UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

ATOMIC SAFETY AND LICENSING BOARD

'82 JUL 20 A11 :26

Before Administrative Judges:
Herbert Grossman, Chairman
Dr. Frank F. Hooper
Gustave A. Linenberger

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In the Matter of	)	
	)	
SOUTH CAROLINA ELECTRIC AND GAS COMPANY, ET AL.	)	Docket No. 50-395 OL
	)	
	)	
(Virgil C. Summer Nuclear Station, Unit 1)	)	July 20, 1982

PARTIAL INITIAL DECISION

Appearances

On behalf of the Applicants:

Joseph B. Knotts, Jr., Esq., Debevoise & Liberman, Washington, D.C. and Randolph R. Mahan, Esq., Columbia, South Carolina

On behalf of the State of South Carolina:

Richard P. Wilson, Esq., Assistant Attorney General, Columbia, South Carolina

On behalf of the NRC Staff:

Steven Goldberg, Esq. and Mitzi A. Young, Esq., Washington, D.C.

On behalf of the Intervenor:

Brett Allen Bursey, pro se, Little Mountain, South Carolina

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PARTIAL INITIAL DECISION
(Seismic Issues)

I. INTRODUCTION

This matter is a contested operating license proceeding within the meaning of 10 C.F.R. § 2.4(n). This partial initial decision considers the application for issuance of a facility operating license to the South Carolina Electric & Gas Company ("SCE&G") and the South Carolina Public Service Authority ("SCPSA") (hereinafter "Applicants") to authorize the operation of the Virgil C. Summer Nuclear Station, Unit 1. The facility consists of a single pressurized water reactor located on SCE&G's site in Fairfield County, South Carolina. The reactor is designed to operate at core power levels up to 2785 thermal megawatts, with a net electrical output of approximately 900 megawatts. The facility is adjacent to Monticello Impoundment, an SCE&G-owned and operated pumped storage hydroelectric project (Federal Energy Regulatory Commission Project 1894), about one mile east of the Broad River and approximately twenty-six (26) miles northwest of Columbia, South Carolina.

On June 30, 1971, SCE&G, then the sole Applicant, filed an application with the Atomic Energy Commission, now the Nuclear Regulatory Commission, for a permit to construct and operate the V.C. Summer Nuclear Station, Unit 1. Construction Permit No. CPPR-94 was issued on March 21, 1973, following reviews by the Commission's Regulatory Staff and the Advisory Committee on Reactor Safeguards, as well as public hearings before an Atomic Safety and Licensing Board in

Winnsboro, South Carolina on January 29-30, 1973. LBP-73-11, 6 AEC 213 (1973); aff'd, ALAB-114, 6 AEC 253 (1973).

On May 17, 1974, SCE&G filed an application to amend its construction permit to add SCPSA as co-owner and co-licensee, having executed a sale of a one-third interest in the facility to SCPSA on October 18, 1973.

On April 18, 1977, the Commission published in the Federal Register (42 Fed. Reg. 20203) a notice of the receipt of an application by the Applicants for a facility operating license for the Summer facility. In response to that notice, Brett Allen Bursey ("Intervenor") filed a "Petition to Intervene" dated May 27, 1977. In that petition, Intervenor requested hearings. On June 8, 1977, this Atomic Safety and Licensing Board was established to rule on petitions to intervene. On July 15, 1977, the Board[1/] issued an Order granting Mr. Bursey leave to intervene. [2/] On March 23, 1978, the Board issued a Memorandum and Order granting the State of South Carolina's March 10, 1978 petition to participate as an interested State pursuant to 10 C.F.R. § 2.715(c).

1/ Pursuant to Notice issued January 9, 1978, the Board was reconstituted to reflect appointment of Ivan W. Smith, Esq. to replace former Chairman Fredric J. Coufal, Esq. whose schedule did not allow him to continue in this case. Pursuant to Notice issued January 17, 1980, the Board was again reconstituted to reflect appointment of the current Chairman, Herbert Grossman to replace former Chairman Ivan W. Smith, Esq., whose schedule did not allow him to continue in this case.

2/ The intervention was granted over Applicant's objections as to timeliness and failure to submit a contention meeting the requirements of the NRC's regulations.

On March 23, 1981 an organization comprised of Fairfield County residents, Fairfield United Action ("FUA"), filed a petition for leave to intervene, to which it attached twenty-seven proposed contentions and their bases. Applicants and NRC Staff opposed the petition. On April 30, the Board granted the FUA petition and accepted ten (10) of its contentions for litigation. The ten accepted contentions related to two general subject matters - Applicants' management capabilities and adequacy of emergency planning efforts. Applicants and the NRC Staff appealed the Board's order admitting FUA. On June 1, 1981 the Atomic Safety and Licensing Appeal Board issued its decision reversing this Board's order insofar as it granted the intervention petition of FUA. ALAB-642, 13 NRC 881. The Commission chose not to review the Appeal Board's decision. On appeal to the D.C. Court of Appeals, ALAB-642 was later affirmed in an unpublished opinion.

This Partial Initial Decision involves only the seismic issues in controversy. A supplemental partial initial decision will be issued shortly covering the remaining issues. With regard to the seismic issues, the Board finds in favor of plant safety in the event certain conditions are met. They involve continued seismic monitoring and the successful completion during the plant's first year of operation of a confirmatory program involving seismic safety margins of plant equipment and components. If the other matters are resolved satisfactorily, the granting of the operating license will be made subject to these conditions.

II. OPINION

The major seismic issues relate to earthquakes induced by the impoundment of the Monticello Reservoir, which was created as part of a planned electric power generating complex. The Monticello Reservoir stores water for a pumped storage faciity, provides cooling water for the nuclear plant, and serves as a make-up source for emergency cooling water. Find. 1.[3/]

Filling of the reservoir began on December 3, 1977, and full pond elevation occurred on February 8, 1978. Prior to the filling of the reservoir the USGS seismograph station at Jenkinsville (3 miles east-southeast of the site) had recorded about one local low level earthquake every six days from 1974 to 1977. After impoundment of the reservoir the number of events had increased to several hundred per week. The largest earthquake at the Monticello Reservoir known to NRC Staff at the date of its February 1981 SER was the magnitude (M_L) 2.8 event that occurred on August 27, 1978. The earthquake occurred about a mile northwest of the plant at a depth of approximately 110 meters. Find. 2.

A U.S. Geological Survey strong motion accelerometer located about 640 meters southeast of the epicenter and within a mile of the Summer

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3/ "Find." references are to the Board's Findings of Fact, infra.

plant produced a strong motion record of the event. The record was significant because the peak horizontal acceleration of 0.25g exceeded the maximum horizontal ground acceleration for the safe shutdown earthquake (SSE) of 0.15g for rock foundations. This response spectra anchor point of 0.15g would be applicable to the main Summer facility which was built on rock. The SSE peak acceleration for structures founded on soil was 0.25g. Find. 3.

In addition to mentioning the actual exceedance[4/] of the design basis peak acceleration evident in the strong motion record of the 2.8 M_L event, Staff's SER reflected additional concerns. It indicated that there were conflicting estimates of expected magnitudes for future events, as follows (Find. 4): Applicants - 4.0; Staff - 4.5; ACRS - around 5; and differing opinion of Staff seismologist - 5.3. Higher magnitude earthquakes would be expected to produce higher peak ground accelerations.

Intervenor Bursey's original contention, submitted before the Monticello Reservoir was filled, referred to the possibiity of reservoir induced seismicity causing 5.0 magnitude earthquakes. As restated in the Board's Prehearing Conference Order of April 24, 1978, the contention reads as follows (Find. 5):

4/ The word "exceedance," although not found in standard dictionaries, is a statistical term that was used by the seismology experts throughout the hearing. See, e.g., Staff's reference to "high frequency exceedances." Staff's updated testimony, ff. Tr. 5758, at 4.

Contention A 4

(a) The FSAR is inadequate with respect to the description of seismic activity in the area of the Summer plant site;

(b) The Plans for monitoring site seismicity are inadequate in that they do not consider the seismic effect of filling a reservoir. Site seismicity should be monitored for one year subsequent to filling the reservoir and prior to granting of the operating license.

