committee on Reactor Safeguards (ACRS), the Staff requested the review assistance of several experts in the area of probability analysis. These included Dr. William Vesely of the NRC staff, Mr. Don Bernreuter of Lawrence Livermore Laboratory (LLL) a contractor to NRC, and Mr. Lawrence Wight of TERA Corporation, a subcontractor to LLL. See Bernreuter, ff. 1801 and Vesely, ff. 1801.

1. Geologic Design Bases

a. Regional Setting

17. The GETR is located in the Central California Coast Ranges near Pleasanton, California, about 35 miles east-southeast of San Francisco (Lic. Ex. 1 at 8) in a highly active tectonic environment. Staff Ex. 1.A. at 10. The reactor is built on the southwest limb of the Livermore syncline within the Vallecitos Valley. The Coast Ranges are structurally related to the San Andreas fault system, a fault which forms a major sector of the boundary between the North American and Pacific lithospheric plates extending from Cape Mendocino to the Gulf of California. Movement across this boundary is apparently occuring at about 6 cm/year with the Pacific plate moving northward relative to the North American plate. This movement results from a regional orientation of the maximum principal stress that is approximately north-south. Staff Ex. 1.A. at 10, 11.

18. In the vicinity of the San Francisco Bay, the San Andreas fault system consists of the main San Andreas fault itself and several other branching and subparallel faults. One of these is the Calaveras fault zone which passes about 2 to 3 kilometers west of the GETR site. Lic. Ex. 21 at 20; Tr. 285-6

(Harding); Tr. 994 (Justus). Geologic and geodetic data indicate that the Calaveras fault is moving in a right slip sense (rocks west of the fault move north relative to rocks east of the fault). The Greenville fault, which may also be considered a part of the San Andreas fault system, lies about 16 kilometers east of the GETR site. The major branches of the San Andreas fault system, including the Calaveras fault, have been characterized as having the potential for generating a maximum earthquake in the range of magnitude 7 to 7.5. Stip. Paras 2.k.-r.; Tr. 695 (Jahns); Tr. 681-82 (Kovach).

19. Although not a fault of regional significance, the Verona fault is important because of its proximity to the GETR. The Verona fault has been characterized as a west to west-northwest trending thrust fault creating a 2200 feet wide zone of faulting which surrounds the GETR. Staff Ex. 1.A.; App. A; Lic. Ex. 1 at 12-14; Stip. par-. c.

b. Separation of Calaveras and Verona Faults

20. Having identified the geologic features of regional significance, the Board now turns to a consideration of whether the regional fault of consequneces, the Calaveras, is related to the Verona, the fault which is closest to the GETR, and which is presumed for the purpose of this hearing to cause surface offset at the GETR site. In this regard, an extensive record was developed concerning whether the Calaveras and Verona faults are connected. Both the Staff (Tr. 1197 (Herd)) and the Licensee (Tr. 247 (Harding)) concluded that the Verona and Calaveras faults were not connected. The Intervenors questioned Dr. Ellsworth of the USGS whether the Calaveras fault as mapped should be shifted to the east closer to the GETR because of a series of instrumentally located epicenters of the earthquakes whic appear east

of the mapped location of the fault. Tr. 1021. If the Calaveras fault were shifted to the east, it would approach the Verona fault and the GETR. However, Dr. Ellsworth testified that there was insufficient evidence to propose a shift in the location of the Calaveras fault from its mapped trace. Tr. 1021-22 (Ellsworth). Dr. David B. Slemmons, stated that it is very unlikely that the Calaveras Fault would cause new surface breakage east of where the fault is now mapped. Tr. 1017-18 (Slemmons). USGS geologists Drs. Darrel Herd and Earl Brabb agreed with this statement. Tr. 1019 (Herd and Brabb).

21. Dr. Herd testified that he had mapped in the area east of the Calaveras fault, and found a trace of a fault southwest of the GETR. Tr. 1016 (Herd). Mr. Richard C. Harding also found another fault to the north of the fault which Dr. Herd discovered, and southwest of the GETR. Tr. 389-90 (Harding). Both Mr. Harding (Tr. 383) and Dr. Herd (Tr. 1016; 1068-70) testified that the faults southwest of the GETR are not connected because of the differences in ages of faulting as well as the existence of unbroken Livermore gravels which lie between the faults. Dr. Herd further testified that he could uncover no field evidence that the traces are connected to the Calaveras fault, or that Calaveras fault is connected to the Verona fault. Tr. 1016 (Herd). Further evidence of lack of a Calaveras-Verona fault connection was expressed by Mr. Harding, who indicated that no movement has occurred on the Verona fault during a period in which there have been many large earthquakes on the Calaveras fault. Tr. 292 (Harding).

22. Similarly, Dr. Herd conducted a systematic review of evidence for recent displacements in the Calaveras Fault zone, including that part of the Vallecitos Valley between the Calaveras and Las Positas Faults. He could not find any

evidence that the Calaveras and Las Positas faults are connected. Tr. 1084 (Herd). Thus, although Dr. Herd believes that the Verona Fault is connected to the Las Positas Fault (Tr. 1076-77 (Herd), the Verona would not be connected with the Calaveras through a connection with the Las Positas. Although the Intervenors rely on Dr. Herd for support for a possible connection between the Las Positas and Calaveras faults (Int. Findings 37), the Board notes that an accurate reading of Dr. Herd's testimony is that there is no sufficient geologic evidence to confirm or support such a connection. Tr. 1082 (Herd). Similarly, the Intervenors mischaracterize Dr. Slemmons' testimony as being that the Vernoa connects the Las Positas with the Calaveras. Int. Finding 48. In fact, Dr. Slemmons testified that he would assign little weight to the interpretation which would connect these faults together because of differences in mechanisms and difficulties in the dip of the fault planes involved. Tr. 1676 (Slemmons). Mr. Harding discounts the likelihood of a connection between the Las Positas and Verona faults. Tr. 298-99; 2051-55 (Harding).

23. A connection of the Verona fault northward to other faults was precluded, according to Mr. Harding, since it did not intersect Trench E. Tr. 274-77 (Harding); Lic. Ex. 1 at 23-25. Mr. Harding conceded that the Verona fault could "snake" around the trench and continue northward, but that such a configuration would be difficult to envision. Tr. 427 (Harding). Dr. Brabb indicated that the Verona could continue past Trench E, but that it would then have different character from that observed in the trenches closer to the GETR. Tr. 1088 (Brabb).

24. Dr. Brabb indicated that it is possible for the Verona to be connected with the Pleasanton fault. Dr. Brabb indicated that his study of the

Pleasanton fault zone was limited to a small amount of review of the work of others. Tr. 1094 (Brabb). Although Intervenors would find that Dr. Brabb supports a tectonic and structural relationship between the Pleasanton and Calaveras faults (Int. Finding 40), Dr. Brabb in fact indicated that he did not know what the relationship was between the Pleasanton and Calaveras faults. Tr. 1096 (Brabb). Dr. Herd, on the other hand, testified that he had studied and mapped the area of the Pleasanton fault zone (Tr. 1094), and that he did not consider it possible for the Pleasanton fault to be connected with the Verona fault. Tr. 1087 (Herd). Mr. Harding also testified that the two faults are not connected, and that the Calaveras fault was not connected with the Verona. Tr. 263-65, 292, 313 (Harding).

25. Intervenors during cross-examination of the Staff panel tried to determine whether the major event along the Calaveras fault could cause sympathetic faulting along the Verona fault. Dr. Ellsworth testified that he was not aware of such observations in the San Andreas system except for very minor and apparently surficial movements triggered on faults in the Imperial Valley region and the possible association of movement on the Las Positas fault with the January 14, 1980 earthquake on the Greenville fault. Tr. 1230 (Ellsworth). Dr. Slemmons testifed that sympathetic movement on a second fault has always been small in the worldwide earthquake events; that there are several examples of conjugate faulting in the worldwide data where faults are more in a rectangular pattern, but for branching faults such as those of the San Andreas system, movement on one has historically been independent of movement on others. Tr. 1230-31 (Slemmons). Dr. Jahns testified that it is extremely unlikely for an earthquake on the Calaveras to cause offset on the Verona, since the geometries and movement senses are fundamentally different

between the two faults. Tr. 647, 654 (Jahns). Accordingly, the Board discounts the development of sympathetic faulting along the Verona fault from a larger event on the Calaveras fault.

26. Having reviewed and considered all of the evidence of record as to whether the regional fault of consequence, the Calaveras, is connected to the Verona, the Board agrees with the Staff and Licensee that the Verona may be considered to be separated from the Calaveras. The Board agrees with Staff geologist Dr. Philip Justus that the Calaveras is a well defined zone of faulting which does not include the GETR site. Tr. 1789 (Justus). Furthermore, the Board finds that the Calaveras fault was sufficiently investigated so as to permit a finding of fact that the Calaveras is not structurally related to the Verona fault, and that the only influence of the Calaveras fault on the GETR site is through vibratory ground motion. (See findings, infra at section 1.d., re. design offset and ground motion at the GETR site.)

c. Verona Fault

27. Because the Verona fault is the geological fault in closest proximity to the reactor, it is of obvious importance. An extensive record was developed as to the relevant characteristics of this feature. The Verona fault lends its name to the zone of faults recognized in the trenches and boreholes near GETR. Each of the principal faults identified in trenches B-1/B-3, B-2 and H in the vicinity of the GETR are referred to as the Verona fault. USGS geologists, as advisors to the NRC Staff, undertook a comprehensive review of arguments and data provided by GE relating to the absence of the Verona fault. Staff Ex. 1.B at 7. Their detailed review was reported in "Faults at the General Electric Test Reactor Site, Vallecitos Nuclear Center, Pleasanton, California, A Summary

Review of Their Geometry, Age of Last Movement, Recurrence, Origin, and Tectonic Setting and the Age of the Livermore Gravels" (Staff Ex. 1.B., App. B.). The report provides supporting bases for the conclusion that the Verona fault should be considered to be a tectonic (earthquake) fault. This conclusion has been stipulated to for the purpose of this hearing. Stip. para. 2.b.; see also, section 1.d.(1), infra.

28. The USGS also completed a study of the Livermore Valley region seismicity. This study, entitiled "Seismicity of the Livermore Valley, California Region 1969-1979, Open-File Report 80-515", was prepared by W. L. Ellsworth and S. M. Marks, Staff Ex. 1.B., App.C. With respect to the Verona fault, this study indicated that the Las Positas, Pleasanton and Verona faults are identified as probably seismically active faults. This conclusion was modified with respect to the Verona Fault so as to label it possibly active. Ellsworth, ff. 996, at 3. In addition, Ellsworth and Marks conclude that earthquake focal mechanism solutions for events near Vallecitos Valley demonstrate that this region is a zone of active thrust faulting and that some of these thrust events are in possible association with the Verona fault. Staff Ex. 1.B., Section A at 9.

29. After careful review, the USGS indicated that the most recent fault movement is believed to have occurred since 2,000-4,000 years before present. Staff Ex. 1.B. App. B. Dr. Slemmons indicated he would place an error band for fault displacement in the soil between approximately 1,500-2,000 years to 4,000 years before present for trench B-1, also making the Verona a tectonic structure. Staff Ex. 1.B., App. E. Based on these recommendations, the Staff concluded, and the Board agrees, that offset of the youngest soil horizon could have occurred within the last 2,000 years. This determination is important because it relates to surface slip rate and recurrence estimates which are relevant to surface offset. Staff Ex. 1.B., Sec. A., at 10.

30. These characteristics of the Verona fault are also important for purposes of modeling and of design. The surface and near-surface dip angle of a Verona fault strand is likely to fall in the range of 10 to 45 degrees. Stip. para. j; Staff Ex. 1.B., Section A, at 20. The Verona fault zone has an outcrop width of 2200 feet. Stip. para. c; Tr. 1260 (Justus). The maximum surface length of the Verona fault is 12 km. Stip. para. f; Staff Ex. 1.B., Section A, at 18. The Board finds that these values are reasonable and are supported by the record in the proceeding.

d. Surface Fault Offset

31. Previously GE concluded that measurements of offset soil stratigraphic markers confirm that the maximum amount of offset that has occurred on a single shear surface within the last 20,000 years is less than 1 meter and, therefore, that an assumed offset of one meter is conservative. Based on further investigations (Phase II, including probability analyses), GE indicated that a zero offset for the reactor building and no more than three feet in a plane 15-25 degrees from horizontal on observed shears at the site should be used for design criteria. As a result of the Staff's analysis and on the advice of consultants, it concluded in the Staff Setember 27, 1979 report that 2 1/2 meters of reverse-oblique net slip along a fault plane which could vary in dip from 10 to 60 degrees provides a conservative description of surface slip on the Verona fault zone during a single event. This judgement was based in part on observations and comparisons with the maximum calculated net slip displacement observed during the 1971 San Fernando, California earthquake. The position was based also on comparisons with the available worldwide fault offset information for reverse and

reverse-oblique slip faults as well as the recommendations of the USGS and Dr. Slemmons. In addition, because of an inability to quantify the likelihood of new rupture between the existing shears, the Staff concluded that this offset could also occur beneath the reactor. Staff Ex. 1.B at 11.

32. Subsequently, both GE and the Staff presented their conclusions to a subcommittee of the ACRS. As a result of that meeting and the questions raised by the Subcommittee and its consultants, further review of the seismological parameters and a probabilistic assessment of the surface fault potential was undertaken. As a result of the Staff's review of GE's April 12, 1979 submittal of a Jack R. Benjamin and Associates probability study and generally negative conclusions regarding it, GE undertook a new probability study. In addition, the Staff received a number of reports from GE relating to the probability study, supporting bases for geolologic assumptions in the study, a fault evaluation of GETR excavation photographs, dip of faults, discussions of the Livermore Valley regional seismicity, and the significance of observations of the 1979 Imperial Valley earthquake. Staff Ex. 1.B. at 1,2.