At the final Prehearing Conference held on April 7 and 8, 1981, Intervenor Bursey submitted his summary of contentions in which he contended that a near-field magnitude of 5.3 should be used for assessing seismic safety. He also referred to the recently discovered Wateree Creek fault near the reactor as posing new seismic considerations that must be resolved prior to licensing. The Wateree Creek fault had been mapped and reported in 1980 and was the subject of some discussion in the February, 1981 SER, including the possibility of some association of the fault with the RIS (reservoir induced seismicity). In addition to the RIS and the Wateree Creek fault, the SER also discussed the Charleston earthquake of 1886 which had been localized to the immediate Charleston area at the construction permit stage and was not assumed to migrate outside of that region for determining ground motion at the Summer site. South Carolina Electric and Gas Co. (Summer Nuclear Station, Unit 1), LBP-73-11, 6 AEC 213, 218 (1973). The February 1981 operating license SER reexamined the evidence with regard to localizing the 1886 event to the immediate Charleston area and reaffirmed the construction permit conclusion. Find. 6.

In our Order following the final prehearing conference (at 4-6), the Board permitted a "broadening" of Intervenor's restated contention in view of the changed situation (i.e., the newly-created RIS and the

discovery of the Wateree Creek fault) since the contention was adopted, as discussed in the SER. We broadened the seismic contention to include all of the seismic considerations covered in the SER and extended the period during which Intervenor claimed the monitoring of seismicity should be continued until the end of 1983. Find. 7.

We might point out, however, that we did not intend to, nor did we, broaden the contention to include a de novo reexamination of matters determined at the construction permit stage or an examination of any other matter that could not fairly be considered as being covered by Intervenor's original contention as supplemented by the newly-discovered information contained in the SER. We did not go beyond the contention to consider matters under our sua sponte authority. Specifically, we considered all of the matters discussed in the SER relating to RIS and the Wateree Creek fault, and Intervenor's contention that the seismic monitoring should be continued through 1983, as an updating of his original contention in light of the new matters disclosed by the SER. With regard to the Charleston earthquake, we intended only to examine the "relation between the reservoir induced seismicity and the Charleston tectonic earthquake" of 1886 (Remainder of Order Following Fourth Prehearing Conf., May 13, 1981, at 5), and to determine whether, as a preliminary matter, the knowledge acquired since the construction permit proceeding cast any doubt upon the reasonableness of the determination that the 1886 event should be localized to the Charleston area. We are satisfied that, even under critical Board examination, no evidence has been introduced that suggests that a de novo reexamination is advisable of the construction permit finding that the 1886 event can

be localized to the Charleston area.5/ See Tr. 919-23, 960, 1154-5.

Applicants and Staff presented their initial seismic testimony from June 22 to 24, 1981. Intervenor and the State of South Carolina presented no evidence. Applicants, Staff and the differing Staff seismologist continued to disagree on the anticipated maximum event that they had set at 4.0 M_L, 4.5 M_L and 5.3 M_L, respectively. Applicants based their prediction of a maximum earthquake of M_L = 4.0 primarily on a model by Professor James Brune of the University of California at San Diego. Stf. Ex. 1 at 2-24; Applicants Exs. 2, 3, 4; Tr. 835-36. Although Applicants continued to disagree with the higher

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5/ Our opinion should not be read as implying agreement or disagreement with the conclusions of the construction permit board that the 1886 event should be localized to the Charleston area. We make no independent determination that the historical seismicity in the area (i.e., the continuing focal mapping of low and moderate seismic events which appear to be concentrated around the local Charleston area) is sufficient, factually or legally, to establish that the 1886 event is "reasonably related to tectonic structures" in the local Charleston area so that that earthquake need not be migrated to the boundary of the Piedmont and Coastal Plain provinces near the site. See Part 100, Appendix A, V.(a)(1)(iii). We recognize that scientific opinion on localizing the 1886 event to Charleston is mixed now as it was at the construction permit stage. We determine only that the construction permit findings were reasonable in light of the information known then or now and that none of the new information raises sufficient concern to warrant reopening the issue.

estimates of magnitude made by Staff, ACRS, and the differing Staff seismologist, they calculated peak ground accelerations for these higher magnitude events also through use of the Brune model in conjunction with formulas by Hanks and McGuire needed to adapt the Brune model to near-source earthquakes. That method depends on estimates of stress drop, seismic moment, shear wave velocity, density and attenuation. Using a constant stress drop of 25 bars, but varying the source distance with the increasing magnitude, Applicants determined zero-period accelerations (ZPA) for various magnitude earthquakes, as follows: 4.0 M_L = 0.14g ZPA; 4.5 M_L = 0.22g ZPA; 5.0 M_L = 0.20g ZPA and 5.5 M_L = .22g ZPA. Even though 0.22g ZPA exceeded the design basis acceleration of 0.15g for the Summer plant built on rock, Applicants attempted to demonstrate that the use of a 0.22g peak acceleration anchor point for response spectra derived from amplification ratios determined by Johnson and Traubenik and using the structural damping allowance of 7% under Regulatory Guide 1.61 would not exceed the original SSE spectrum calculated at 2% damping except in frequencies higher than 9 hertz (cycles per second). Acceptance of these exceedances could then be justified on the basis of certain built-in conservatisms used in the facility design. Finds. 8, 10, 11.

The maximum ZPA of 0.22g arrived at through the Hanks and McGuire adaptation of Brune model ("H-M model") had already apparently been exceeded at the strong motion accelerometer, which had recorded ground motion of 0.25g during a 2.8 M_L event on August 27, 1978. Applicants attributed that reading to amplification of motion in the 56-foot soil column underneath the strong motion accelerometer. The

Applicants used deconvolution procedures to infer ground motion at bedrock of about half the value of the motion recorded at the surface. Their deconvoluted motion estimate of 0.130g and 0.106g for the two horizontal components for the August 27, 1978 event was found to compare well with a peak acceleration of 0.121g calculated for a similar magnitude event under the Brune model using a stress drop of 25 bars and a source-to-site distance of 1 kilometer. Find. 16.

Although Staff used methods other than the Brune model to calculate a maximum magnitude earthquake (and arrived at a 4.5 M_L compared to Applicants' 4.0 M_L), it relied exclusively on Applicants' H-M adaptation of the Brune model to determine peak ground acceleration. Furthermore, it concluded that Applicants had demonstrated that the ground motion was amplified in the soil column at the strong motion accelerometer site. Find. 17.

Applicants presented most of their case on seismicity[6/] and Staff presented and concluded its seismic presentation during the week of June 22, 1981. During the week of July 6, 1981 when the hearing was not in session, the Board informed the parties during a conference call that it intended to call independent experts as Board witnesses. At the hearing the following week, the Board confirmed this course of action. In response to a Staff request, the Board Chairman identified

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6/ All that was left to be presented by Applicants on the seismic issue was some brief testimony to indicate that it would not be economically feasible to unload the Monticello Reservoir to test the seismic effects of unloading, and the recall of a witness to lay a further foundation for an exhibit that had been stricken for lack of foundation.

four areas of specific concern: (1) whether "the [g] values suggested for the different magnitudes have been fully substantiated by the testimony"; (2) whether "the application of those time histories pegged to these [g] values have been fully substantiated;" (3) whether there has been a "full enough discourse on the accelerometer readings at Jenkinsville;" and (4) "whether the Charleston earthquake ought to be migrated to the periphery of the Coastal province or the edge of the Piedmont province." Find. 19.

Several days later, the Licensing Board discussed these concerns further. Tr. 3790-3817. It focused on three principal issues: (1) peak acceleration (g) values for ground motion, (2) appropriate response spectra, and (3) earthquake magnitudes. The major portion of the Board's concern related to Staff's acceptance of Applicants' use of the Hanks and McGuire adaptation of the Brune model to determine the g values. It questioned whether Staff's review of Applicants' use of this model had been sufficiently critical with regard to whether that model was an appropriate one to use, and whether the proper values had been used as inputs in applying that model. Find. 20. The Board Chairman suggested that, in general, an applicant will try to find the best material and the best experts that support its case. Thus, if the Staff review had not been critical enough of Applicants' analysis, the Board could be handicapped in making its own determination. Tr. 3790-93.

The Board questioned whether the exclusive use of Applicants' ground motion model to determine the appropriate g values and the information used in the calculation (i.e., stress drop, source diameter, etc.) was the "best kind of information to look at." The Board

suggested that the Staff might also look at empirical data correlating ground motion with different magnitude earthquakes and might even find some "better data" to look at. Tr. 3793-94. The Board also indicated that it expected the independent Board witnesses to update the strong motion figures at the Summer site by, at least, consulting with "the person who was responsible for the accelerometers at Jenkinsville." Find. 20.

As to the issue of migrating the Charleston earthquake to the perimeter of the Piedmont province, the Board indicated that it was in basic agreement with the arguments of Applicants' counsel (given at Tr. 2520-21) that this issue was resolved at the construction permit stage and would only become a question for the operating license proceeding if there were "any drastic change in the information since then." We did not see that matter as a "critical issue in the case." As indicated above, although the experts might differ on localizing a repetition of the 1886 event to the immediate Charleston area, there has been no drastic change in the information available to this Board over what was considered during the construction permit stage that would justify reopening the issue. Find. 21.

Staff objected to our calling the Board witnesses and petitioned for directed certification of that ruling. After extensive briefing by the parties, a series of issuances by the Appeal Board, and responses by us to those issuances (as directed by the Appeal Board), the Licensing Board was permitted to call its own experts after reviewing supplementary testimony filed by the Staff. A full discussion of the

procedural aspects of our calling the Board witnesses is included as an Appendix, infra, to this initial decision.

Staff's supplemental testimony, received by us on September 15, 1981, reaffirmed Staff's reliance upon Applicants' ground motion model - the H-M adaptation of the Brune model to determine a peak acceleration anchor point on which to anchor the response spectra based upon amplification ratios of Johnson and Traubenik. Staff further reaffirmed the use of 25 bars of stress drop in the formula. Find. 23.

At the further seismic hearings held January 11-16, 1982, Applicants' ground motion model was shown to be unreliable. The 25-bar stress drop limitation based upon calculations made of the August 1978 event was shown to have been considerably exceeded in two subsequent events. For these events, stress drop could be reasonably calculated at from 37 to 100 bars, depending upon the exactness of the formula and the variations in parameters, such as cutoff frequency and digitization rate. The Board accepts as a best estimate for these events stress drops of approximately 60 to 65 bars. A doubling of stress drop would approximately double the resulting calculated ground acceleration. Furthermore, stress drops at Monticello were shown to be highly variable for different events, rather than stable as suggested earlier. As the further testimony disclosed, even in California where stress drops are considered to be relatively stable, they have been shown to increase with increasing magnitude within the magnitude range of interest. Finds. 27-29, 31-33, 110.

As to the response spectra based upon the amplification ratios of Johnson and Traubenik, Staff later reversed its position and considered

them inappropriate for the high frequency ground motion from shallow RIS, the only type of seismicity covered in the original evaluation. The Board agrees. Finds. 35, 82, 111.

The further seismic hearings in January of 1982 also did not establish any support for Applicants' position that the peak acceleration of 0.25g recorded at Monticello during the August 27, 1978 event had been amplified through the soil column. The evidence suggested that there was no amplification due to soil or topography. In addition, the record also disclosed a subsequent reading, on October 16, 1979, of 0.35g, which even further surpassed the SSE peak acceleration anchor point of 0.15g on rock. No amplification could be established for that reading, either. Finds. 25, 36-49, 112.

However, at the January 1982 hearings, other lines of evidence established the seismic safety of the nuclear power plant structures. Staff differentiated between normal tectonic depth earthquakes (occurring 5-16 km deep) at which a maximum 4.5 M_L earthquake might be expected, and shallow earthquakes occurring in the upper 3 km. For the normal tectonic depth earthquakes, empirical observations from historical earthquakes of peak accelerations and epicentral intensities, and response spectra derived from earthquakes at Mammoth Lakes and Oroville, California, establish ground motion limits within the SSE design basis parameters for both plant and equipment. Any postulated exceedances could easily be accommodated by conservatisms in plant design and construction. Finds. 55-57, 63, 69-76, 78-79, 89, 92, 108, 113.

With regard to the shallow RIS, for which the Board accepts a maximum magnitude of 3.8 M_L, Staff has utilized the envelope of response spectra from data already recorded at Monticello to demonstrate that the ground motion from the maximum magnitude postulated event will exceed Applicants' SSE design response spectra only at frequencies greater than 10 hertz. Finds. 58-61, 64-65, 83-87, 114. For that reason, and based upon empirical observations with regard to epicentral intensities from other shallow earthquakes in the eastern United States, and from observations of damage from other earthquakes, Applicants and Staff have demonstrated that the maximum magnitude shallow earthquake will not damage the nuclear plant structures. Finds. 90-92, 114. However, because some of the safety related equipment and components have natural frequencies above 10 hertz, and some of the systems and equipment are mounted on or near the foundation slab where they will experience high frequency motions transmitted directly through the slab, Applicants have committed themselves to reviewing the systems and equipment necessary for shutdown and continued heat removal to confirm that explicit safety margins exist for each component. The Board agrees that the review may take into account appropriate reductions of ground motion attributable to the embedment of the foundations in rock and that the Summer plant can commence operations prior to the completion of the confirmatory program. Finds. 93-97, 115. Considering that the evidence adduced failed to establish amplification in the ground motion recordings due to soil, topography or accelerometer pad-soil interaction, the Board will not approve any reliance upon amplification

factors in the confirmatory program based upon evidence produced here.Finds. 36-49, 115.

The Board found no evidence to indicate that the Wateree Creek fault posed any danger to the Summer nuclear plant. Finds. 102-105, 116. Nor did it find any evidence that would warrant reexamining the finding of the construction permit Licensing Board that the 1886 Charleston earthquake should be localized to the immediate Charleston area. Finds. 98-101, 117.

In view of the unreliability of the H-M model and the inappropriate application of the Johnson and Traubenik amplification ratios to shallow earthquake, high frequency, motion, upon which the FSAR and SER relied, the Board agrees with Intervenor's contention that the FSAR was inadequate with respect to the description of seismic activity in the area of the Summer plant site. The Board had not even been notified, until October 20, 1981, of the 0.35g peak horizontal acceleration recorded at the October 1979 event. Find. 25. However, the inadequacies of the FSAR were cured by the extensive evidentiary record of this proceeding.

Historically, the largest magnitude earthquakes from reservoir induced seismicity have occurred up to 10 years after the reservoir had been filled. In the Piedmont province, Lake Jocasse, South Carolina, experienced its largest earthquake of 3.7 M_L six years after impoundment. Find. 64. Accordingly, the Licensing Board agrees with Intervenor that site seismicity must be monitored at least until the end of 1983, which would be six years after impoundment. At that time,

Staff should consider further monitoring as an additional licensing requirement.

The Board concludes that the seismic safety of the Summer Nuclear Plant will be assured if the operating license were made subject to two conditions: (1) that seismic monitoring be continued at least until December 31, 1983, the need for further monitoring to be reevaluated at that time; and (2) that Applicants successfully complete the confirmatory program during the first year of operation to demonstrate that explicit safety margins exist for each component necessary for shutdown and heat removal in the event of the maximum potential shallow earthquake.

III. Findings of Fact

A. Background and Issues

1. The major seismic issues relate to earthquakes induced by the impoundment of the Monticello reservoir, which was created as part of a planned electric power generating complex. The Monticello reservoir stores water for a pumped storage facility, provides cooling water for the nuclear plant, and serves as a make-up source for emergency cooling water. Stf. Ex. 1 (SER) at 2-21.

2. Filling of the reservoir began on December 3, 1977, and full pond elevation occurred on February 8, 1978. Prior to the filling of the reservoir the USGS seismograph station at Jenkinsville (3 miles east-southeast of the site) had recorded about one local low-level earthquake every six days from 1973 to 1977. After impoundment of the reservoir the number of events had increased to several hundred per

week. Id. at 2-22; Tr. 1011-12. The largest earthquake at the Monticello reservoir known to NRC Staff at the date of its February 1981 SER was the magnitude (M_L) 2.8 event that occurred on August 27, 1978. The earthquake occurred about a mile northwest of the plant at a depth of approximately 110 meters. Stf. Ex. 1 at 2-27; Tr. 5197-98.

3. A U.S. Geological Survey strong motion accelerometer located about 640 meters southeast of the epicenter and within a mile of the Summer plant produced a strong motion record of the event. The record was significant because the peak horizontal acceleration of 0.25 g exceeded the maximum horizontal ground acceleration for the safe shutdown earthquake (SSE) of 0.15 g for rock foundations. This response spectra anchor point of 0.15 g would be applicable to the main Summer facility which was built on rock. Id. at 2-20, 2-27; Tr. 898-99, 901. The SSE peak acceleration for structures founded on soil was 0.25 g. Ibid.