33. The Staff and its consultants reviewed the newer information, and subsequently the Staff modified its conclusion regarding the proper design value for surface offset to assign to the GETR site. A brief overview of the basis for the Staff's selection of a final design value of one meter of offset beneath the reactor was provided by Dr. Jackson (Tr. 1389-95) and by Dr. Justus (Tr. 1888-92; Justus and Jackson, ff. 996, at 8-11). The bases for the selection of the final geologic design basis were set forth in the Staff's safety evaluation reports (Staff Exs. 1.B. and 1.C.).

34. The USGS geologists concluded that one meter of surface offset is not a conservative estimate of the total amount of offset that could occur along the

Verona fault. Morris, Brabb and Herd, ff. 996, at 5. The USGS indicated that the total amount of offset will not necessarily occur on any one fault plane or strand of the Verona fault. The USGS indicated, however, that it did not develop, nor was it its responsiblity to develop a design value for surface offset beneath the GETR. Id. The Staff agrees that the possibility exists that offsets larger than one meter could occur at some time in the future in the Verona fault zone, but that it is unlikely that an offset greater than one meter would occur on a single splay of the Verona fault directly beneath the reactor. No such splay of the Verona fault is known to go beneath the plant, but for purposes of design of the facility, the consideration of one meter of offset on a splay of the fault beneath the reactor is required. Tr. 1394-95 (Jackson).

35. The USGS concluded that there were no direct measurements of Holocene (less than 10,000 years old) displacements in the GETR trenches on a single splay of the Verona which exceeded three feet in length. Staff Ex. 1.B., App. B at 7, 22; Tr. 1484-85 (Herd). Dr. Slemmons testified that the areas of trenching, i.e. where the 2 to 3 feet offsets were measured, are where the likely maximum displacements to be expected near the GETR. Tr. 1189-90 (Slemmons).

36. The USGS interpreted 5 feet of offset from the log made of trench T-1. Counsel for the Licensee and the Board members questioned the USGS in detail regarding this interpretation. Tr. 135-79; 1430-1523. Dr. Herd and Dr. Brabb testified that this interpretation was not based on a direct measurement as was done in subsequent trenches. Rather, the 5 feet of inferred offset in T-1 is based on an interpretation of data and the log which was made several years after the USGS trench visit. Tr. 1165-66

(Brabb); Tr. 1477 (Herd).[7] T-1 was excavated for the purpose of determining whether there was or was not an active fault in close proximately to the plant and not for measuring the amount of displacement. Tr. 1159 (Jackson); Tr. 1134 (Herd). Drs. Brabb and Herd indicated some of the difficulties in interpreting the offsets in trench T-1 without more information and verification of the soils in the trench and the unavailability of logs until well after the trench was closed. Tr. 1468 (Brabb); Tr. 1472-74 (Herd). Further, Dr. Herd's interpretation of the displacements, which was based in part upon photographs taken of the trench excavation (Staff Exs. 5A and 5B), requires that the surface soil is offset. However, no offset of the surface soil is reported in the log of T-1. Tr. 1507-10 (Herd). Dr. Herd concluded that the likely explanation is that the offset A-2 soil horizon was simply not identified by the persons logging the trench. Tr. 1509-10 (Herd). The Licensee's consultant, on the other hand, interpreted T-1 to exhibit at most 2 feet of displacement. Lic. Ex. 1, App. A, at A-1.

37. Testimony by Dr. Jackson and Dr. Slemmons suggests additional reasons why a definitive conclusion is not possible from the evidence produced at the hearing from the extensive examinations on trench T-1. T-1 was located in a swale, with a rise on either side of it, whereas subsequent trenches were located on slopes inclined to the west. Consequently, there could

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[7] The Board notes that the Intervenors incorrectly attribute to Dr. Herd a position that Trench T-1 shows 5 to 7 feet of offset. Int. Findings 42, 44. In fact, Dr. Herd testified that under his interpretation of T-1, about 5 feet of offset was the preferred amount. Tr. 1163, 1155 (Herd).

have been some erosional aspect parallel to the fault at trench T-1. Tr. 1513 (Jackson). Dr. Slemmons indicated that T-1 may be a unique location where the two faults recognized in the B trenches come together (merge). Tr. 1295 (Slemmons).

38. Thus, the interpreted 5 feet of offset in T-1 may be a cumulative displacement of multiple events, each occurring on the splays of the Verona, and none of which would necessarily exceed 3 feet of displacement individually. Id. The inconsistency between the possible offset of 5 feet in T-1 and 2-3 feet offsets measured in the other trenches further led Dr. Slemmons to conclude that trench T-1 probably exhibited a cumulative affect of two events, rather than a single event. Tr. 1585 (Slemmons).

39. In light of the 22 direct measurements of displacements in the trenches closer to the GETR, all of which exhibited displacements of 3 feet or less (Staff. Ex. 1.B, App. B at 22; Lic. Ex. 1 at 50-51) and the above discussion indicating the inappropriateness of using T-1 as a model for indicating geologic activity beneath the GETR, the Board does not find the intepretation of a possible 5 feet of offset in trench T-1 to be controlling in the selection of a design value offset for the GETR.

40. In input parameters to the surface offset specified for this site include a set of conservative assumptions. Justus and Jackson, ff. 996 at 10. First the Staff assumes that the Verona fault is a tectonic (earthquake) fault even though there is some probability that the features are landslide related (passive). Id. Both GE consultants (Lic. Ex. 1 at 28) and the California Division of Mines and Geology (Staff Ex. 1A at App. D) conclude that the features are landslide in origin. Second, the Staff assumes that a magnitude 6.5 earthquake will occur on the Verona fault

during the lifetime of GETR, although there is some probability that either no earthquake or only smaller events could occur. Third, the Staff assumes that the Verona fault will rupture greater than its maximum mapped length of km to a total of 12-15 km even though analysis of worldwide data indicates that actual rupture can be substantially less than the total length of the fault. Justus and Jackson, ff. 996, at 10.

41. Fourth, the Staff further assumes that the surface offset that will take place as a result of an earthquake will be similar to the mean of the observed offsets which resulted from the 1971 San Fernando earthquake. This assumption is made even though the analogy between the Verona fault and the San Fernando fault zone is conservative. Stip. para. 2.e. Fifth, t Staff concludes that the offset will occur directly beneath the reactor. The Staff concludes this even though it recognized that movement is more likely to occur on those existing larger faults which have Holocene offset rather than between the faults. Tr. 1017, 1032 (Slemmons). Although the Staff recognizes the possible existence of fault features in the reactor excavation photos, it does not see faults similar to those in trenches observed elsewhere on the site where significant displacement has been observed. Justus and Jackson, ff. 996, at 11. Sixth, the Staff further assumes that all of the displacement takes place coseismically (during the time of the earthquake shaking) even though afterslip (displacement after the earthquake) may have contributed to the final offset. In addition, combined loads caused by fault offset at the surface and vibratory ground motion are considered to act simultaneously, even though this is a worst case assumption. Tr. 1050, 1053 (Jackson).

42. Seventh, the Staff also requires that surface offset be considered even though the actual probability calculations indicate that the likelihood of offset occurring beneath the reactor building is extremely low. Vesely, ff. 1801, at 3; Bernreuter, ff. 1801 at 8, 9. Finally, the Staff requires consideration of surface offset even though geotechnical engineering considerations indicate that any fault will deflect around the reactor. Pichumani, ff. 996. at 7. In consideration of the above factors, the Staff believes that its judgment with respect to surface offset and ground motion parameters is reasonably conservative when placed in the total context of its understanding of all information on this site as enumerated in the May 23, 1980 SER and including the geotechnical engineering findings. Justus and Jackson, ff. 996, at 11. The Board examines these considerations below.

(1) Consideration of Landslide v. Tectonic Origin of the Verona

43. This issue is not in dispute for the purposes of this hearing, and was not the subject of cross examination by the parties. Stip. para. 2.b. However, despite the conclusion of the USGS (Morris, Brabb and Herd, ff. 996, at 3); Dr. Slemmons (Slemmons, ff. 996, at 3), and the Staff (Staff Ex. 1.B., Sec. A, at 6) that the Verona is tectonic in origin, the Board notes that Earth Sciences Associates (Lic. Ex. 1 at 28), Dr. Jahns (Tr. 431-36 (Jahns)), and the California Division of Mines and Geology (Staff. Ex. 1.A., App. D) concluded that a landslide is the preferred interpretation of the cause of the Verona shears. Accordingly, the Board notes that there is at least some conservatism in the parties' concluding that the Verona fault is tectonic in origin.

(2) Consideration of Occurrence of M 6.5 Event on Verona Fault

44. A further conservatism lies with the assumption that a Magnitude 6.5 earthquake will occur on the Verona during the lifetime of the facility, causing the surface offset beneath the GETR. However, in response to a question by Dr. Ferguson, the geologists and seismologists on the Staff panel, including the USGS members and Dr. Slemmons, testified that an event of a Magnitude 6 to 6.5 on the Verona was very unlikely in the near future, and that perhaps thousands of years could elapse before such an event would occur. Tr. 1657-63. In light of the testimony that it is unlikely that such a M 6 to 6.5 event would occur on the Verona fault for up to 10,000 years (Tr. 1663 (Slemmons)), the Board agrees that the assumption of such an event during the lifetime of the GETR is indeed a conservatism.

(3) Consideration of Fault Rupture Greater Than the Mapped Length of Verona

45. The Staff assumed that the Verona will rupture to a length of 12-to-15 kilometers of total length, despite its entire mapped length of up to 12 kilometers. Justus and Jackson, ff. 996, at 10. This is despite the fact that worldwide data indicates that actual rupture can be substantially less than the total length of the fault. Id. The length of rupture becomes important as a factor in estimating expected maximum surface offset and magnitude of events from the fault. See, Tr. 1184-88 (Slemmons); Lic. Ex. 21 at 17.

46. Under questioning by the Intervenors, Dr. Slemmons testified that he had considered possible scenarios of the length of the Verona fault, including rupture lengths of up to 15 km. He factored the possible lengths of the

Verona into his worldwide data base, and concluded that a best fit to the data would suggest a likely maximum event of approximately a 6.5 Magnitude, which would in turn correlate with displacement of about 1 meter. Tr. 1187 (Slemmons); Slemmons, ff. 996, at 3. Similarly, Dr. Kovach for the Licensee considered seismic moment correlations which related the magnitudes of events to fault area, displacement, and other properties. He assumed various fault areas, based on fault rupture lengths up to 15 km, and arrived at a range of magnitudes which were no higher than 6.3. From that magnitude event, he derived a maximum surface offset of less than 1 meter. Lic. Ex. 21 at 16, 17.

47. The Board concludes that it is conservative to assume that the Verona fault ruptures along a length of 12 to 15 kilometers, and that the Staff's and Licensee's use of such a rupture length in calculating the surface offset for the Verona fault is also conservative.

(4) Comparison With 1971 San Fernando Event

48. The Staff further assumed, in arriving at the 1 meter offset design value, that the surface offset of the Verona will take place as a result of an earthquake analogous to that which was experienced in 1971 on the San Fernando fault system. Justus and Jackson, ff. 996, at 11 This assumption was made despite the conclusion, as stipulated by all parties, that the analogy between the Verona and the more active San Fernando fault zone is conservative. Stip. para. 2.e. There are a number of characteristics of the San Fernando fault which indicate that it has a greater capability of producing a large earthquake than the Verona fault. Tr. 1184 (Slemmons). The analogy was made by the Staff, however, because of the sparcity of data on thrust fault movement. Staff Ex. 1 B. at 18.

49. The Staff performed an analysis of measurements of offset that occurred during the 1971 San Feranado event, and concluded that 97% of the observations were less than 1 meter, with 5 observations equal to or in excess of 1 meter. Id. at 19. The Staff concluded that 1 meter of vertical offset exceeds the mean plus 2 standard deviations for the San Fernando data. Observations of offsets in excess of the above values were concluded to be due to movement distributed across the fault zone, and not on a single plane. The mean value of the horizontal movement would be about 0.4 meters and 1 meter net slip accounts for the mean plus one standard deviation for all segments of the fault. Id. at 19. The Staff offered that its statistical interpretation must be viewed cautiously because of the possible bias in the sampling in measurement of offsets in the field. Id.

50. The Licensee also did a statistical analysis in an effort to correlate all of the available data from the 1971 San Fernando earthquake. Lic. Ex. 1, App. B. GE developed the analysis using 10 reported data sets for the San Fernando offsets, including 238 measurements of vertical offset and 81 measurements of horizontal offset. Id. at B-3. GE concluded that the mean value for net slip on the San Fernando fault was 0.22 meters, and that the mean plus 1 standard deviation for net slip was 0.72 meters. Id.

51. At the commencement of the hearings, the USGS issued an open-file report which presented a statistical analysis of the data developed by R. Sharp. Tr. 258 (Swanson). The report indicated that the mean values of the San Fernando surface displacements, based upon Sharp's data and analysis, range between 0.59 and 0.78 meters, depending on how the analysis was performed. Tr. 555 (Reed).

52. The Board inquired of the Staff and Licensee as to whether the latest Sharp analysis modified their positions regarding the offsites observed during the San Fernando event. Tr. 469-70; 556-59. The analysis by Sharp did not change the Staff's conclusions regarding the San Fernando analogy but further supported the Staff conclusion that the design basis 1 meter surface displacement from a Verona event exceeds the mean offsets observed for the San Fernando event. The new Sharp analysis resulted in a refinement of the Staff witness panel's observation regarding the width of the zone of breakage of the San Fernando fault zone. Tr. 1315-16 (Brabb, et al.); Tr. 557-58 (Swanson). GE similarly concluded that the Sharp analysis did not change its conclusions. Tr. 553-6 (Reed); Tr. 551-3 (Harding).