4. In addition to mentioning the actual exceedance of the design basis peak acceleration evident in the strong motion record of the 2.8 M_L event, Staff's SER reflected other concerns. It indicated that there were conflicting estimates of expected magnitudes for future events, as follows: Applicants - 4.0; Staff - 4.5; ACRS - around 5; and differing opinion of Staff seismologist - 5.3. Stf. Ex. 1 at 2-24 to 2-25; Stf. Ex. 1(a) at Appendix D. Higher magnitude earthquakes would be expected to produce higher peak ground accelerations.

5. Intervenor Bursey's original contention, submitted before the Monticello reservoir was filled, referred to the possibility of

reservoir induced seismicity causing magnitude 5.0 earthquakes. Clarification to Petition to Intervene, August 19, 1977, par. 7. As restated in the Board's Prehearing Conference Order of April 24, 1978, the contention read as follows:

> Contention A 4
>
> (a) The FSAR is inadequate with respect to the description of seismic activity in the area of the Summer plant site;
>
> (b) The plans for monitoring site seismicity are inadequate in that they do not consider the seismic effect of filling a reservoir. Site seismicity should be monitored for one year subsequent to filling the reservoir and prior to granting of the operating license.

6. At the final prehearing conference held on April 7 and 8, 1981, Intervenor Bursey submitted his summary of contentions in which he contended that a near-field magnitude of 5.3 should be used for assessing seismic safety. He also referred to the recently discovered Wateree Creek fault near the reactor as posing new seismic considerations that must be resolved prior to licensing. Inter. Summary of Contentions at 3-4. The Wateree Creek fault had been mapped and reported in 1980 and was the subject of some discussion in the February, 1981 SER, including a possibility of some association of the fault with the (RIS) reservoir induced seismicity. Stf. Ex. 1 at 2-19 to 2-20, 2-26 to 2-27. In addition to the RIS and the Wateree Creek fault, the SER also discussed the Charleston earthquake of 1886 which had been localized to the immediate Charleston area at the construction permit stage and was not assumed to migrate outside of that region for determining ground motion at the Summer site. South Carolina Electric

and Gas Co. (Summer Nuclear Station, Unit 1), LBP-73-11, 6 AEC 213, 218 (1973). The February, 1981 operating license SER reexamined the evidence with regard to localizing the 1886 event to the immediate Charleston area and reaffirmed the construction permit conclusion.

7. In our Order following the final prehearing conference (at 4-6), the Board permitted a "broadening" of Intervenor's restated contention in view of the changed situation (i.e., the newly created RIS and the discovery of the Wateree Creek fault) since the contention was adopted, as discussed in the SER. We broadened the seismic contention to include all of the seismic considerations covered in the SER and extended the period during which Intervenor claimed the monitoring of seismicity should be continued until the end of 1983.

B. Applicants Use of the Brune Model

8. In its submittals to Staff and its presentation to the Licensing Board at the initial hearings on seismicity held June 22-24, 1981, Applicants relied primarily upon a model by Professor James Brune of the University of California at San Diego to predict a maximum magnitude earthquake at the site of M_L = 4.0. Applicants also used the Brune model to determine peak acceleration. This model depends on estimates of stress drop, seismic moment, sheer wave velocity, density and attentuation. Stf. Ex. 1 at 2-24, 2-30; Tr. 861. One of the critical parameters used by Applicants in applying the Brune model was a maximum assumed stress drop of 25 bars, based upon a calculation by Fletcher of the USGS that the maximum stress drop for the August 1978 earthquake was 17 bars. Another critical parameter was the assumed maximum dimension of geological structures within the

immediate vicinity of the reservoir, assumed to be 1 km or less. Stf. Ex. 1 at 2-24 to 2-25; Stf. Ex. 2.

9. Staff's consultant from the LASL, Dr. Karl Newton, and the Advisory Committee on Reactor Safeguards, independently of the Brune model, estimated the maximum reservoir-induced earthquake at Monticello to be M_L 4.5 and around 5, respectively. Stf. Ex. 1 at 2-24; Stf. Ex. 1a at D. Applying the Brune model, but using inputs of a stress drop of 100 bars and a source dimension of 3.2 km (length of the clusters of seismic activity), Dr. Andrew Murphy of the NRC Office of Nuclear Regulatory Research arrived at a possible event of magnitude 5.3 M_L in the immediate vicinity of the reservoir. Stf. Ex. 1 at 2-24 to 2-25.

10. Because there are so few near-field ground motion data containing peak accelerations, the applicants used the Brune model as a basis for their theoretical calculations for the M_L = 4.0 maximum earthquake they predicted and for the larger magnitude earthquakes predicted by Staff and the ACRS. Since the Brune model is a far field model, the Applicants used an extension of this model proposed by Hanks and McGuire (H-M model) to adjust it to the near field. Staff updated testimony, ff. 5758, at 28-29, 42. Using a stress drop of 25 bars, Applicants determined zero-period acceleration (ZPA) values of 0.14 g for an M_L = 4.0 event at a source distance 2.0 km; of 0.22 g for a M_L = 4.5 event at 2.0 km; of 0.20 g for a M_L = 5.0 event at 3.0 km; and 0.22 g for a 5.5 M_L event at 4.0 km. The increase in source distance with increase in assumed magnitude was attributable to the assumption that a higher magnitude earthquake would

require a larger source dimension and hence would occur deeper and farther from the plant site. Appl. Ex. 2, 3, 4; Tr. 1138.

11. Even though the 0.22 g ZPA exceeded the design basis acceleration of 0.15 g for the Summer plant built on rock, Applicants attempted to demonstrate that the use of a 0.22 g acceleration used as an anchor point to appropriate response spectra would not exceed the original safe shutdown earthquake spectra anchored to 0.15 g. Applicants derived response spectra from the Hanks and McGuire model estimate of peak acceleration using amplification ratios determined by Johnson and Traubenik to estimate peak velocity and peak displacement. Johnson and Traubenik had examined records in the M_L range of 4.7 to 6.5 recorded at rock sites at distances of 2 to 7 km from earthquake faulting and had derived amplification ratios at close distances as a function of magnitude. The Applicants considered these preferable to the Regulatory Guide 1.60 spectrum which is derived from a composite of strong motion records recorded mostly from earthquakes greater than M_L = 6.0 and at different distances out to 100 km. The Regulatory Guide 1.60 spectrum does not attempt to differentiate between site conditions, different magnitudes or distance ranges. Stf. Ex. 1 at 2-30; Stf. Suppl. Testimony ff. 5758, at 34; RM-1, ff. Tr. 5042. Regulatory Guide 1.60 itself (at footnote 2) indicates that it does not apply to sites which 1) are relatively close to the epicenter of an expected earthquake or 2) which have physical characteristics that could significantly affect the spectral combination of input motion.

12. Applicants' original SSE design spectrum anchored at 0.15 g was derived from studies by Newmark and Hall and differed slightly from the response spectra in Regulatory Guide 1.60. Tr. 879-880; Stf. Ex. 1 at 2-20. A 2% damping value was used. As a result of the reservoir-induced seismicity, a comparison was made between the new spectra based upon the amplification values of Johnson and Traubenik for 5 to 7% of critical damping, with the original design spectrum for 2% damping. It was found that the 2% SSE spectrum was exceeded only in the frequency range greater than 9 hertz. Chen, ff. Tr. 5324, at 5-6; Stf. Ex. 1a at 3-2. Subsequent to the original analysis, Regulatory Guide 1.61 was issued. It allows a 5% damping value for prestressed concrete and a 7% value for reinforced concrete structures in the seismic analysis. Ibid.

13. The internal concrete structures have fundamental frequencies higher than 9 hertz, which is in the frequency range where the original design spectrum falls below the new spectra values. For this reason, the Applicants generated a new time history input motion using the Oroville, California earthquake as a basis, and scaled that up to a 0.22 g peak value. It was found that the new floor response spectra based on the adjusted Oroville earthquake time history did not exceed corresponding floor response spectra for the facility design. Similar comparisons were made for equipment and systems, and demonstrated that the new spectra were bounded by the original design spectra except in some cases in the 20-30 hertz range. The exceedances in this frequency range were then found acceptable on the basis of certain built-in conservatisms used in the facility design. Ibid.