53. The Board further notes that Dr. Slemmons concluded that the San Fernando was a conservative model to base offset predictions against the Verona fault. He testified that rocks of similar age are uplifted in the hills behind the San Fernando to much greater heights than in the Vallecitos hills, and that the rate of slip or the strain rate for the San Fernando fault is much higher than for the Verona fault zone. Tr. 1293 (Slemmons). Dr. Slemmons noted that that the topographic expression of the Verona fault zone is subdued as contrasted with the San Fernando fault zone. Moreover, Dr. Slemmons indicated that the amount of movement during the most recent slip event has been verified from numerous trenches along the Verona fault zone to be from about 2 to 3 feet on individual fault splays, as compared with the 2.5 meters measured along the San Fernando fault zone. Id. at 1293-94. Dr. Slemmons concluded that he thought no method is more conclusive than to use the site-specific date to relate possible seismic cycles and mechanisms which are based on the physical observation at the fault itself. Several measurements show that the last offset or offsets accumulated

along the Verona fault have been between 2 and 3 feet, resulting in a greater likelihood of a repetition of that sort of event than a larger offset. Id. at 1294.

54. For the above reasons, the Board concludes that it is conservative to utilize data from the 1971 San Fernando event in estimating possible expected offsets to occur in future events along the Verona. In addition, the Board agrees with the Staff that it is appropriate to utilize mean or characteristic values of offsets from the worldwide data set, including the San Fernando event, rather than maximum offset values. The maximum San Fernando fault offset of 2 1/2 meters was the result of a 12 to 15 kilometer-long rupture of a 100 kilometer-long fault as compared to the 8 to 12 kilometer-long Verona fault. To utilize the maximum values as opposed to the mean or mean plus 1 standard deviation-observed offset of the San Fernando for comparison purposes with the Verona would compound two conservatisms. See Tr. 1891 (Justus).

(5) Consideration that Offset Will Occur Beneath the Reactor

55. A further conservatism is the Staff's requirement in its geologic design basis that the offset be assumed to occur directly beneath the reactor. This assumption is conservative because of the recognition that offsets are more likely to occur on existing faults which have recent Holocene offsets. However, the analysis of photographs of the excavation of the GETR foundation led Mr. Harding to conclude that there were no faults at the GETR. Tr. 387-88, 451 (Harding). Dr. Brabb testified that, although preliminary examination of photographs of the excavation led the USGS to conclude that there were probable faults at the site, a reexamination of better quality photographs led them to downgrade the likelihood of faults from being probable to possible. Tr. 1036

(Brabb).[8/] However, Dr. Brabb testified that there is no reliable positive evidence of the existence of faulting under the reactor foundation. Tr. 1039 (Brabb). Given this testimony, the Board finds it very conservative to assume the existence of a capable fault beneath the reactor building based on the information presented at this hearing.

56. Likewise, it would be extremely conservative to assume the formation of a new fault splay beneath the reactor caused by movement along the Verona fault strands located to the northeast and southwest of the reactor. This conclusion is based on Dr. Slemmons' testimony that there is a very, very strong control for repeated offsets to occur on the previously demonstrated planes of weakness, as opposed to the creation of new offsets in areas not previously faulted. Tr. 1032; 1017 (Slemmons). The Staff concluded that, although the possibility exists that features in the reactor excavation photos could be faults, these features are not equivalent to those observed in the trenches elsewhere on the GETR site where significant displacement has been observed, such as the B trenches. Justus and Jackson, ff. 996, at 11. The Board concludes that it is conservative, therefore, to assume that an offset will occur directly beneath the reactor.

57. (6) Consideration of Coseismic Slip and Combined Loads

The Staff required that the entire one meter offset be assumed to occur coseismically (concurrent with the earthquake), even though afterslip may have contributed to the final amount of offset. Justus and Jackson, ff. 996, at 11.

8/ Dr. Brabb defined "possible" as follows: it cannot be precluded that there is some reasonable evidence in the photographs that lead him to the supposition that the features he sees might possibly be a fault. Tr. 1059 (Brabb).

Dr. Jackson testified that such an assumption is conservative because worldwide observations indicate that most of the time surface movement along the fault, or creep, would continue to occur for some time after the earthquake, as opposed to occurring entirely within the 20 to 30 second time of strongest ground motion. Tr. 1050 (Jackson). The USGS agreed with this conclusion. Tr. 1050 (Morris). Indeed, Dr. Jackson testified that the assumption of coseismicity is a worst case assumption. Tr. 1053 (Jackson).

58. The Staff also required, as part of its design basis, that the total surface offset and vibratory ground motion be considered to occur concurrently. This factor accounts for the uncertainty caused by insufficient evidence to indicate whether strong ground motion and surface fault displacement will be separated in time. Staff Ex. 1.B., Section A, at 6; Justus and Jackson, ff. 996, at 11.

59. The Board questioned the Staff geosciencies panel as to the conservatism involved in assuming that the design basis events will occur coseismically. Although the Staff and USGS scientists had different opinions as to the frequency with which fault creep may occur after an earthquake is over, the panel agreed that the assumption of coseismicity is a conservative one. Tr. 1050-53 (Jackson, Justus, Morris, Brabb, Herd and Devine).

60. In sum, the Board concurs with the Staff conclusion that the assumption of total amount of offset occurring beneath the reactor simultaneously with the time of maximum vibratory ground motion is a conservatism.

(7) Consideration of Probability Analyses

61. A significant conservatism proposed by the Staff is the requirement that surface offset be considered as part of the design basis for the GETR despite

the conclusion of statisticians that probability calculations indicate that such a likelihood is extremely low, especially beneath the reactor building. Justus and Jackson, ff. 996, at 11. A brief summary of the testimony on probability analysis, as well as the basis for this Board's conclusion, are set forth below.

62. In April 1979 GE submitted a probabilistic study in support of an argument that indicated a quantifiable lower likelihood of fault rupture between the existing shears than on them during an earthquake event. Lic. Ex. 10. As a result of discussions with the Staff (Tr. 1811-12 (Vesely)), the Licensee submitted a new probability analysis by Jack R. Benjamin and Associates (JBA) on March 12, 1980. Lic. Ex. 14. Based on the JBA results, which indicate that the probability of offset beneath GETR is $1 - 1.2 \times 10^{-6}$, GE maintains that a zero-offset design criteria be used for analyses. See also, Lic. Ex. 16.

63. As a result of questions by the ACRS subcommittee members, the Staff initiated a new review of this information and solicited the review assistance of Lawrence Livermore National Laboratory (LLL), which in turn utilized a subcontractor, the TERA Corporation (TERA). In addition to its review of the GE methodology and model, LLL/TERA developed its own model and methodology. The validity of the geologic parameters input assumptions was assessed and a judgment regarding overall applicability of this proposed method was made with the assistance of David B. Slemmons. Dr. Slemmons' letter report was introduced as Appendix E to the Staff Ex. 1.B. The review of GE's "Additional Probability Analysis" by LLL and TERA was presented as Appendix F to Staff Ex. 1.B. The Staff's evaluation of the proposed JBA/GE probabilistic model and the LLL/TERA report is contained in Section B of Staff Ex. 1.B., and was prepared by Dr. William Vesely.

64. GE's consultant calculated a best estimate probability for a surface displacement of any size under the reactor of 10^{-6} per year, with an upper bound or worst case probability of 10^{-4} per year. Lic. Ex. 1 at 80-82. The data from the on-site trenches showed that there were repeated movements along the two shears which bracketed the reactor building, but with no movement or shears having occurred between the shears or under the reactor building foundation for a least 128,000 to 195,000 years. Lic. Ex. 1 at 72. Given these facts, GE developed a simple model which calculated the probability that a surface displacement of any size would occur between the shears and intersect the foundation of the reactor building. Lic. Ex. 1 at 72-79; Lic. Ex. 10. This model yielded an annual probability in the order of 10^{-6} to 10^{-7} per year for a surface displacement of any size beneath the reactor building. Lic. Ex. 1 at 72-79; Lic. Ex. 10.

65. Since the initial model assumed that a new fault could occur at random at any location between the existing shears, and that the timing of the event would be random, the Staff requested that a new model be developed to test the validity of the random time assumption or "Poisson" model. Tr. 543-60 (Reed); Tr. 1811-12 (Vesely). GE developed a more complex model which used a "hazard-increasing function," under which the likelihood of a shear between the existing shears increased as the time since the last earthquake increases. Tr. 462 (Reed); Lic. Ex. 1 at 79-82; Lic. Ex. 14. Further, the NRC Staff requested sensitivity analyses be performed under which the geologic input parameters could be varied and the results analyzed to determine whether and in what way variations in geologic parameters would change the end results of the probability analysis. Lic. Ex. 1 at 79-82; Tr. 1811-12 (Vesely). The hazard-increasing function model yielded results which were within at least

a factor of 10 of the Poisson model. Lic. Ex. 1 at 79-82; Lic. Ex. 10; Lic. Ex. 14. The best estimate probability was about 10^{-6} per year, with values ranging up to 7.2×10^{-6} per year. Lic. Ex. 1 at 81; Lic. Ex. 14. The sensitivity analyses indicated that in order to achieve a probability greater than 10^{-5} per year, it was necessary to select unrealistic values of geological input parameters (e.g., soil ages younger than any which the geological experts would support). Lic. Ex. 1 at 82-83. Thus, an absolute upper bound on the annual probability of a surface displacement of any size beneath the reactor foundation would be 10^{-4} per year. Lic. Ex. 1 at 82-83; Lic. Ex. 16.

66. The Intervenors presented testimony of Professor Brillinger in regard to the GE probability analyses. Int. Ex. 5. Professor Brillinger's basic criticisms of the GE probability analyses appeared to be that GE's modelling assumptions (a) used Bayesian techiques and (b) did not account for the three dimensions of the reactor building. Int. Ex. 5 at 3. He did not offer any criticism of the probability testimony presented by the Staff.

67. Professor Brillinger was critical of the modelling techniques employed in the GE consultant analyses. Professor Brillinger preferred "classical" statistical techniques to Bayesian techniques, inasmuch as Bayesian techniques require the application of judgment. Tr. 721-4 (Brillinger); Int. Ex. 5 at 5. On the other hand, Staff witness Dr. Vesely testified that Bayesian techniques can be and have been used in NRC regulatory practice for making probability assessments, if they are accompanied by sensitivity analyses which qualify the judgmental factors. Tr. 1813-14 (Vesely). For example, they have been used in risk analyses of nuclear reactors, as well as in developing test guidelines for their components. Tr. 1814-15 (Vesely). However, Dr. Brillinger did not review the Licensee's parametric sensitivity

analysis of its earlier probability studies. Cf. Int. Ex. 6 with Lic. Ex. 16. The Staff also conducted sensitivity studies, the results of which are discussed below. In light of Dr. Brillinger's failure to incorporate a review of the Licensee's or Staff's sensitivity studies into his evaluation of the use of Bayesian techniques in this analysis, the Board does not accord much weight to this criticism.

68. Professor Brillinger expressed his view that the probability analysis should have used a three dimensional geometric model. Int. Ex. 5 at 3; Tr. 790-91 (Brillinger). However, Professor Brillinger did not know whether this would significantly affect the results of the analysis. Tr. 519-20 (Brillinger). Staff witness Dr. Slemmons testified that the probability of the fault rupture in the GETR foundation would increase by 1.6 to 2.3 times over the results given by the JBA model if a multidimensional model were employed. Staff. Ex. 1.B., App. E, at 9. In the context of interpreting probability analyses, however, the Board notes that error bands of a factor of 10 to 100 are not large. Tr. 1869 (Vesely).

69. Dr. Brillinger, on the other hand, indicated that he did not perform any independent analyses, nor did he estimate the significance of the impact of any of his criticisms on the Licensee's probability analyses. Tr. 811-13 (Brillinger). As the Board noted on the record, Dr. Brillinger's testimony raises a number of very general questions, very few specific questions, and almost no answers. Tr. 811 (Chairman Grossman). For example, Dr. Brillinger indicated that one of his concerns was that assumptions in the JBA analysis could be incorrect. Tr. 829-30 (Brillinger). Although Intervenors argue that Dr. Brillinger concluded that certain assumptions were wrong (Int. Finding 21), Dr. Brillinger did not indicate any that he disagreed with.

Further, one of Dr. Brillinger's main criticism of the Licensee's probability analysis seemed to be that the Licensee employed conservative, rather than realistic, assumptions in the analysis. Tr. 712-14 (Brillinger). However, the result, he testified, would normally be that compounding conservatisms or values would tend to produce worse results rather than favorable ones for the Licensee. Id. at 714. When questioned, Dr. Brillinger could not conceive of an example why this would not also be the case for the probability analysis for GETR (i.e., why the use of conservative assumptions would not also produce a conservative probability analysis which overstates the likelihood of a design basis geologic event at the GETR). Id. For these reasons, also, the Board does not accord great weight to Dr. Brillinger's critique of the Licensee's probability analyses performed for this proceeding.

70. In order to provide an independent assessment of the Licensee's probability analysis, the NRC requested LLL to develop a probability analysis using alternative methodology. LLL in turn subcontracted a portion of the analysis to TERA Corporation. The TERA review was led by Lawrence Wight. The LLL/TERA review included a review and evaluation of GE's submittals to the NRC regarding the probability of surface rupture beneath the GETR. LLL/TERA also prepared an independent assessment of the probability of such a rupture. Bernreuter, ff. 1801, at 2.

71. TERA's analysis, concurred in by LLL, concluded that the probability of occurrence of a 1 meter offset on the main Verona fault zone is about 5×10^{-5} per year. Bernreuter, ff. 1801, at 2. This calculated probability was not determined by relying on historical seismicity data, which itself provides an indication of that occurrence relationship, but instead relied on a slip rate based on inferred occurrence of earthquakes on a fault. This earthquake

occurrence model resulted in the first of four conditional probabilities which when multiplied together result in the probability surface rupture beneath the GETR. Rather than using the slip rate from trenches B-1, B-2, and B-3, TERA and LLL independently calculated the slip rate, using the topographic expression between the Vallecitos hills and the valley within which the test reactor sits. The actual measurements taken from the trenches were used as an independent qualitative check on the results of the LLL/TERA analysis. Tr. 1803-04 (Wight). This strain rate, used in the modelling, was more conservative than the actual measured strain rate taken from offsets in the trenches. Cf. Tr. 1822 (Wight) with Stip. para. 2.a.

72. A second conditional probability was then calculated to determine, given the occurrence of an earthquake, what the likelihood would be of that earthquake-fault rupturing the surface. A third conditional probability was calculated to produce the likelihood, given an earthquake of a given size rupturing at the surface, of the fault at the surface rupturing by the GETR facility. The fourth conditional probability was estimated to determine, given the above conditions, what the likelihood was of a displacement being experienced at that point on the fault. LLL/TERA multiplied all of these conditional probabilities together, yielding the likelihood of various size displacements occurring on a postulated Verona fault. Tr. 1804-05 (Wight).

73. At this point, LLL/TERA applied two steps to determine the likelihood of displacements beneath the reactor. The first one was to determine the conditional probability of a geometric argument, the distance between the shears in trenches B-1/B-3 and B-2 compared with the size of the foundation. Tr. 1805 (Wight). This step would reduce the probability of 5×10^{-5} per year by a factor of .06 for an estimate that the offset will occur beneath the reactor.

Id.; Bernreuter, ff. 1801, at 2. A final step was then taken which was Bayesian in approach. This step was to take account of the fact that no shears had been experienced between the shears represented in trenches B-1/B-3 and B-2 for a given period of time. This last factor would reduce the probability of exceeding a 1 meter displacement beneath the reactor to the order of 10^{-6} to 10^{-8} per year. Tr. 1806 (Wight). All calculations done up to the final step would be classical statistical analysis, as opposed to Bayesian analysis. Id. at 1805. The conclusion of the LLL/TERA report is that the probability of faulting beneath the GETR is very low, and the use a mean plus 1 standard deviation value of 1 meter for net offset beneath the facility can be considered conservative. Bernreuter, ff. 1801, at 2.

74. Dr. Slemmons, who also performed a review of the probability analysis, had some critical comments about the GE analysis. Staff Ex. 1.B., App. E. However, he concluded that the Staff use of 1 meter of offset beneath the GETR is conservative in several respects: the likelihood of a new rupture through the foundation during the next faulting event is very low; the evidence for the three faults that were trenched near the site all have evidence for offset of from about 2 to 3 feet from the most recent faulting event, or series of events, and that the offsets observed in the trenches could have been the result of exagerated net-slip displacement from surficial gravity affects. Slemmons, ff. 996, at 3. Dr. William Vesely of the Staff reviewed the probability analysis and models developed by GE's consultants, as well as those of LLL and TERA, regarding the probability of surface rupture at GETR. As part of this review, he specifically evaluated the various sensitivity studies that were performed by GE and himself and the critiques that were made to determine the credible results that could be obtained from the probabilistic modelling. Vesely, ff. 1801, at 2.

75. Based on his review, Dr. Ve~:ly concluded that the probability models could be used to predict gross probabilities of surface rupture. He also concluded, as indicated in his report (Staff. Ex. 1.B., Section B), that upper bounds on the probability of surface rupture could be obtained which accounted for various data and modelling uncertainties. Based on the sensitivity analysis performed by Dr. Vesely, GE's consultants, and LLL/TERA, and the alternative modelling, Dr. Vesely concluded that the probability of a surface rupture offset occurring beneath the reactor building has been showed between lie between 1×10^{-6} per year and 1×10^{-5} per year (to order of magnitude precision), with 1×10^{-4} per year being a conservative upper bound. He concluded that the probability results for the GETR are credible and should be used to supplement the deterministic evaluations in making a final decision. Vesely, ff. 1801, at 3. Indeed, the Intervenors' witness, Dr. Brillinger agreed that it was useful and reasonable to use a probabilistic study to supplement a deterministic or empirical finding. Tr. 842 (Brillinger).

76. The Board inquired of the Staff as to the probability of an unacceptable geologic event in relation to its analysis of the acceptability of restart of the facility. Dr. Jackson responded that the Staff normally requires that a geologic and seismic event be part of the design basis if the probability of that event is 10^{-3} to 10^{-4} per year. Tr. 1669 (Jackson). However, the Staff indicated that there are events for nuclear power plants involving core meltdown with annual probabilities on the order of 10^{-4} , and that these reactors have not been ordered to shutdown. Tr. 1821 (Vesely).

77. The Board recognizes that several members of the Staff geology/seismology panel cautioned against basing licensing decisions solely on probability. Tr. 1352-61 (Jackson, Brabb, Herd, Devine, Justus).[9/] However, as indicated by the Staff, probability assessments were not the sole basis for decision-making in this proceeding. They do however provide a frame of reference for making a judgment on geological offset parameters that are not at the upper bound for the dispersion of the available data. Furthermore, they help provide a perspective of the type of data which is needed and which is most critical to making a conservative estimate of the surface offset displacement. Staff Ex. 1.B. at 15, 16. The Board concurs with this observation.

78. On the basis of the probability analyses performed, the Board concludes that the inclusion of the one meter design offset for the GETR is indeed as conservatism as the Staff testified.

(8) Consideration of Subgrade Rupture Mechanism

79. A final conservatism in the Staff's proposed design basis is the consideration of surface offset even though geotechnical engineering considerations indicate that a fault will deflect around the reactor.

9/ The Intervenors assert that Dr. Brabb is concerned that some of the probabilistic studies used geologic parameter assumptions which are unreasonable. Int. Finding 60. The Board notes that Intervenors again misstate the record. In fact, Dr. Brabb testified that he felt that there was inadequate investigation of existing shears, causing him to question the adequacy of information used in the studies. Tr. 1538-39 (Brabb). Further, Dr. Brabb responded that he had neither done a study of the modelling or statistical analysis of any of the probability reports done for the GETR, nor that he had performed a thorough review of the geologic data that went into the probability analyses. (Tr. 1675 (Brabb).

80. Testimony was received and cross-examination was conducted on the results of a thrust fault rupture beneath the GETR.

81. The Licensee presented testimony to the effect that, based on its analysis, the postulated Verona fault would not surface beneath the GETR, but rather would deflect around it. Lic. Ex. 1 at 84-94; Lic. Ex. 20. The Staff had reviewed the Licensee's analysis and presented testimony which agreed with that analysis. Staff Ex. 1.D.; Pichumani, ff. 996.

82. The Intervenors offered no direct testimony on the issue of fault deflection.

83. The Licensee testified that, if a fault began beneath the reactor, the irregular loading condition in the soil beneath the reactor will cause deformation and flow of the soil in such a way that the dislocation will bypass the reactor. Lic. Ex. 1 at 92.

84. If the reactor were sitting on hard rock that was subjected to a thrust fault, the reactor would be lifted partially off the ground. Id. at 85. Part of the foundation would be suspended without support, a cantilever condition, and a relatively severe load imposed on the foundation. Id. at 86. If, however, the reactor was on soft mud or loose sand, the fault would not lift the reactor. Tr. 238 (Meehan). The soil would deform or flow in such a way that the fault would bypass the reactor. Lic. Ex. 1 at 86-87.

85. The soil beneath the GETR is neither hard rock or soft mud but something in between. Tr. 239 (Meehan). The base of the GETR foundation mat, which is located about 20 feet below grade, is underlain by very dense clayey sand and gravel with occasional layers of very dense sandy and/or gravelly clay to a depth of 70 feet. Stip. para. m. Groundwater levels were shown to vary from 20 to 28 feet below plant grade (Id.).

86. For purposes of design evaluation, GE assumed that the GETR site is geologically capable of thrust faulting, with thrust fault angles dipping from 10 to 45 degrees, dip being measured at or near ground surface. Lic. Ex. 20 at 4.

87. GE's stability analysis visualizes that the thrust fault forms a passive Rankine wedge of soil that is pushed by a major principal stress. Pichumani, ff. Tr. 996, at 5. The inputs to the calculations are the weight of the soil, the strength properties of the soil, the location of the groundwater table and the weight of the reactor. Tr. 2289 (Meehan).

88. The principal special condition that exists at GETR is the weight of the reactor, which is 4000 pounds per square foot. Tr. 2289 (Meehan).

89. The structural mechanics of a thrust fault can be simulated by applying a force to a block of soil. This vise-like squeezing will eventually cause a failure along a thrust fault. Lic. Ex. 1 at 91. Using a computer, the force for hundreds of possible failure planes was calculated. The force required to cause a failure plane that breaks ground directly beneath the reactor is always higher than the force required to cause a failure outside the reactor. Id. at 92.

90. GE concluded that the results of its computer analyses show that given the GETR foundation loads and dimensions, and the soil conditions known to exist to depths of 70 feet or more beneath the structure, faults beneath the GETR will be deflected in such a way that ground movement would occur outside of the perimeter of the reactor. Lic. Ex. 20 at 9.

91. The Staff testified that GE's method of wedge analysis is based on sound soil mechanics principles that have been accepted and applied by foundation engineers in the design of earth retaining structures. Pichumani, ff. Tr. 996,

at 5. The Staff's expert, Dr. Pichumani, testified that he was aware of one instance where a fault deflected around a massive structure, the Banco Central in Nicaragua. Tr. 1610 (Pichumani). None of the members of the Staff's geology/seismology panel had observed a fault deflecting around a structure. Tr. 1612-1614. However, Dr. Pichumani stated that all that fault movement means is a failure plane forms and the problem becomes the same as any other slope stability problem, types of which have been observed and analyzed many times before. Tr. 1637 (Pichumani). The weight of the GETR structure, 8000 tons, is the main consideration Tr. 1641 (Pichumani). The Licensee and the Staff noted that the conclusions reached by this analysis are specific to the conditions at the GETR. In the case of a lighter structure with the same soil conditions, the fault may not be deflected. Tr. 1640-1641 (Pichumani); Lic. Ex. 1 at 92, 93.

92. The Staff checked a few of GE's parametric calculations and found them to be correct. Pichumani, ff. Tr. 996, at 6. The Staff performed additional calculations for an assumed wedge depth of 100 feet using similar soil conditions and got similar results for the 21 foot surcharge load. Staff Ex. 1.D. at 4. The Staff would be concerned about the stability of the GETR structure if 6 or 7 feet of overburden were removed. Tr. 1668 (Pichumani).

93. An independent check of GE's conclusion was made by the Staff by performing a similar static stability analysis using a three-dimensional wedge. The results of this analysis confirmed GE's conclusion that the postulated thrust fault plane will be deflected away from the base of the reactor slab. Pichumani, ff. at 6, 7. Accordingly, the Board agrees that the assumption of surface offset occurring beneath the GETR is conservative in light of the above geotechnical engineering considerations.

e. Conclusion Regarding Geologic Design Bases

94. In consideration of the above factors, the Board agrees that the use of a surface offset design value of one meter beneath the GETR is reasonably conservative when placed in context of the total information presented in this proceeding. This conclusion is supported by all of the witnesses who testified as to the appropriate design value for surface offset beneath the GETR. Justus and Jackson, ff. 996, at 8-11; Slemmons, ff. 996, at 3. Newmark and Hall, Staff Ex. 1.B., App. A., at 5; Bernreuter, ff. 1801, at 2; Vesely, ff. 1801, at 3; and Harding, Jahns, and Reed, Lic. 1, at 2, 58, 68, and 84.

95. In addition, the Board agrees that the following geologic design parameters required by the Staff and pertinent to Issue 1 are appropriate: the outcrop width of the Verona fault zone at GETR be taken as at least 2200 feet; the Verona fault splays existing or which may develop be assumed to vary in dip from 10-45 degrees, to have reverse-oblique net slip character, and to slip coseismically and simultaneously with strong ground motion. See Staff Ex. 1.B., Section A, at 5, 6.

96. Furthermore, to the extent that a seismic event could trigger a landslide near the GETR, the hazard from such an event has been adequately considered by the Staff and Licensee and was not in dispute in this proceeding. The parties have stipulated that: 1) the procedure used to assess landslide stability is appropriate; 2) the investigations regarding landslides meet 10 CFR Part 100 and the applicable NRC standard review plan section; 3) a 1.0 meter slope displacement is conservative, and 4) such slope displacements need only be considered to occur near the toe of the slope, at some distance from the GETR, and therefore need be considered in the design of safety related equipment located in that area such as the fuel flooding system piping, but need not be considered

in the design of the GETR reactor structure. Stipulation paragraphs 1-4, contained in Staff counsel letter to the Board dated May 22, 1981. The Board finds that these conclusions are adequately supported by the record (Staff Ex. 1.C., Part I) and agrees that a one meter slope displacement near the toe of the slope is an appropriate and conservative geologic design basis for this proceeding.

2. Seismologic Design Bases

97. The development of a seismic design value for a facility such as the GETR involves two basic steps. The first, involving the seismologist, requires the development of a controlling earthquake for the site in terms of its expected maximum magnitude and peak instrumental acceleration. The second step, involving earthquake engineer, involves the conversion of the peak instrumental acceleration values into effective accerations, or ground motions which the structure is actually expected to experience. These two steps are considered in turn.

a. Design Basis Earthquake

98. As indicated previously, the GETR site is located in a complex fault environment 2 to 3 kilometers east of the Calveras fault within the Verona fault zone and within 3 kilometers of the Las Positas fault. The regional seismicity was studied by Ellsworth and Marks, whose report was received into evidence as Appendix C to Staff Ex. 1.B.

99. The Board considers that the potential earthquake sources that are important in assessing the vibratory ground motion hazard at the GETR site are the Calaveras fault and the Verona fault. Staff. Ex. 1.A. at 30; Stip. para. 2.k. Of the two, the Calaveras fault has the greater potential for generating strong vibratory ground motion at the GETR site. The parties have stipulated that a

magnitude 7 to 7.5 event could be associated with this fault system. Stip. paras. 2.k., r.; Tr. 695 (Jahns). This value is supported by the testimony of Staff and Licensee seismologists. Devine, ff. 996, at 3; Tr. 681-82 (Kovach). It is well established that faults which are branches of and subsidiary to the San Andreas fault have the potential for generating earthquakes ranging up to a maximum of magnitude 7.5. Stip. para. 2.1. A larger earthquake (magnitude 8 to 8 1/2) could occur on the main San Andreas fault, but due to its distance from the GETR site, approximately 50 kilometers, such an event would result in less vibratory ground motion at the site than would be caused by the potential events from the Calaveras or Verona fault. Staff Ex. 1.A. at 30.