14. Dr. Andrew Murphy of the NRC Staff differed with the Applicants' and official Staff positions on the magnitude of the maximum reservoir-induced earthquake at the Monticello reservoir. Although he did not personally consider the Brune model to be as reliable as other models that could be used for determining a maximum magnitude reservoir-induced earthquake, he used the Brune model for his calculations. His differences with the Applicants related to their use of a 1 km source dimension and 25 bars of stress drop. He explained that the use of 25 bars of stress drop in Applicants' calculations was justified on the basis of a 17-bar stress drop calculation for the August 27, 1978 earthquake by a member of the USGS who had apparently updated his results to show that the stress drop was about 17 bars on one horizontal axis and around 90 bars on the other horizontal axis. He also relied upon the length of the clusters of seismic activity of 3.2 km as a source dimension. Using 100 bars as a stress drop (to conservatively reflect the range of 17 to 90 bars calculated for the August 1978 event) and the 3.2 km source dimension, he arrived at a magnitude (M_L) 5.3 event as possible in the immediate vicinity of the reservoir. Stf. Ex. 1 at 2-24 to 2-25; Stf. Ex. 2; Tr. 1063-65, 1205.

15. At the opening seismic hearings held from June 22-24, 1981, the Licensing Board examined Applicants' and Staff witnesses in depth concerning the use of the Brune model and the critical parameter of 25 bars of stress drop used in Applicants' calculations. In particular, some of the Board questions were very critical with regard to: Applicants' maintaining a constant stress drop with an increase in

magnitude; the historical observations that might support the 25-bar figure; the lack of correlation of the 25-bar figure with the higher deviatoric stress observed in the bore holes at the Summer site; the possibility of variability of stress drop with location at the Summer site; the Staff's basis in the literature and historical observations for accepting a constant of stress drop throughout a range of magnitude; the variability of the stress drop in relation to a change in source diameter; and the representative nature of the Brune model for use in the eastern United States in view of the reliance upon empirical data from California and China. Tr. 861-77, 933-37, 940-46, 971-74, 1004-07, 1018-19, 1122-34, 1136-37, 1186-90, 1207-13, 1221-22.

16. The maximum ZPA of 0.22 g arrived at through the H-M adaptation of the Brune model had already been exceeded at the strong motion accelerometer, which had recorded ground motion of 0.25 g during a 2.8 M_L event on August 27, 1978. Applicants attributed that reading to amplification of motion in the 56-foot soil column underneath the strong motion accelerometer. Applicants used deconvolution procedures to infer ground motion at bedrock of about 1/2 the value of the motion recorded at the surface. Their deconvoluted motion estimate of 0.130 g and 0.106 g for the two horizontal components for the August 27, 1978 event was found by Staff to compare well with a peak acceleration of 0.121 g calculated for a similar magnitude event under the H-M model using a stress drop of 25 bars at a source-to- site distance of 1 km. Stf. Ex. 1 at 2-28, 2-30; Tr. 1157.

17. Although Staff used methods other than the Brune model to calculate a maximum magnitude earthquake (and arrived at a 4.5 M_L

compared to Applicants' 4.0 M_L), it relied exclusively on Applicants' application of the H-M model to determine peak ground acceleration. Furthermore, it concluded that Applicants had demonstrated that the ground motion was amplified in the soil column at the strong motion accelerometer site. Stf. Ex. 1 at 2-27 to 2-31; Stf. Ex. 1 at 2-27 to 2-31; Stf. Ex. 1(a) at 3-2.

18. During the opening seismic sessions, the Licensing Board questioned Applicants' and Staff's witnesses with regard to this area. We questioned critically the ground motion figures actually recorded near the site (Tr. 757-63), and the basis for Staff's acceptance of Applicants' theory that there had been an amplification of ground motion from bedrock to the Jenkinsville accelerometer because of soil and topographical characteristics (Tr. 1141-46).

19. Applicants presented most of its case on seismicity, and Staff presented and concluded its seismic presentation during the week of June 22, 1981. During the week of July 6, 1981 when the hearing was not in session, the Board informed the parties during a conference call that it intended to call independent experts as Board witnesses. At the hearing the following week, the Board confirmed this course of action. Tr. 2512. In response to a Staff request, the Board chairman identified 4 areas of specific concern to him: 1) whether "the [g] value suggested for the different magnitudes have been fully substantiated by the testimony"; 2) whether "the application of those time histories pegged to these [g] values had been fully substantiated"; 3) whether there has been a "full enough discourse on the accelerometer readings at Jenkinsville"; and 4) "whether the

Charleston earthquake ought to be migrated to the periphery of the Coastal province or the edge of the Piedmont province." Tr. 2514-15.

20. Several days later, the Licensing Board discussed these concerns further. Tr. 3790-3817. It focused on three principal issues: 1) the g values for ground acceleration, 2) the application of response spectra, and 3) earthquake magnitudes. Tr. 3790. The major portion of the Board's concern related to Staff's acceptance of Applicants' use of the Hanks and McGuire adaptation of the Brune model to determine the g values. We questioned whether Staff's review of Applicants' use of this model had been sufficiently critical with regard to whether that model was an appropriate one to use, and whether the proper values had been used as inputs in applying that model. Tr. 3790-93. The Board questioned the exclusive use of the Brune model to determine the appropriate g values and whether the information used in the calculation (i.e., stress drop, source diameter, etc.) was the "best kind of information to look at." Tr. 3793. The Board also indicated that it expected the independent Board witnesses to update the strong motion figures at the Summer site by, at least, consulting with "the person who was responsible for the accelerometers at Jenkinsville." Tr. 3799.

21. As to the issue of migrating the Charleston earthquake to the perimeter of the Piedmont province, the Board indicated that it was in basic agreement with the argument of Applicants' counsel (given at Tr. 2520-21) that this issue was resolved at the construction permit stage and would only become a question for the operating license proceeding if there were "any drastic change in the information since

then." Tr. 3798. We did not see that matter as a "critical issue in the case." Ibid. As we find below, although the experts might differ on localizing a repetition of the 1886 earthquake to the immediate Charleston area, there has been no drastic change in information available to this Board over what was considered during the construction permit stage that would justify reopening the issue.

22. On August 7, 1981, Staff filed a petition for directed certification seeking to restrain the Licensing Board from calling Board witnesses without first affording the Staff the opportunity to respond to the Board's concerns. Subsequently, Staff informed the Appeal Board that it would file supplemental testimony addressing these concerns on or about September 15, 1981. On August 27, 1981, the Appeal Board issued a memorandum indicating that it expected the Licensing Board to review Staff's supplemental testimony when received, and, that if the Licensing Board were still of the view that it could not resolve the seismic issue on the basis of the evidence adduced by the parties themselves, to provide the Appeal Board with its reasons.

23. On September 15, 1981, Staff filed its supplemental seismic testimony. It reviewed Applicants' ground motion model (the H-M adaptation of the Brune model, together with the Johnson and Traubenik amplification ratios) and the input parameters for the model and found it reasonable for Applicants to use this model to predict near-field ground motions. Supplemental testimony at 33. Staff indicated that the most important parameters in Applicants' model were stress drop and source dimension. It found that Applicants' choice of 25 bars of stress drop

was conservative and that the source dimensions used in the model were reasonable. Id. at 24, 33.

24. On October 15, 1981, the Licensing Board issued a memorandum and order, LBP-81-47, 14 NRC 865, reaffirming its intention of calling seismology experts as Board witnesses. On October 19, 1981, the Appeal Board denied Staff's petition for directed certification thereby permitting the Licensing Board to proceed with calling its own expert witnesses at a further hearing on the seismic issues.

25. On October 20, 1981, Staff notified the Licensing Board by Board Notification (BN-81-32) of a significant earthquake that had occurred on October 16, 1979 that had not been reported to the Board. The accelerometer data from that event indicated that there had been peak accelerations recorded of 0.35 g, 0.36 g and 0.18 g for the two horizontal and one vertical components, respectively, dwarfing the 0.25 g recording of the August 27, 1978 earthquake.

26. In its October 15, 1981 Memorandum and Order, LBP-81-47, supra, the Licensing Board had also ordered that Staff file further written testimony, to be presented at further hearing, responding in full to the Board experts' reports which had been received in September of 1981. Because of the "new" seismic information contained in the Board notification of October 20, 1981, and the pendency of certain soil tests being conducted by Applicants to determine the extent of any amplification in the Jenkinsville accelerometer recordings due to the location of that accelerometer, the Staff's time for filing the further testimony was extended until December 31, 1981. The testimony was filed

on that date and was subsequently received in evidence at the further seismic hearings held January 11-16, 1982, following Tr. 5758.