100. The parties have also stipulated to the expected maximum magnitude event associated with the Verona fault, a value of M6 to 6.5. Stip. para. 2.k. The Board finds that this value is also adequately supported by the record. Dr. Kovach presented a correlation of fault area (area along the fault plane at depth) with magnitude for worldwide data in order to estimate the expected magnitude for the Verona fault. Lic. Ex. 21 at 14-16. This correlation yielded magnitudes ranging from 5.8 up to 6.3, with a most likely value of 6.1. For the stipulated fault length of 12 km, Dr. Kovach's estimate would be a magnitude of 6.0 or slightly less. Lic. Ex. 21 at 16.

101. Dr. Slemmons presented independently derived correlations of fault length, surface offset, and magnitude for a range of conditions which one might associate with the Verona fault. These analyses showed that for a 12 km length, one can expect a magnitude ranging between 6 to 6.5. Tr. 1187 (Slemmons);

Slemmons, ff. 996, at 3; Staff Ex. 1.B., App. E.[10/] Mr. Devine, the Assistant Director of Engineering Geology for the USGS, also agreed with the use of 6 to 6.5 magnitude for the Verona fault. Devine, ff. 996, at 3.

102. As noted previously, there was speculation on the part of Drs. Brabb and Herd that the Verona could be connected with the Las Positas fault. However, if the Verona fault were connected with the Las Positas fault, the additional 15 km length added by the strike-slip Las Positas fault would still not produce an estimated magnitude which would exceed 6.5 by more than one tenth of an order of magnitude. Tr. 1584-86 (Slemmons). This is because the fault length is not a very sensitive parameter when estimating magnitude based on the area of a fault. Tr. 1574 (Devine). For example, a change of fault area of 50% or so would have only a minor impact on the estimate of magnitude for the fault. Id. Dr. Kovach's correlations show that for an increase in length of a factor of 2, one might expect an increase in magnitude of 0.3. Lic. Ex. 21 at 16. Accordingly, the Board concludes that a magnitude 6.5 event on the Verona fault can be considered to be appropriate.

10/ The Intervenors mistakenly attribute a statement by Dr. Slemmons to be supportive of a magnitude 6.75 event on the Verona. Int. Finding 47. However, Intervenors have failed to understand that Dr. Slemmons was only indicating that depending on the type of faulting data base one selected from the worldwide data, a 3 feet offset could be correlated with an event of 6 to 6 3/4 magnitude. Tr. 1187 (Slemmons). However, he testified that: "... the magnitude to be expected on the Verona fault would be somewhere from somewhat above 6, 6-1/4 to approximately 6-1/2." Id. Intervenors further misstate the record by attributing to Dr. Slemmons the conclusion that if the Verona is connected to the Calaveras fault, the GETR site could experience a magnitude 7.3 earthquake on the Verona fault. Int. Finding 50. An accurate portrayal of Dr. Slemmons' testimony is that the 7.3 number is the result of inadequate data, but that this has been since remedied by his newer plot, with a result near 6.7 Tr. 1207-08 (Slemmons).

103. The maximum vibratory ground motion that could be associated with events on the Calaveras and Verona faults were described for the Staff by Mr. Devine as follows:

> Maximum vibratory ground motion at the GETR site would result from a magnitude 7 to 7.5 earthquake centered on the sector of the Calaveras fault nearest the site, with acceleration peaks at the free-field surface (i.e. without incorporating factors dependent on soil-structure interaction or behavior of the structure) which could be slightly in excess of 1 g. The horizontal vibratory ground motion at the GETR site resulting from an earthquake of magnitude 6 to 6.5 centered on the Verona fault could contain acceleration peaks as high as 1 g, but the overall level and duration of shaking would be less than that expected from the Calaveras fault. Devine, ff. 996, at 3.

104. GE presented testimony by Dr. Kovach in which the peak instrumental values for relevant earthquake records were discussed and analyzed. Dr. Kovach developed a correlation of peak instrumental acceleration with distance data from the 1979 Imperial Valley and 1979 Coyote Lake earthquakes records. Lic. Ex. 21 at 17-18. Dr. Kovach then tested this correlation against maximum peak instrumental acceleration data for seven earthquakes ranging in magnitude from 7 through 7.7. Id. at 19-20. Based upon this correlation, Dr. Kovach determined that for the GETR site, expected values of peak instrumental accelerations would range from .58 g to .74 g for a magnitude 7 to 7.5 event on the Calaveras fault. He concluded that expected accelerations would range up to about .4 g for a 6 to 6.5 event on the Verona fault. Lic. Ex. 21 at 21-22; Tr. 593-96 (Kovach).

105. In response to Intervenors' questioning, Licensee and Staff witnesses indicated that they had not used all peak acceleration values instrumentally recorded during the 1971 San Fernando event at the Pacoima Dam, or the 1979 Imperial Valley earthquake. See, Tr. 675-79 (Kovach), and Tr. 1020-21, 1671-74

(Devine). However, the site conditions at the Pacoima Dam were unique. The accelerometer which recorded the high peak acceleration value at Pacoima Dam was located on a steep ridge which runs up to the abutment of the dam, which had the effect of concentrating energy and amplifying the recorded acceleration. Lic. Ex. 21 at 22; Tr. 2003-5 (Bolt). No such ridge exists at the GETR site, nor is there any geological analog at the site. Tr. 2005 (Harding). The GETR site is underlain by dense, stable Livermore gravels which would not exhibit any tendency to amplify vibratory ground motion in any manner resembling the Pacoima Dam conditions. Tr. 1596 (Brabb); Tr. 2002-03 (Jahns). No damage was observed at Pacoima Dam in spite of recorded accelerations exceeding 1.2 g. Tr. 1713-15 (Hall).

106. Dr. William Hall presented a comparison of the Regulatory Guide 1.60 response spectrum to the earthquake record for the Pacoima Dam site. Dr. Hall's comparison shows that the Regulatory Guide 1.60 spectrum, when anchored to 0.75 g effective, exceeds the Pacoima Dam record in all cases except for several short duration, high frequency peaks, which would not affect the structure of a nuclear power plant. Significantly, in spite of peak accelerations in excess of 1 g, there was no significant damage observed at the Pacoima Dam site. Tr. 1713-15 (Hall).

107. The Intervenors also questioned the 1.74 g vertical acceleration recorded at Station 6 during the Imperial Valley 1979 event. This data point was the product of peculiar site conditions which do not exist at the GETR site. The Imperial Valley Station 6 was located in a wedge of ground in close proximity to the intersection of two fault rupture locations. This tended to amplify the vertical throw and the corresponding vertical accelerations. Lic. Ex. 21 at 22-23; Tr. 1020, 1588-911 (1595-96 (Devine); Tr. 2001-2 (Bolt). In addition,

the soil/sediment conditions in the Imperial Valley bear directly on the observed accelerations. The Imperial Valley site is underlain by thick alluvium. This produced steep velocity gradients at the approach to the surface, which tended to amplify the vertical motion. Tr. 526-27 (Kovach); Lic. Ex. 42; Tr. 2001-3 (Bolt). Neither of these conditions found at Imperial Valley is found at the GETR site. The GETR is not located on a wedgelike portion of ground situated in close proximity to the junction of two fault ruptures. Tr. 2003 (Jahns). Moreover, the GETR site is not characterized by the presence of deep alluvial sediments. The GETR site is underlain at depth by dense Livermore gravels, and the high velocity gradients which contributed to the high vertical accelerations at Imperial Valley Station 6 cannot be expected at GETR. Stip. paras. 2.m., n.; Tr. 1596 (Brabb and Herd); Tr. 1997-98 (Harding).

108. Finally, the high vertical acceleration recorded at Station 6 occurred at frequencies in excess of 10 hertz, Tr. 2003 (Bolt) and was the result of a single peak of acceleration, rather than sustained ground motion. Tr. 1020 (Devine). This latter point is important, since such characteristics do not result in damage to a structure such as the GETR. Id.; see also, Tr. 2007-8 (Bolt).

109. Similarly, a 1.3 g vertical acceleration observed at the Gazli, USSR earthquake was caused by unusual site conditions leading to high velocity gradients (Tr. 690-95 (Kovach); Tr. 2005-6 (Bolt)) and the GETR site geology would not lead to comparable amplification. Tr. 1997-98 (Harding).

110. Intervenors questioned the Licensee witnesses about USGS Report 81-365 and its effect on correlating acceleration values with earthquake magnitude. Tr. 621, 634; see also, Int. Findings 3, 6. However, Mr. Devine of the USGS testified that this report was supportive of his conclusion that the appro-

priate peak accelerations felt at the GETR associated with magnitude 7.5 and 6.5 events on the Calaveras and Verona faults, respectively, of slightly in excess of 1 g. and as high as 1 g., respectively. Devine, ff. 996, at 3.

111. The Intervenors also questioned, on the basis of the Imperial Valley earthquake record data points, whether it is conservative to specify vertical accelerations as 2/3 of the horizontal accelerations, pointing to a few data points where vertical accelerations exceeded this ratio. The Licensee and Staff witnesses agreed that the relevant data show that, after anomalous readings are eliminated, it is appropriate to treat vertical accelerations as 2/3 the amount for the horizontals. Tr. 524-26 (Kovach); Tr. 1647-49 (Devine); Tr. 1718-19 (Hall); Tr. 2007-8, 2030-32 (Bolt). Significantly, the few instances where verticals do exceed horizontals are generally characterized as involving frequencies of oscillations in the upper end of the scale, which are not of concern to structures. Id.; see also Tr. 1725 (Martore).

112. An additional significant factor is that buildings in general are inherently strong in the vertical direction, and the rigid massive structures involved in nuclear power plants are relatively insensitive to vertical loadings. Tr. 699-70; 2082-89 (Kost). Vertical loadings account for an insignificant fraction of the total loads placed on a nuclear power plant structure under design basis seismic conditions. Tr. 2082-89 (Kost); Tr. 1727 (Hall). Therefore, the Board concludes that the Staff's use of vertical accelerations 2/3 of the size of the horizontal accelerations is well supported by the evidence.

113. Finally, the Intervenors questioned whether seismic focusing or directivity could result in amplification of accelerations at the GETR site, apparently referring to a paper published by Dr. Bolt concerning the Livermore/

Greenville earthquake sequence. Tr. 575-8 (Questioning by Barlow). At the Intervenors' urging, GE produced Dr. Bolt as a witness. See Tr. 1991-2076. Dr. Bolt testified that the phenomenon of seismic focusing is part of every earthquake, and therefore is part of the data base and cannot be separated from it (Tr. 2001 (Bolt)), but that its significance in terms of effects may be quite small. Id. at 2001. Dr. Kovach and Mr. Devine agreed that the effects of focusing are included in the existing earthquake data base from which the criteria for vibratory ground motion for the GETR are derived. Tr. 697 (Kovach); Tr. 1021 (Devine). Further, although focusing could have had a role in causing the results which occurred at Livermore (Tr. 1993-97 (Bolt)), it is unlikely that the observations of the Livermore earthquakes of 1980 would apply to the GETR site. Tr. 1997 (Harding). The Livermore site was characterized by deep layers of soft alluvium, while the GETR site is characterized at depth by dense Livermore gravels, which would not enhance the intensity of the ground motion as would conditions at Livermore. Id; Tr. 1997-98 (Harding). Consequently the Board finds that, to the extent focusing is a factor to be considered in establishing a seismic design basis for the GETR, it is an inherent part of the data base from which the seismic design basis was derived.

114. In conclusion, the Board finds on the basis of the record as a whole, and giving due consideration to the Intervenors' concerns raised during cross-examination, that it is reasonably conservative to factor into the seismic design basis for the GETR the following maximum effects from earthquakes: peak horizontal accelerations at the free-field surface slightly in excess of 1 g from the Calaveras fault, and up to 1 g peaks from the Verona, with vertical accelerations 2/3 of those values. We now turn to the analysis by

earthquake engineers to apply these values toward a proper seismic design value for use in the structural analysis for the GETR.

b. Effective Acceleration

115. Since the peak instrumental accelerations analyzed by the seismologist may not be directly applicable to structural analysis, the earthquake engineer must assimilate the data provided by the geologist and seismologist and develop a set of structural design parameters. Tr. 1698 (Hall); Tr. 2158-60 (Kost). The two principal design parameters are: a) a "response spectrum", and b) an "effective acceleration," to which the response spectrum was anchored. The "response spectrum" is a plot of the responses of a number of simple damped oscillators, having various frequencies in terms of the acceleration of the mass, the relative velocity, and the relative displacement. Tr. 1708-09 (Hall); see Staff Ex. 8. This curve, which in the GETR case was prescribed by Regulatory Guide 1.60 (R.G. 1.60), was derived from a statistical compilation of historic earthquake ground motion records, and envelopes the mean plus one standard deviation of the data from those records. Tr. 1677; 1711-13 (Hall).

116. Drs. Newmark and Hall selected the Regulatory Guide 1.60 response spectrum to characterize, as a function of frequency, the response velocities, displacements, and accelerations for use in the structural analysis. Staff Ex. 1.B., App. A, at 2, 3. In recognition that structural response and damage potential is related to repeated motions of strong energy content, and considering the Staff recommendation of peak instrumental accelerations, Drs. Newmark and Hall recommended acceleration values of .75 g effective and .6 g effective as conservative anchor points for locating the response spectrum for events correlated with the Calaveras and Verona faults, respectively. Ex. 1.C., App. A, report of Sept. 29, 1980, at 6-8; Hall, ff. 1680, at 5.

117. Effective acceleration was defined by Dr. Hall, quoting from Dr. Nathan Newmark, as:

> that acceleration which is most closely related to structural response and to damage potential of an earthquake. It differs from and is less than the peak free-field acceleration. It is a function of the size of the loaded area, the frequency content of the excitation, which in turn depends on the closeness to the source of the earthquake, and to the weight, embedment, and stiffness of the structure and its foundation. Hall, ff. 1680, at 4.

118. The analysis by Drs. Newmark and Hall indicated that .6 g and .4 g would represent acceptable values for effective acceleration associated with events on the Calaveras and Verona faults, respectively. Staff Ex. 1.B., App. A at 5; Staff Ex. 1.C., App., report of Sept. 29, 1980, at 8. Drs. Newmark and Hall added an additional margin of conservatism to each of these values when he chose the values of .75 g effective and .6 g effective for the Calaveras and Verona faults, respectively. Id. In order to account for greater uncertainty in the geological and seismological base of information for the Verona fault, and because of the use of magnitude 6.5 value for an earthquake on this fault, Drs. Newmark and Hall added a greater margin of conservatism to their choice of an acceleration value for the Verona. Id. The Staff specified that these horizontal accelerations represented by the Regulatory Guide 1.60 response spectrum should be multiplied by a factor of two-thirds to obtain the appropriate values for vertical accelerations for design purposes. Tr. 2258-59 (Martore).

119. In selecting the anchor point, the amplitude of peak instrumental accelerations is not the sole parameter of interest to the earthquake engineer. Single high frequency, high amplitude peak instrumental acceleration values identified by the seismologist are not useful indicators of damage potential and structural response resulting from vibratory ground motion. The earth-

quake engineer will consider the frequency and duration of these peaks in light of the characteristics of the structure. Tr. 1714-15, 1740-41 (Hall); Tr. 1725 (Martore). High frequency, short duration instrumental peaks such as those observed during the 1971 San Fernando earthquake, will not significantly affect the characteristically massive structures associated with nuclear reactors. Id.

120. In this sense, then, in accordance with the definition given by Dr. Newmark, the effective acceleration normally is not that value connected with the high spikes of instrumentally recorded high frequency accelerations commonly found to occur close to the source of seismic energy release, such as in the case with GETR with respect to the Verona and Calaveras faults. On the other hand, the effective acceleration would be expected to be very close to the peak instrumental acceleration for locations at significant distances from the source, zones where such high frequency acceleration peaks normally are not encountered. Accordingly, for design purposes, the effective acceleration value is used to anchor the design response spectrum. Hall, ff. 1680, at 5; see also Tr. 2158-63 (Kost).

121. The Board notes that Intervenors did not present any affirmative evidence on the matter of earthquake engineering, nor did they draw into serious question any of the Staff-recommended seismic design bases. In light of the uncontroverted evidence on this point, the Board concludes that it is appropriate to use earthquake engineering judgment to reduce peak acceleration values for the GETR to effective acceleration values of .75 g and .6 g to represent seismic design bases for this proceeding.

c. Conclusion Regarding Seismologic Design Bases

122. The Board finds that in arriving at the design basis values for vibratory ground motion, the Staff relied upon data and methods which are well supported by the available evidence and well established in nuclear regulatory practice. Moreover, the Staff gave proper recognition to the available instrumental earthquake records, and the peculiarities of those records. For the GETR, the Board concludes that Regulatory Guide 1.60 Response Spectra, anchored to .75 g effective acceleration and .6 g effective acceleration for events on the Calaveras and Verona faults, respectively, are conservative seismic design bases.

B: ISSUE TWO: WHETHER THE DESIGN OF GETR STRUCTURES, SYSTEMS AND COMPONENTS IMPORTANT TO SAFETY REQUIRES MODIFICATION CONSIDERING THE SEISMIC DESIGN BASES DETERMINED IN ISSUE ONE ABOVE, AND IF SO, WHETHER ANY MODIFICATION[S] CAN BE MADE SO THAT GETR STRUCTURES, SYSTEMS AND COMPONENTS IMPORTANT TO SAFETY CAN REMAIN FUNCTIONAL IN LIGHT OF THE DESIGN BASES DETERMINED IN ISSUE ONE ABOVE

123. The Licensee submitted prefiled direct testimony on this issue in a 131-page document entitled "Testimony of Garrison Kost, Harold Durlofsky and Dwight L. Gilliland Concerning Issue 2 Submitted on Behalf of the General Electric Company." Lic. Ex. 22.

124. The Staff submitted prefiled direct testimony on this issue. Burdoin, Martore and Nelson, ff. 2200. The Staff also introduced its Safety Evaluation which was originally sent as enclosures to Staff letters to the Licensee dated October 27, 1980 and January 15, 1981. Staff Ex. 1.C., 1.D.

125. The Intervenors submitted prefiled direct testimony on this issue in the form of a page containing the statement of Mr. John B. Rutherford. Rutherford, ff. 2201.

126. Intervenors' witness' direct testimony consisted essentially of a statement that, as a structural engineer, he could not guarantee "that a structure will resist the estimated amount of earth movement occurring beneath or directly adjacent to the structure without some structural damage." Tr. 2201 (Rutherford). The Board attempted to determine the basis for this unsupported statement. Tr. 2185. The witness had not reviewed the engineering studies done by the Licensee and the Staff. The witness also postulated release of radioactive material in the event of an earthquake, but could not specify any means by which the material could be released. Tr. 2197 (Rutherford). The witness had no specific information, either engineering, geologic

or seismic, to present to the Board in the form of analysis. Tr. 2193 (Rutherford).

127. Intervenors' proposed findings of fact concerning this issue[11/] consisted of statements taken from the testimony of Glenn Barlow. As noted in the findings for Issue One supra,[12/] Mr. Barlow's testimony was not admitted into evidence by the Board.

128. The Board therefore bases its finding on material submitted by the Licensee and the Staff, as modified in response to Board questions and cross-examination.

1. Description of the Facility

129. The GETR is a high-flux, pressurized water reactor which operates at a maximum power of 50 MW thermal. Pressure is maintained in the pressurizer by nitrogen gas. The reactor core is contained in a 2-foot diameter cylindrical pressure vessel positioned on the bottom of a 9-foot diameter pool. The pool is flooded with demineralized water to a level 11 feet above the top of the reactor vessel or 23 feet above the core. Demineralized water is pumped through the reactor vessel and out to heat exchangers for cooling. Coolant enters the pressure vessel near the top of the reactor vessel via two 12 inch diameter inlet pipes, flows downward through the core and out near the bottom via two 12-inch diameter outlet pipes. The reactor

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11/ "Intervenors' Proposed Findings of Fact and Conclusions of Law "dated July 23, 1981, findings 93 through 100.

12/ Fn. 6. See also, "NRC Staff's Brief in Support of Certain Proposed Conclusions of Law," dated July 31, 1981.

coolant operates at a maximum temperature of 180 degrees F and maximum pressure of 150 psig. The coolant is subcooled at atmospheric pressure. Staff Ex. 1.C, at A-1; Lic. Ex. 22 at 2-6.

130. The reactor does not produce electricity, and dissipates the heat produced through coolant towers. It operates at a stable steady state power level without any load demand changes. Lic. Ex. 22 at 3.

131. The reactor, primary coolant system, irradiated fuel storage facility, experimental facilities and miscellaneous reactor auxiliary systems are housed in a reinforced concrete structure located in a steel contaiment building. The structure is of heavy, massive construction. The foundation mat is 4'8" thick. The vertical walls that make up the sides of the concrete core structures are 6'6" thick. Tr. 1912 (Kost).

132. The reactor core contains square cross-section fuel elements, filler pieces, and six bottom-mounted, top-entry control rods arranged in a close-packed square array. Experiment capsules may be positioned in the filler pieces to utilize the high core neutron flux. The number and position of fuel and filler pieces is adjusted as necessary to achieve the appropriate reactivity balance and flux distribution. Surrounding the square array, appropriately shaped beryllium and aluminum peripheral pieces round the core into a 2-foot diameter, 3-foot high cylinder. Lic. Ex. 22 at 8.

133. The six individually actuated combination control rod and fuel follower assemblies are each separated from the other by at least one lattice unit. Shutdown or scram action permits the simultaneous drop of all control rods by gravity with primary coolant assist. The fuel follower section drops out of the core and the poison section enters the core. Any combination of

five control rods provides a minimum shutdown margin of at least 1.0% $\Delta k/k$ under all reactor loading or operating conditions. For the normal core, which contains an equilibrium xenon concentration and partly burned fuel, either center rod or any combination of three or more rods is sufficient to ensure lasting subcriticality. Lic. Ex. 22 at 9.

134. A storage facility (canal) for irradiated fuel is located adjacent to the pool and is also within the massive concrete shielding structure. The canal is filled with high purity demineralized water. Canal gates, which normally separate the pool and canal, are removed during shutdown to facilitate refueling. The irradiated fuel is stored in leak-tight fuel storage tanks located in the bottom of the canal. The canal water is circulated through a separate heat exchanger system to remove residual heat from the stored fuel. Lic. Ex. 22 at 9.

135. A domed, cylindrical steel containment building encloses the reactor, pool, adjace storage canal, shielding, heat exchangers, primary pump, and reactor servicing and experiment areas. The containment building extends approximately 90 feet above ground and 20 feet below ground surface; the diameter is 66 feet. Containment building penetrations permit secondary coolant water to be pumped from the primary, pool and canal system heat exchangers to the cooling tower. Control and instrument penetrations permit reactor control and experiment instrumentation to be monitored in the adjacent reactor control room. Lic. Ex. 22 at 13.

136. Based on the uncontroverted testimony of the Licensee and Staff, the Board finds that the foregoing description is an accurate depiction of the GETR facility.

2. Operation of Reactor Cooling System Following Scram/Shutdown

137. A natural convection cooling system provides backup cooling for the reactor under certain emergency conditions and also during normal shutdown periods. In the event of high reactor inlet temperature, low reactor differential pressure, low primary cooling flow or seismic switch trip, the reactor scrams and an emergency cooling trip signal causes four valves to open the primary system to the reactor pool. A pneumatically reset, solenoid-tripped, spring-to-open, emergency cooling valve is provided on each leg of the two primary inlet cooling lines. In each of the primary coolant outlet lines in the reactor pool, check valves (installed vertically) open due to gravity when the primary system is depressurized. If the primary pump continues to run, approximately 33% of the primary flow is bypassed to and from the pool with the cooler water from the pool mixing with the primary system. If the primary pump stops, the flow through the reactor reverses in a short interval; and natural convection cooling circulates from the pool through the open check valves up through the core and back to the pool via the emergency cooling valves. The residual heat from the relatively small mass of the core and structure can easily be removed following shutdown or scram so long as makeup water is available (normally supplied from the pool via the vertical check valves into the bottom of the core). No electrical energy is required to maintain a safe shutdown status for extended period. Lic. Ex. 22 at 11, 13, 14. The decay heat load for the GETR is about 2 percent of a modern power reactor. Within 40 hours after shutdown, it is at a level of about .1 megawatt thermal. Tr. 1906 (Gilliland). As long as the fuel is kept covered with water, the cladding temperature of the fuel will remain low enough to prevent damage by means of heat transfer due to pool boiling. Staff Ex. 1.C. at A-2.

138. The Board finds that the shutdown and cooling sequence presented above is consistent with the uncontroverted evidence developed in the record of this proceeding.

3. Postulated Accident Following Design Basis Event

139. The Board has determined that one meter of offset coupled with .6 g effective acceleration for an event on the Verona fault, as well as a .75 g effective acceleration for an event on the Calaveras fault with no simultaneous offset, are conservative geologic and seismic design bases. Sections II.A.1.e. and II.A.2.c, supra.

140. The Licensee considered three steps necessary for providing protection during and following the design basis seismic event:

> (1) Reactor scram at the onset of the seismic event to terminate the fission heat source.
>
> (2) Initial removal of decay heat by boiling/evaporation of the water inventory existing in the reactor pool and fuel storage canal at the onset of the seismic event.
>
> (3) Long-term cooling/decay heat removal by providing sufficient makeup water flow to the reactor vessel and fuel storage containers.

Staff Ex. 1.C. at A-1; Lic. Ex. 22 at 16.

141. Based on a review of possible failures resulting from the seismic event, both the Staff and the Licensee concluded that the rupture of the primary coolant piping, for determination of reactor cooling requirements, is the most limiting postulated accident to follow from the design basis seismic event. Staff Ex. 1.C. at A-3.

142. The assumptions made for evaluating this postulated accident include:

(1) The worst postulated earthquake occurs with reactor trip initiated by the seismic scram system;

(2) Simultaneous non-mechanistic rupture of the primary system piping; and

(3) Heat transfer and decay heat rates based on 25 day power run of the reactor operating at 50 MW.

Staff Ex. 1.C. at A-2; Lic. Ex. 22 at 16, 17.

143. Results of the analysis of the primary pipe rupture show that water will drain from the reactor vessel and pool through the primary return lines until the water reaches the level of the return line outlet from the reactor vessel (5.5 feet above the fuel). Lic. Ex. 22 at 16, 17; Staff Ex. 1.C. at A-1, A-2. The water level drops to the top of the core at 45 hours after the event assuming no makeup flow. At that time, the boil-off from decay-heat requires makeup water to the core at a rate of .8 gpm. Staff Ex. 1.C. at A-2.

144. The Staff and the Licensee concluded that the cooling water makeup requirements for stored fuel are set by the case which considered a freshly discharged core. The assumptions made for evaluating this fuel storage situation include:

(1) The seismic event occurs six hours after shutdown from a 25-day run at 50 MW;

(2) The temperature of the canal water is assumed to be 130°F;

(3) Heat transfer calculations for the stored fuel are based on decay heating equivalent to an infinite irradiation of a single core at 50 MW with a 6-hour decay prior to the seismic event; and

(4) The primary pipe rupture discussed above is assumed to occur due to the seismic event. Staff Ex. 1C at A-2; Lic. Ex. 22 at 19.