27. In its updated supplemental testimony on seismicity, Staff reexamined its acceptance of Applicants' choice of 25 bars as the appropriate stress drop in the H-M adaptation of the Brune model. It based its reexamination upon new information available to it. The most important of the new information was the calculation made by Applicants' of the average rms stress drops for the 6 events recorded at Monticello which had significant ground motion. The Staff recalculated Applicants stress drop figures to eliminate Applicants' reduction factor for soil amplification and arrived at stress drops for the six events of approximately 12, 19, 23, 42,7/ 7 and 48 bars. Staff concluded that 50 bars is the appropriate rms stress drop to use in conjunction with the H-M application of the Brune model. Staff updated testimony, ff. 5758, at 32-34. Staff also indicated that, because of the lack of data and understanding associated with eastern U.S. earthquakes, it becomes "problematic" to determine the values for stress drop, or even to assume a constancy with increasing magnitude, for stress drop in the eastern U.S. and, in particular, for eastern RIS. Id. at 30-31.

7/ Staff erred in its recalculation of an October 27, 1978 event of $\overline{M}_L$ = 2.4 and should have arrived at a figure of 46 bars, rather than 42 bars. See Appl. Ex. 43 at 5, Table 4. Applicants had earlier calculated a stress drop of 65 bars for that event. McGuire's Evaluation of Joyner-Fletcher Report, ff. Tr. 5075, at Table 1. Presumably under the Joyner-Fletcher method of calculating stress drop, the figure would be even higher than 65 bars.

28. In its updated supplemental testimony, Staff concluded that Applicants' model is physically reasonable but needs to be treated with caution and, when possible, should be used in conjunction with other approaches. Id. at 35. At the further hearing, however, Staff's main seismology witness, Dr. Leon Reiter, retreated considerably from any reliance upon Applicants' model. After hearing the bulk of the testimony, he concluded that it was not possible to come to any definitive results using Applicants' model or to determine which parameters (i.e., which values of stress drop and source diameter) are to be used in applying the model. He recommended that the Board look at other approaches. Tr. 5804.

29. Board witness Dr. William Joyner testified that he and his USGS colleague, Dr. Fletcher, had calculated average rms stress drops for the August 1978 event of 32 and 25 bars (for the two horizontal components) and for the October 1979 event an average of 60 bars. Joyner summary, ff. Tr. 4696, at 3; Tr. 4824. Board witness Dr. Enrique Luco calculated a stress drop from the August 1978 event of 100 bars. Tr. 4730; Luco report, ff. 4731, at 4-5. He believed that Applicants had used erroneous formulas in arriving at their figures. He repeated the Joyner and Fletcher calculation of stress drop for the

October 1979 event and arrived at over 60 bars.[8/] Tr. 4966-67, 4978. Even Applicants' chief seismology witness, Dr. Robin McGuire, an architect of the H-M adaptation of the Brune model, testified that, if soil amplification factors are not taken into account, the stress drop for the August 1978 event would be on the order of 25 bars and, for the October 1979 earthquake, on the order of 50 or 60 bars. He also calculated a stress drop of 65 bars for an October 27, 1978 event. Moreover, he estimated uncertainties in calculating stress drops even in California where stress drops are relatively stable, as being on the order of a factor of 2, plus or minus 1 standard deviation. Tr. 5559-60; McGuire's Evaluation of Joyner-Fletcher Report, ff. 5075, at Table 1. If stress drop is increased by a factor of 2 in Applicants' model, the resultant acceleration would be doubled. Tr. 5922.

8/ The Joyner-Fletcher-Luco calculation of stress drop of between 60 and 65 bars for the October 1979 event, which was essentially unchallenged by Applicants, was based upon a moment magnitude calculation. Tr. 4815. If that moment magnitude stress drop calculation were converted to a local magnitude (M_L) calculation, as Staff converted Applicants' original stress drop figure, the resulting stress drop would be approximately 85 bars for that event of M_L = 2.8 and moment magnitude = 3.1. See Appl. Ex. 43 at Tables 3, 4. In the Board's opinion, it would make more sense to use a moment magnitude stress drop in a calculation based upon seismic moment. Staff's decision to use an M_L calculation was undoubtedly attributable (perhaps unnecessarily) to the definition in Appendix A to Part 100 of "magnitude" as meaning the numerical value on a Richter scale. Local magnitude (M_L) is a Richter scale; moment magnitude is not. We do not interpret that definition as requiring that every calculation must be based upon a Richter scale, although Staff may be justified in converting to Richter units early in the calculation for the sake of accuracy.

30. In the original seismic hearing Applicants' witness Dr. Alexander testified that the maximum deviatoric stress observed in two bore holes at the Summer site was on the order of 100 bars, that the average stress drop that might be released in an earthquake would be in the range of 20%, and that therefore a release of 20 to 25 bars could be expected. Tr. 991-92. At the further hearing in January, 1982, that same witness testified that, in a situation such as at the Monticello reservoir where the pore pressures are high because of the reservoir, all of the deviatoric stress (on the order of 100 bars in some locations) could be released during an earthquake. Tr. 5097-99, 5108.

31. At the original hearing, Applicants offered evidence that there is no general increase of stress drop with magnitude, at least over a range of 2 or 3 magnitude units. Appl. Ex. 4 at 4. This assumption, that stress drop remains fairly constant over a range of magnitudes, was a critical factor in Staff's acceptance of Applicants' model. Tr. 1127-31, 1221-22. At the further hearing in January, 1982, it was disclosed that Applicants' major witness on eastern United States earthquakes, Dr. Otto Nuttli, had concluded that in the east, in contrast to the west, stress drop will increase with magnitude. Staff updated testimony, ff. 5758, at 33. Other seismologists have shown that even in California, where stress drop is relatively constant, stress drop in the Mammoth Lakes region increases steadily with magnitude for magnitudes less than about 3.4, although it is fairly constant for larger earthquakes. Ibid.

32. The H-M adaptation of the Brune model is based upon observations of California earthquakes. Hanks and McGuire have found that their equation for peak acceleration gives adequate results in California if a constant stress drop of 100 bars is used, regardless of the actual stress drop measured or calculated for that event. Staff updated testimony, ff. 5758, at 29; Luco report, ff. 4731, at 2.

33. Based on the foregoing paragraphs, the Board finds that the H-M adaptation of the Brune model cannot be relied upon to predict peak accelerations from future events at the Monticello reservoir. On the basis of the evidence adduced, one cannot even determine rms stress drop, appropriate for ground motion calculations, for the two most significant events that had occurred at the Monticello reservoir, the August 1978 and October 1979 earthquakes. The estimates for these two events range from 17 bars to 100 bars. Our best estimate of the rms stress drop would be in the range of 25 to 30 bars for the August 1978 event and from 60 to 65 bars for the October 1979 event, both of which were at an estimated magnitude of M_L = 2.8. We estimate an rms stress drop for an October 27, 1978 event of between 50 and 65 bars where the magnitude was estimated at M_L = 2.4. Because of the evidence that stress drop in the eastern United States generally increases with magnitude and that even in some California areas it increases with magnitude below magnitude 3.4, we cannot even accept the 60-65 bar range of the October 1978 and October 1979 events as a conservative figure for higher magnitude shallow events at the Monticello reservoir. We would also have to consider the

possibility of a 100-bar stress drop if we were to rely upon the H-M model, which we expressly decline to do.

34. With regard to Applicants' use of the Brune model to estimate maximum magnitudes in which Applicants used a source dimension of 1.0 km, questions posed by the Board's experts failed to reveal any support in the literature or engineering practice for the quantitative limit of 1 km at the Monticello reservoir, or for using the Brune model to determine the largest seismic event that could occur at a site on which to base an engineering judgment. Furthermore, Applicants' main expert in this area, Dr. Sheldon Alexander, conceded that once a rupture had begun the fracture could propagate beyond the stress field into a stress-free region to, perhaps, double the rupture radius. Nor could he even rule out the possibility of rupture on multiple fault planes in a single earthquake event (such as en echelon faulting), that would permit a release of higher energy (and hence result in a higher magnitude earthquake) within the limited source dimension. Tr. 5101-15. Moreover, the in situ stress measurements and 1 km source dimension used to apply the Brune model to determine maximum magnitude, were based upon measurements in 2 boreholes that were 700 meters and 900 meters deep. There was no way of knowing what was below those holes or anywhere else in the vicinity of the site. Tr. 5904.