The results of the analysis show that following approximately 34 hours after shutdown with no makeup, water must be added to the fuel storage canal at a rate of 1.64 gpm to account for boil-off due to decay heat. This makeup flow rate requirement decreases with time. Staff Ex. 1.C. at A-2, Lic. Ex. 22 at 19.

145. Therefore, the total makeup flow requirement for both the core and the canal is 2.44 gpm. Tr. 2249 (Nelson).

146. The Board finds that the conclusions of the Licensee and the Staff as to the most limiting postulated accident and the assumptions made for its analysis are uncontroverted in the record of this proceeding and are reasonable to be used for accident analysis following a design basis event.

147. The Board concludes that because of the reduced power density of the GETR fuel following a reactor scram, heat transfer due to pool boiling is sufficient to maintain the cladding temperature low enough to prevent fuel damage. Thus, to prevent fuel damage it is sufficient to shut down the reactor and keep the fuel in the reactor and storage canals immersed in water.

4. Structures, Systems and Components Important to Safety

148. The Licensee has identified the systems necessary to shut down GETR, maintain the reactor in a safe shutdown condition and to cool stored fuel assuming the accident and fuel storage locations discussed above. These systems include new systems, existing systems and existing systems with modifications. The parties have stipulated that all of the safety-related structures, systems and components necessary to shut down the facility and

maintain the reactor in a safe shutdown condition during and following the design basis seismic events are identified in Table I, Section A of Staff Ex. 1.C. Stip. para. 2.q.

149. An amplification and further description of the structures, systems and components identified in Table I follows.

150. To assure emergency cooling by natural circulation of pool water or from the proposed Fuel Flooding System, the primary system must be shut down and depressurized. A seismic trip system will scram the reactor, open the emergency cooling valves and isolate the pressurizer at a low seismic activity level of approximately 0.01 g peak ground acceleration. The depressurization would be accomplished within one second of seismic scram actuation, prior to any significant seismic load being reached. In the event of a loss of power the emergency cooling valves fail open and the pressurizer isolation valves fail shut. Staff Ex. 1.C. at A-4.

151. The reactor concrete structure, reactor pressure vessel and the canal fuel storage tankes serve as the containers for fuel cooling water. Integrity of these structures must be maintained to assure that coolant leakage will not exceed that assumed in the analyses (60 gph from reactor pool; 400 gph from storage canal) and, in the case of the reactor concrete structure, that support for other safety related equipment is retained. Water contained within these structures at the time of the seismic event serves as the initial heat sink for fuel decay heat. Staff Ex. 1.C. at A-4.

152. The canal is separated from the pool by a 3-piece removable gate to allow underwater pool and canal transfers. All irradiated fuel, not in the core, is stored in racks designed to maintain a subcritical configuration. The racks

are inserted in stainless steel tanks. To replace the water removed by boiling, the proposed Fuel Flooding System will supply adequate water flow to the fuel stored in the canal in the event of a seismic event, without operator action. Modificiations to the fuel storage tanks include redundant supply line and nozzles for each tank. The nozzles are installed to act as siphon tubes to maintain all tanks at the same level. The reactor pressure vessel supports the core and other internals which must maintain their integrity. Staff Ex. 1.C. at A-4.

153. Control rods must function properly to shut down the reactor and maintain the reactor in a shutdown condition. All systems penetrating the reactor vessel or storage canal whose failure would result in an unanalyzed coolant leak path, must maintain their integrity. These systems include the pool and vessel drain lines, poison injection lines, capsule coolant system, canal emergency recirculation system, control rod drives and isolation valves associated with these systems. Restraints will be added and valves seismically qualified to assure the necessary integrity. Staff Ex. 1.C. at A-5.

154. A pneumatically closed, spring opened, solenoid-tripped, emergency cooling valve is provided on each of the two primary inlet cooling lines. A check valve is provided on each of two primary outlet cooling lines. On receipt of the seismic trip signal or a loss of power to these valves the emergency cooling valves open the primary system to the reactor pool. System depressurization is assured by closing the primary system pressurizer isolation valves and pressurizer supply valve. Depressurization does not cause flashing and blowdown of the primary system because the coolant is subcooled at atmospheric pressure. Staff Ex. 1.C. at A-5.

155. If a rupture occurs in the primary piping water will drain from the pool and reactor vessel until the level drops to the level of the anti-siphon valves. Standpipes will be added to the top of the check valves to insure that the water level in the reactor vessel remains above the core regardless of the water level in the pool. The standpipes serve as the injection points for makeup from the fuel flooding system. Staff Ex. 1.C. at A-5.

156. The fuel flooding system is initiated automatically by the seismic trip described above to provide water to the core and to the fuel storage tanks without operator action. The system will consist of two identical redundant legs each capable of delivering the required flow rate. The required flow rate of 2.44 gpm is the maximum evaporation rate from the irradiated fuel subsequent to postulated canal and pool drainage. Sufficient water is provided for seven days of operation at this flow rate. The reservoirs will be situated on a hill adjacent to the containment building at an elevation to provide adequate gravity feed flow. Each supply leg will approach and penetrate the containment building from a different angle and will be routed to the fuel storage baskets and to one of the stand pipes to be installed on the emergency cooling system. The flow control valves are air operated and fail open on loss of air. The solenoid air control valve will vent air pressure from the flow control valve opertor on loss of power, making the system fail safe. Staff Ex. 1.C. at A-5.

157. The Board concludes that the safety-related structures, systems and components discussed above are adequate to shut down GETR and maintain the reactor in a safe shutdown condition.

158. Testimony was offered and received into the record of this proceeding concerning whether the failure of other equipment during the design seismic event would jeopardize the safety-related equipment.

159. The Licensee proposed additional modifications to insure that failure of non safety-related equipment during the seismic event will not affect the capability to safely shut down the reactor. A description of these modifications follows.

a. Modifications to Provide Additional Assurance of Reactor Vessel Integrity

160. The reactor pressure vessel is centered in the pool five feet below the top of the vessel with three restraints. The restraints attach to the side of the pool. Evaluation showed that one of the pins was of inadequate strength, and it was replaced. Lic. Ex. 22 at 24.

161. There are four different kinds of restraints that are or will be installed on the primary piping system to eliminate stresses on the reactor vessel, thus assuring its integrity. The first kind strengthens the gusset below the 20-inch elbow connected to the primary pump discharge. A second restraint is a saddle and U-bolt arrangement that provides a vertical restraint for the 14-mch reactor vessel discharge pipe. The third type provides vertical restraint of the right pump discharge pipe and the left heat exchanger inlet pipe where the two run in parallel. It is planned to mount the restraint on the floor of the equipment room. The fourth category of pipe restraints are collars that attach the pipes to the walls. There are 16 of them, and they consist of them, and they consist of a clamp around the pipe with an interconnecting strut to a wall bracket. Lic. Ex. 22 at 24, 25.

162. In addition to the large pipe restraints described above, restraints were added to the small diameter piping that is connected to the bottom of the pool and the vessel. Lic. Ex. 22 at 25.

163. Restraints were also added to the primary heat exchanger. Collars were placed around the heat exchanger near its top and center. Struts were installed between the collar and attachment points on the walls. In addition, a restraint is attached to the bolt circle on the bottom of the heat exhanger with struts connecting the restraint with attachment points on the walls. Lic. Ex. 22 at 25.

164. Restraints were placed around the pool heat exchanger so it would not fall into the primary system piping. Standpipes were installed above the emergency cooling check valves so that in the unlikely event of loss of water from the pool, water would stay over the core. Lic. Ex. 22 at 25.

b. Modifications to Provide Additional Assurance of Canal Storage Tank Integrity

165. The canal storage tanks are located in the storage canal on the bottom at the end farthest from the pool. A new canal storage tank has been constructed that consists of three leak-tight inner tanks placed in a leak-tight outer tank. There are, thus, two leak-tight containers to assure water will remain over the stored fuel elements in the unlikely event that water is drained from the canal. The inner tanks are constructed of one-quarter-inch 304 stainless steel, and the outer tanks are of one-half-inch 304 stainless steel. The thick-walled outer container also provides physical protection for the inner tanks. Lic. Ex. 22 at 26.

166. Modifications have also been made to prevent equipment on the third floor from dropping on the canal storage tank or reactor pressure vessel. This missile impact system consists of a series of structural frames that are strategically located on the third floor of the reactor building, and are designed to prevent the overhead train assembly from impacting either the reactor vessel itself or the fuel storage tanks. The frames are covered with approximately 14 inches of aluminum honeycomb. The function of the honeycomb is to mitigate the postulated impact of the polar crane assembly, and in this way minimize the loads both on the frames and on the floor of the reactor building. Tr. 1919 (Durlofsky).

167. The Board concludes that the modifications proposed and/or made by the Licensee provide adequate assurance of the integrity of the reactor vessel and the canal storage tank.

5. Accident Analysis of Structures, Systems and Components Important to Safety

a. Seismic Scram System

168. The scram circuitry is activated by two kinemetrics triaxial seismic triggers. The three component triggers (two horizontal and one vertical) will replace the existing two component (two horizontal) triggers. The sensitivity of these seismic triggers is such that they will initiate trip signals at ground accelerations of 0.01 g and are seismically qualified to ground accelerations up to 0.5 g. Staff Ex. 1.C. at B-1.

169. The GETR scram system operates when (among other events) the seismic switches close. The reactor control rods are disengaged from the drive mechanism 180 milliseconds after either of these two seismic switches make

electrical contact. That is, all the electrical and electronic scram circuitry have operated and the control rod magnetic latch circuit has been interrupted and the control rod begun its drop by the end of 180 millisecond period. The control rod then drops by the forces of gravity and primary coolant flow so as to be fully inserted from a 36-inch withdrawn position within 500 milliseconds from the time the control rod is disengaged from the drive. Based on available rod drop data, it is conservatively estimated that within 300 milliseconds from the time the control rod is disengaged from the 36-inch withdrawal staring position, or 480 milliseconds from seismic switch trip, the control rods will be at or below the 12.2-inch withdrawn position whereupon the reactor is considered to be shut down. Staff Ex. 1.C. at B-8, B-9.

169. The emergency cooling power-operated valves, pressurizer valves and fuel flooding system admission valves are the only valves for which initiating action is by seismic trip or scram circuitry. The emergency cooling power-operated valves and the fuel flooding system admission valves begin to open and the pressurizer valves to close within 190 milliseconds after triggering of the scram system. The remainder of the valve operation is complete within a total of one second from scram seismic trip. Staff Ex. 1.C. at B-9.

170. In order to determine the adequacy of the seismic scram system, with regard to the trigger level (0.01 g) and time required to complete the scram action (1 second), the Licensee submitted a study of near field time histories to the Staff. The main object of this study was to determine whether consequential horizontal or vertical accelerations would be reached before completion of the scram action. Staff Ex. 1.C. at C-12.

171. The earthquake threat at the GETR site comes from two main sources, strike slip events (up to magnitude 7.5) on the Calaveras fault-2 km away and thrust events (up to magnitude 6.5) in the immediate vicinity of the plant. Thirty-six sets of records from well recorded events up to surface wave magnitude = 6.9 for strike slip and surface wave magnitude = 7.0 for thrust faulting were analyzed. Several sets of accelerograms were recorded at distances less than 1 kilometer from the fault. The data set can be considered a representative sample of all available data in the magnitude and distance range of interest. Envelopes of all horizontal and all vertical accelerations during the first second after recording 0.01 (the seismic trigger level) were computed and plotted. The highest peaks were associated with the Pacoima Dam record from 1971 San Fernando earthquake. These were 0.13 g for the horizontal component recorded 0.66 seconds after reading 0.01 g and 0.24 g for the vertical component recorded 0.52 seconds after reaching 0.01 g. It is the Staff's position that in determining the adequacy of the seismic scram system that high frequency ($\geq$ 10 Hz) peaks of this amplitude (approximately 0.25 g) could occur anytime during the first second after 0.01 g on either or all components of motion. Staff Ex. 1.C. at C-12.

172. The Staff testified that, based on the reliability assessment of the scram system, tests performed on the control rods and internal components, and evaluations performed, reasonable assurance is provided that the circuits required to perform automatic actions will function satisfactorily, considering the minor loadings postulated during the first second of the design seismic events. Staff Ex. 1.C. at B-4 to B-9, C-12.

173. The Board finds that the uncontroverted evidence in the record described above supports the conclusion that the seismic scram system will safely shut down the reactor on the onset of the design basis event.

b. Structural Analysis

174. The Staff and Licensee testified that, given the seismic design parameters, only the following structural and mechanical requirements must be satisfied:

> 1. The structural integrity of the massive concrete structure which supports other systems and components important to safety must be maintained.
>
> 2. The structural integrity of the reactor vessel and canal fuel storage tanks must be assured.
>
> 3. A source of water, including the associated piping system, must be available after the seismic event to provide water to the spent fuel canal storage tanks and the reactor pressure vessel to replenish that lost through boil off and evaporation in the process of cooling the fuel.

Staff Ex. 1.C. at C-2; Martore, ff. 2200 at 4; Lic. Ex. 22 at 23-24.

175. Upon questioning by the Board, Staff witness Nelson testified that containment integrity was not required for the design bases seismic event. Containment integrity is required to mitigate the consequences of GETR design bases accidents which involve a core melt. However, the worst accident caused by the seismic event was determined to be a loss-of-coolant accident by the quickest means, the rupture of the primary piping. This loss-of-coolant accident does not involve a core melt. The Staff did not take into account the possibility that there might be first a design-basis accident in which there was a need to rely upon the containment, and subsequently a

seismic event which might breach the containment. The Staff testified that there is no need to require that it be postulated that those two very low likelihood events be considered simultaneously for design purposes. Tr. 2212, 2214, 2215, 2230 (Nelson).

176. The Board notes that 10 CFR Part 50, Appendix A, Criterion 2 requires the design bases for nuclear power plants to reflect combinations of accident conditions with the effects of natural phenomena, such as earthquakes. The Staff responded that this regulation's applicability is limited to power plants and the GETR is not a power plant. Therefore, this requirement is not applicable to the GETR. See, "NRC Staff's Brief in Support of Certain Conclusions of Law" dated July 31, 1981. Based upon consideration of the Staff's arguments, the Board finds that 10 CFR Part 50, Appendix A, Criterion 2 is not required to apply to the GETR.