35. In its SER and at the opening seismic hearings, Staff did not question Applicants' use of ground motion ratios of Johnson and Traubenik to construct response spectra anchored to the peak acceleration values determined from the H-M application of the Brune model. See Stf. Ex. 1 at 2-30. These Johnson and Traubenik

amplification values are lower than those used in Regulatory Guide 1.60. Tr. 5599. At the further hearing held in January of 1982, Staff expressed considerable reservations about the Johnson and Traubenik amplification ratios. Because they were derived from records in the M_L range of 4.7 to 6.5, at epicentral distances of from 2 to 17 km, and were filtered at 20 hertz to exclude higher frequencies, Staff questioned whether they were applicable to high frequencies generated within several kilometers of the source. Staff concluded that for small magnitudes and for distances within several kilometers, the Johnson and Traubenik amplification factors are not tested and do not take into account high frequencies (20 hertz or more). Staff updated testimony, ff. Tr. 5758, at 34-35. The Board agrees with Staff (id. at 41-42) that, in view of the high frequency motion, low magnitudes (less than the lowest magnitude earthquakes taken into account by Johnson and Traubenik), and small hypocentral and epicentral distances anticipated, the Johnson and Traubenik amplification ratios are inappropriate for the shallow RIS expected at Monticello reservoir.

C. Amplification of Ground Motion

36. In its submittals to Staff and at the original hearing, Applicants argued that the peak acceleration at the Monticello reservoir known at that time, of 0.25 g for the August 27, 1978 event, had been amplified in the 56-foot soil column below the strong motion accelerometer. Staff found that the Applicants had demonstrated that ground motion had been amplified in the soil column and that such amplification would not occur at the plant site, where most of the

foundations are on bedrock. Stf. Ex. 1 at 2-28 to 2-29; Tr. 760-64. Prior to the further hearings held in January of 1982, Applicants conducted theoretical studies and field tests to determine whether there had been ground motion amplification at the USGS strong-motion accelerometer location for the peak instrumental accelerations of 0.25 g and 0.35 g for the August 1978 and October 1979 events. The purpose of these studies was to see the effect of the soil on the records obtained at the dam abutment, not to input something into the plant. Tr. 5576.

37. Applicants conducted a theoretical soil modelling study to demonstrate the ground motion amplification at the accelerometer site. The primary concern was whether the surface motion had been amplified as it propagated from the underlying bedrock. If amplification occurred, peak accelerations within bedrock would be less than recorded at the instrument location. Martin testimony, ff. Tr. 5522, at 1.

38. Applicants' expert performing the analyses, Dr. Geoffrey Martin, concluded that all cases have amplification ratios greater than 1.0, and that they range from 1.4 to 2.9. Id., at 11. Somewhat inconsistently, he further concluded that the amplification ratio at high frequencies (i.e., the frequencies at which peak accelerations were recorded for the August 1978 and October 1979 events) is approximately 1.0. Id. at 13-14. He further testified that with regard to earthquakes such as occurred at the Monticello reservoir, at the peak accelerations in the 20 to 25 hertz range, there would be no significant amplification. Tr. 5538-41, 5569-74. Later, Dr. Martin admitted in response to questions posed by Board witness Trifunac that,

for the models used in the soil study at greater than 20 hertz, the function would be less than 1, indicating that there could have been deamplification in the Monticello readings from bedrock to the accelerometer. Tr. 5667-70. Dr. Trifunac testified that the results of that study could be used to support the position that ground motion in the 20 to 35 hertz range could have been deamplified by a factor of 2 in the strong motion recordings at Monticello, although he (Dr. Trifunac) was not in favor of any reliance upon that study. Tr. 5671-73, 5675.

39. The event that was modelled by Dr. Martin was not similar to the events that had occurred at Monticello. Rather, it was a representation of a generic event of magnitude 4.0 with a hypocentral distance of 3 km, at a depth of 2 km. Since there was no 4.0 magnitude event at 3 km available, Dr. Martin scaled an Oroville 1975 aftershock with a magnitude of 4.6 and a 15 km hypocentral distance. This Oroville earthquake had a dominant frequency band in the range of around 10 hertz, in contrast to the 20 to 25 hertz dominant frequency band for the Monticello earthquakes. Dr. Martin admitted that the earthquake modelled was not representative of Monticello and that any amplification effect for the peak accelerations at the August 1978 Monticello event from the soil column was not significant. Tr. 5532, 5535-36, 5668-70.

40. Applicants' soil modelling study was based upon a program originally developed by Board witness Dr. William Joyner. Testimony of Martin, ff. 5522, at 4. At the beginning of the hearing session in January of 1982, Dr. Joyner tentatively accepted Applicant's

amplification factor of 2. Tr. 4702-03, 4713-14. However, he requested additional information from Dr. Martin to reach a final conclusion. Tr. 4769-72. Upon receiving that information, Dr. Joyner concluded that he could not accept any amplification factor based on Applicants' model. He explained that because the events were shallow the seismic ray from the focus of the earthquake to the instrument site would be almost horizontal and would not be amplified. Tr. 4980, 5386-88, 5399-5404, 5662-63, 5731-32. He indicated that the other Board witnesses (Drs. Luco and Trifunac) and the Staff did not accept the amplification in the first place. Tr. 5391-93, 5731-32. The Board agrees with Dr. Joyner that the soil modelling study has not demonstrated that any amplification due to the soil column was involved in the August 1978 and October 1979 records of ground motion at the dam abutment site.

41. All of the witnesses, including Applicants' witnesses, have agreed that no significant amplification because of topographic effect was present in the Monticello records. Tr. 4713, 5493, 5514, 5525, 5540.

42. On January 8, 1982, three days before the final sessions on seismicity were scheduled to begin Applicants conducted so-called "plucking tests" on the concrete pad on which the Monticello accelerometer that had recorded the high ground motion was placed. The purpose of the tests was to demonstrate that the high ground motion, since not attributable to soil or topographical amplification, was attributable to amplification due to a correspondence of the natural frequencies of the soil-pad system with the dominant frequencies of the

peak accelerations for the 1978 and 1979 events (in the frequency ranges of 20-25 hertz for peak accelerations and 10 to 15 hertz for peak velocities). The person who purportedly conducted the tests, Dr. Richard Woods, was not present to testify; nor was anyone who was present during the testing. Neither the NRC Staff, nor intervenor was notified that the tests were to be conducted. Appendix to Martin testimony, ff. 5522; Tr. 5541-45.

43. The tests consisted of fastening a rope around the 4-ft. x 4-ft. x 1-ft. concrete pad, with the free end attached to the rear axle of a vehicle. The rope was then tensioned and severed by an axe striking an underlying log positioned close to the pad. This set the pad into free vibration. The horizontal and vertical velocity traces of the vibration were recorded by geophones positioned on the pad. The tests were purportedly carried out with the rope aligned along both principal axes of the pad and were performed in each direction to insure that the results were repeatable. Appendix to Martin testimony, ff. 5522, at 2-3; 5546.

44. In order to describe motion adequately 6 measurements of the motion are necessary: rocking in two directions, sliding in two directions, up and down and twisting motions. Here, only two modes were measured, rocking and vertical, and Applicants were not able to say which mode was which. The exact resolution of frequency values was difficult, particularly the high values at which the peak accelerations for the 1978 and 1979 events had been recorded (because of the small scale of the instruments), so that only average values were computed from the record analysis. Because the stiffness was different in the

two directions, Applicants had to make "idealized calculations". Furthermore, because of the apparently anomolous readings for the two modes that were suspected, Applicants were somewhat confused by what might have been going on in that soil-pad system. Ibid.; Tr. 5548-49, 5565-68.

45. None of the Board or Staff witnesses would attribute any degree of confidence to the results of the plucking tests. Tr. 5567, 5568-69, 5601-03, 5679, 5812-13, 5818, 5819-20, 5841, 5850, 5854, 5983. The Board indicated that it could give no weight to the results of the tests because of their inherent deficiencies, as discussed above. It suggested that, if Applicants wanted to take credit for those tests, they re-run the tests in the presence of Staff experts who would also supply some input into the testing procedure. Staff indicated its availability for any re-testing of the soil pad interaction. Applicants, however, indicated that it would inform the Board by conference call during the next week as to whether they wished to re-run the tests so that the Board could put some weight on the results. Tr. 5980-87, 5992. At a conference call the next week, Applicants informed the Board and the parties that they did not wish to re-run the tests. The Board gives no weight to the results of the pad tests.