177. The Staff testified that Appendix A should not be used as a guideline in that the GETR differs from nuclear power plants in power level, fission product inventory, seismic scram system, lack of need for complex systems to mitigate accidents and the fact that at operating temperature the GETR is subcooled at atmospheric pressure. Tr. 2229 (Nelson).

178. In addition, the Staff has evaluated the offsite radiological impact associated with the design seismic events. The seismic event is assumed to result in breach of the containment above and below grade. Although the Staff's analysis shows the structural integrity of the pool and canal would be maintained, a release of the radioactive containments of the pool water was assumed in order to provide a bound of the radiological consequences of this event. No fuel failure, and hence no fission product release from the

fuel was postulated. It was postulated that all five test capsules would fail, thereby releasing the fission products which could have accumulated with the capsules. Staff Ex. 1.C. at D-1.

179. The offsite radiological consequences resulting from this postulated release are only fractions of the 10 CFR Part 100 guidelines. The 0-2 hour thyroid dose at the exclusion area boundary is 20 Rem, less than ten percent of the 10 CFR Part 100 guidelines values. The maximum 50-year organ dose from ingestion of water at the well nearest the site boundary is less than 10m rem to the GE tract - lower large intestine, from non-sorbed ^{106}Ru. Staff Ex. 1.C. at D-2.

180. The Staff concluded that no offsite radiological impact detrimental to the public health and safety will result from the postulated seismic event, assuming loss of containment. Staff Ex. 1.C. at D-2.

181. Based on the uncontested evidence submitted by the Staff in the record, the Board concurs with the Staff's conclusion.

182. The GETR facility, with proposed modifications, has been reanalyzed by General Electric, and reviewed by the NRC Staff and its consultants, to determine whether adequate assurance is provided that the GETR can safely withstand the effects of the seismic design events. Detailed reviews have been carried out on safety related structures, systems and components required to withstand the loadings representing the hazard defined by the seismic design criteria, including possible effects of shaking and faulting. Martore, ff. 2200 at 4.

183. Analyses were performed to determine representative and conservative input parameters to be used which would be consistent with the seismic

design criteria defined by the Verona fault hazards. Bearing capacity analyses were evaluated to determine the physical load limits on the combined load case comprised of a ground acceleration vibratory motion and a surface rupture offset, the latter represented analytically as an unsupported cantilevered length of the reactor building. Based on these analyses, the Licensee proposed physical limits on the combined loading of vibratory motion and unsupported length of the reactor building. The Staff however did not find the bearing capacity analyses acceptable. Further geotechnical engineering analyses, fault plane analyses, demonstrate that the postulated "unsupported cantilever length" is not expected to develop for the combined load case comprised of a ground acceleration and a surface rupture offset because the fault plane will be deflected away from the base of the GETR foundation mat. Therefore, the Staff concluded that the load combinations proposed by the Licensee provide a conservative representation of the limi ing load combinations resulting from the specific Veronal fault design basis event. Staff Ex. 1.C. at C-8.

184. Analysis of the reactor building for the effects due to the design seismic event on the Calaveras fault were performed using a three dimensional spring-mass model. Loads determined from these analyses were then used as input to a three dimensional finite-element stress analysis to verify that the core structure is adequate to withstand motions induced by the design criteria. Staff Ex. 1.C. at C-7; Lic. Ex. 22 at 48-54.

185. Analyses of the reactor building for the effects of the design parameters related to the Verona fault were performed by combining the effects resulting from the vibratory motion with those resulting from surface

rupture. The effects resulting from the vibratory motion were determined in a manner similar to that described above for the Calaveras event. That is, a spring-mass model was used to determine dynamic response, which was then used as input to a finite element analysis to determine stresses and deformations. The effects of the surface rupture were determined using a finite element model of that portion of the reactor building which supports and protects the safety-related equipment and components necessary for safe shutdown. Staff Ex. 1.C. at C-7; Lic. Ex. 22 at 54-56.

186. The fault orientation used in the analyses was that which produced the most critical loading case for the concrete core structure. The fault was considered to pass through the structure at several locations, and the corresponding effects were addressed. The fault location which produced the highest stresses in the core structure was that where the fault plane intersects the vertical plane containing the center of gravity of the reactor building, causing the building to act as a cantilever. Other fault locations which may cause more excessive deformations of the outer, non-essential reactor building walls were evaluated, but were found to cause less stress in the concrete core structure. The concrete core stresses were computed using a linear elastic three dimensional finite element program which included the consideration of potential cracking and yielding of the floor slabs. Staff Ex. 1.C. at C-7; Lic. Ex. 22 at 60-63.

187. The Licensee and the Staff testified that the detailed analyses performed for the vibratory ground motions and surface rupture offset demonstrate that the concrete core structure which surrounds the pool and storage canal will maintain its integrity in the event that major earthquake motions and/or

surface rupture occur at the GETR site. Thus, the structural and mechanical requirement to assure the integrity of the concrete core structure (which supports other systems and components important to safety) is met. Lic. Ex. 22 at 127; Staff Ex. 1.C. at C-13.

188. The integrity of the reactor vessel and the canal fuel storage tanks was evaluated by assuring the integrity of the supporting concrete core structure as discussed above, and by assuring the capability of all essential components and equipment to meet the seismic criteria. Evaluations of the reactor vessel lower head penetrations indicate that maximum stresses do not increase significantly during the design seismic events and remain less than 10% of allowable. Therefore, failure due to seismic effects is not expected. In addition, it was assured that the failure of any non-safety related components or equipment would not compromise the integrity of essential items. Staff Ex. 1.C. at C-9.

189. General Electric has evaluated the reactor vessel and internals, including the fuel and experiment capsules, for the loads resulting from the design seismic criteria. The fuel assemblies used in the core are flat-plate, uranium-aluminum alloy assemblies, consisting of 19 fuel plates each 0.050-inch thick (nominal), 2.80-in. wide and 3 .25-in. long. The fuel plates are roll-swaged into 6061-T6 aluminum side pieces, which act as protective skin containing the fuel. The allowable stress for this aluminum skin has been appropriately determined to be 200 PSI. This allowable stress does not take credit for the increased yield strength of the aluminum due to irradiation. The results of the seismic analyses indicate displacements at the core region

to be minimal, and stresses on the aluminum fuel covering, about 70 PSI, to be significantly below allowable. Staff Ex. 1.C. at C-9.

190. Supports for the piping system and the other safety related components have been analyzed in accordance with the requirements of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section III, Subsection NF. The piping systems have been evaluated against the loading combinations and acceptance criteria based upon the ASME Boiler and Pressure Vessel Code, Section III, Subsection NC for Class 2 piping. Staff Ex. 1.C. at C-4.

191. The allowable stress limits for structures, piping systems, and compponents are determined on the basis of material properties at temperatures corresponding to the specific load combinations. Staff Ex. 1.C. at C-5.

192. When appropriate, the procedures in the following concrete and structural codes have been utilized to evaluated the structures and components:

1. ACI 318-1971, "Building Code Requirements for Reinforced Concrete," American Concrete Institute, 1971.

2. AISC, "Specifications for Design Fabrication, and Erection of Structural Steel for Buildings," American Institute of Steel Construction, 1969.

Staff Ex. 1.C. at C-5.

193. In addition, to assure the integrity of the reactor pressure vessel and canal fuel storage tanks, to keep all fuel covered with water, a source of make-up water to replenish that lost through boil off and evaporation is required. To achieve this goal, General Electric has proposed to install a Fuel Flooding System with redundant gravity flow (no power required) supply capability. Staff Ex. 1.C. at C-10.

194. The system consists of two redundant legs each capable of delivering the design flow rate. Each reservoir site consists of two 50,000-gallon polyurethane flexible "pillow" or "bladder" tanks situated on a hill adjacent to the containment building at an elevation which provides adequate gravity fed flow. Each supply leg is constructed from 1½" I.D., reinforced snythetic rubber. The line is "snaked" in a shallow trench providing line slack and permitting the line to accommodate postulated surface faulting. The Licensee performed a test to demonstrate that the postulated surface offset would not cause the line to fail. Lic. Ex. 22 at 117. Through the yard area, the line is buried in a 4" stainless steel pipe which protects the line in the event of postulated surface faulting due to either a seismic event or seismic initiated landslide. Each supply leg approaches and penetrates the containment building from a different angle, and is routed to the irradiated fuel storage tanks in the canal and to the reactor pressure vessel. Each supply line inside the containment building is allowed to move within a protective cover. This arrangement protects the line and prevents unacceptably high seismic stresses. The lines inside the containment building are a combination of: (a) high pressure, high vacuum rated reinforced rubber, (b) stainless steel flexible hose, and (c) rigid stainless steel pipe. Reactor pressure vessel water addition (from the Fuel Flooding System) is to the reactor vessel standpipes previously discussed, and therefore, to the bottom of the pressure vessel. Staff Ex. 1.C. at C-10, C-11.

195. An in-service surveillance and inspection program has been developed for the Fuel Flooding System from the source tanks to the points of connection at

the reactor pressure vessel and the spent fuel storage tanks, including the interface with the containment structure. The design and analysis of the Fuel Flooding System together with the implementation of the in-service surveillance and inspection program, provide reasonable assurance that required makeup coolant flow to the reactor vessel and the fuel storage system is available following the design basis seismic events. Staff Ex. 1.C. at C-11.

196. The Licensee testified tha* the structural and mechanical analyses described in the testimony demonstrated that the GETR safety-related structures and equipment as modified meet the following requirements:

(1) The integrity of the reactor building concrete core structure which supports other systems and components important to safety is assured;

(2) The integrity of the reactor pressure vessel is assured;

(3) The integrity of the canal fuel storage tankes is assured; and

(4) The capability of providing make-up water to the spent fuel storage tanks and reactor pressure vessel is assured.

Lic. Ex. 22 at 131.

197. The Staff agreed with the Licensee and will impose technical specifications requiring completion of the modifications on the GETR before it resumes operation. Compliance with the technical specifications and periodic test and maintenance procedures will be verified by the NRC Office of Inspection and Enforcement. Tr. 2243 (Nelson).

6. Conclusion

198. The Board concludes that it has been demonstrated through structural and mechanical analyses that the GETR safety-related structures, systems and components, as modified, meet the requirements to assure that the reactor can be safely shutdown and maintained in a safe shutdown condition during and after the design basis seismic event.

III. CONCLUSIONS OF LAW

The Licensing Board has thoroughly reviewed and evaluated the evidence submitted by all parties with respect to the issues set forth in the Commission's February 13, 1978 Memorandum and Order. The Licensing Board has also considered all of the proposed findings of fact and conclusions of law submitted by the parties. Those proposed findings not adopted by the Board are herewith rejected. Based upon its evaluation of the Staff's and Licensee's safety evaluations, the admitted written testimony of all of the witnesses, as well as the answers elicited from these witnesses in response to questions of the Board and the parties, the Board makes the following conclusions of law:

1. The proper geologic and seismic design bases for the GETR should be as follows:

a) A surface offset design value of one meter of reverse-oblique net slip beneath the GETR should be utilized, along a fault plane of the 2200 foot-wide Verona fault zone, which could vary in dip from about 10 to 45 degrees, occurring during a single event.

b) The Regulatory Guide 1.60 Response Spectra, anchored to .75 g effective acceleration for an event on the Calaveras fault, and .6 g effective acceleration on the Verona fault.

c) Combined loads caused by fault offset at the surface and vibratory ground motion from the Verona fault must be considered to act simultaneously, and that the entire one meter of surface offset is considered to occur coseismically.

d) A seismic event could triger a landslide, causing a 1.0 meter slope displacement occurring near the toe of the slope, at some distance from the GETR; accordingly, the one meter offset caused by the landslide must be considered in the design of safety-related equipment located in the area of the toe, such as the fuel flodding system piping, but need not be considered in the design of the GETR reactor structure.

2. The General Design Criteria of Appendix A to 10 CFR Part 50 apply only to power reactors and does not apply to the GETR.

3. Appendix A to 10 CFR Part 100 applies to power reactors and not to facilities such as the GETR which does not produce electric or heat energy.

4. The design of GETR structures, systems and components important to safety do require modifications, and these modifications can be made so that the GETR structures, systems and components important to safety can remain functional in light of the seismic design bases determined in Issue One above.

5. The proffered testimony of James Glenn Barlow was properly excluded from the record in this proceeding.

IV. ORDER

WHEREFORE, IT IS ORDERED, in accordance with 10 CFR Sections 2.760(a) and 2.762, that this Initial Decision shall constitute the final action of the Commission thirty (30) days after the date of issuance hereof, unless exceptions are taken in accordance with Section 2.762 or the Commission directs that the record be certified to it for final decision. Any exceptions to this Initial Decision or designated portions thereof must be filed within ten (10) days after service of the decision. A brief in support of the exceptions must be filed within thirty (30) days thereafter (forty (40) days in the case of the NRC Staff). Within thirty (30) days of the filing and service of the brief of the appellant (forty (40) days in the case of the NRC Staff), any other party may file a brief in support of, or in opposition to, the exceptions.

IT IS SO ORDERED.

FOR THE ATOMIC SAFETY AND LICENSING BOARD

Herbert Grossman, Esq.

Dr. George A. Ferguson

Dr. Harry Foreman

Issued this ____ day of
___________, 1981 at
Bethesda, Maryland

Respectfully submitted,

Daniel T. Swanson
Counsel for NRC Staff

Richard G. Bachmann
Counsel for NRC Staff

Dated at Bethesda, Maryland
this 31st day of July, 1981

APPENDIX A - LIST OF EXHIBITS

(The Board adopts the list of exhibits contained in "Licensee's Proposed Findings of Fact and Conclusions of Law," dated July 6, 1981, Appendix A).