46. In October 1981, the Applicants conducted two explosion tests near the V. C. Summer Nuclear Station. The purpose of the experiment was to acquire data for a comparative study of ground motion at the USGS accelerograph site and at additional instrument sites in the free-field and on building foundations. In the frequency band from 5 to 50 hertz, amplitudes of ground motion on saprolite soil were found

to be twice those recorded on the foundation of massive structures on bedrock. Somerville testimony, ff., Tr. 5169, at 1. The field experiment suggests that accelerogram records from the USGS SMA-1 on the dam abutment may not be representative of foundation motions on bedrock, and must be modified accordingly in assessing the effects of RIS on massive embedded structures founded on rock. Tr. 5496-98.

47. The observed differences between the foundation and free-field motions were probably attributable to several effects which cannot be determined individually from this experiment. Because of the absence of rock outcrops in the site vicinity, it was not possible to obtain free-field records on rock and thereby isolate any effects that might have been due to the saprolite layer. Other possible effects are that, due to the presence of massive concrete structures on large, deeply embedded foundations, foundation motion might differ from free-field motion because of elastic wave incoherence, elastic wave scattering, foundation embedment, inertial resonance of the building mass, and energy transmission between the ground and the structure. These individual effects cannot be separated using the field test data. Somerville testimony, ff. 5169, at 6-7; Tr. 5496, 5630.

48. Board witness Dr. Joyner felt that the blast test information was not significant because the modes of propagation of ground motion are different from the explosive sources than they are from earthquake sources. Tr. 4713, 4769, 5402-04, 5723-25. Board witness Dr. Luco believed that there could be a reduction of ground motion to the building foundations on rock due to a scattering of the waves and a rigidity of the foundations. He was not convinced that the calculation

performed by the Applicants reflected this effect but agreed that the reductions observed for the explosion cases give an indication that the reduction was taking place. He thought that for seismic excitation, reduction factors might be different from those observed in the experiments, but that some reductions are possible and can be calculated, and that a complete soil structure interaction analysis of the scattering of waves by the embedded foundation would disclose those reduction factors. Tr. 5526, 5600-01, 5609, 5596-97. Board witness Dr. Trifunac was also critical of relying upon the blast test information to establish amplification or reduction of ground motion, although most of his criticism was concerned with applying the results of the shallow explosion tests to the case of deeper earthquakes. Tr. 4707-09, 5204-07, 5670-71, 5716, 5821-22. Staff concluded that although the Applicants had performed a great deal of work in a relatively short period of time and that the analyses of blast test data demonstrated a trend toward significant reductions, it did not feel that the Applicants' results were conclusive in a quantitative sense so as to define the final magnitude of reduction. It could not accept Applicants' factor of reduction of 0.5 on the basis of the blast test data, but looked towards a definition of the reduction factors to be employed on the basis of further studies under a confirmatory program already underway. Staff's updated testimony, ff. 5758, at 4, 66.

49. The Board finds that none of Applicants' studies, the soil modelling study, the blast test study, or the pad plucking tests study, have demonstrated that there was any amplification in the Monticello

ground motion records. The Board finds further that it is unlikely that there was significant amplification in those records due to soil, topography or accelerometer pad-soil interaction effects. The Board, however, finds that it is likely that there would be a significant reduction in ground motion from the free-field to the foundations of the Summer nuclear buildings because of the embedment of those structures on rock, especially in the high frequency range, as suggested by Dr. Luco (Tr. 5600-01, 5605), and that appropriate reduction factors can be determined through the confirmatory tests now underway.

D. Maximum Magnitude

50. Applicants submitted that M_L = 4.0 is the appropriate maximum magnitude event that can be induced by the Monticello reservoir. Alexander testimony, ff. Tr. 5028, at 12; Tr. 5011. Several lines of evidence were presented in support of this conclusion.

51. First, historic experience both locally and within the Piedmont province was cited. Dr. Alexander testified that no reservoir not associated with active fault zones has produced significantly large earthquakes. Tr. 5011. In the Monticello region of the Piedmont province, all events thought to be induced by reservoirs have been less than M_L = 4.0 with a single exception. That exception, the Clark Hill event with M_L = 4.3, was said to be "of questionable association with the reservoir itself" because it occurred long after reservoir impoundment and because other comparable events had occurred in that region prior to impoundment. Tr. 5011-12. The data base for

this conclusion that RIS events in the Piedmont province are less than M_L = 4.0 consisted of 59 reservoirs of similar size to Monticello representing about 2200 years of reservoir operation. McWhorter testimony, ff. Tr. 5031, at 1-2; Tr. 5029.

52. Second, several types of site-specific evidence were said to support the M_L = 4.0 for RIS conclusion. The spatial extent of RIS at Monticello is confined laterally to the immediate area of the reservoir and vertically to a depth of less than 3 km. In fact, with respect to the vertical aspect, Dr. Alexander testified that over 98% of the events were shallower than 2 km and approximately 80% shallower than 1 km. Tr. 5012. These bounds were reached quickly (within 1-1/2 years) and have not expanded since that time. Tr. 5012-13. Only microearthquakes (less than M_L = 3.0) have occurred since impoundment and their average rate of occurrence has been steadily declining with time. Tr. 5013. The shape of the observed frequency versus magnitude curve is consistent with a limiting magnitude. Tr. 5013. And, finally, heterogeneities in rock properties which have been documented were said to limit the extent of any single fault movement to a distance estimated to be 1 km. Tr. 5014. Recorded stress levels at Monticello were also said to be not sufficiently high to allow extensive ruptures to occur very deep. Tr. 5019.

53. Applicants' consultants also examined worldwide reservoir-induced seismicity to evaluate the conclusion that the maximum RIS event at Monticello would be M_L = 4.0. That examination showed that out of 64 confirmed cases of worldwide reservoir-induced seismicity, only 11 had induced events of magnitude 5

or greater. Of those 11 cases, 9 were associated with active faulting and the other 2 were most likely associated with active faulting. Tr. 5029. With the possible exception of the New Madrid, Missouri earthquakes in 1811 and 1812, there have been no observations of surface rupture occurring in the eastern United States. Nuttli testimony, ff. Tr. 5164, at 5. No active faulting exists at the Summer site. Applicants' experts drew a conclusion from this comparison that "for reservoirs in intraplate tectonic settings away from active tectonic elements, a maximum magnitude of about 4 appears to be appropriate." Tr. 5030.

54. Applicants further argued that the shallow depth of the reservoir-induced seismicity at Monticello reservoir is an important factor limiting the maximum magnitude of such events. Approximately 98% of the events have been less than 2 km deep. Experience from earthquakes throughout the entire central and eastern United States suggests that magnitude 4 is the upper limit for such shallow earthquakes. Nuttli testimony, ff. Tr. 5164, at 4; Tr. 5173, 5175.

55. The Staff position in the SER was that the maximum earthquake for design purposes was M_L = 4.5. The distance or depth was not specified. The Staff approved spectra developed by Applicants for this earthquake with the recognition that short duration, high-frequency accelerations from small events could be higher. In developing ground motion estimates Applicants had used a model which assumed that a M_L = 4.5 earthquake would occur at a distance of 2 km. Staff updated testimony, ff. Tr. 5758, at 25. The Staff now regards depth as

one of the key factors in estimating RIS ground motion. Tr. 5763; Staff Req. Find. 113.

56. According to Staff, a definition of maximum magnitude to be used for design purposes is particularly difficult with respect to RIS. The Staff continues to place great emphasis on experience at other reservoirs in the Piedmont and the largest earthquake in the Piedmont that has tentatively been associated with RIS, the magnitude 4.3 event in 1974 near the Clark Hill reservoir. It was also observed that world-wide RIS earthquakes greater than about a 4.5 occurred in active tectonic areas dissimilar to the Monticello region. Based upon this experience, the Staff adhered to the position that a maximum magnitude of 4.5 was conservative. Staff updated testimony, ff. Tr. 5758, at 25-26, 41.

57. Staff cited approvingly from the testimony of Dr. Nuttli who found no evidence anywhere in the eastern or central U.S. of magnitude 4.5 events occurring at shallow depths (2 km or less). While no depth has been estimated for the Clark Hill earthquake, the intensity and felt area are similar to other earthquakes of this magnitude in the eastern and central U.S. for which Hermann (1979) estimates typical depths of 5 to 16 km. Id., Tr. 5886. Based on this, the Staff took the position that, if indeed a 4.5 event were to be triggered by the reservoir at Monticello, the best estimate as to its depth would be this typical normal depth range of 5 to 16 km. Id.; Tr. 568-69.

58. The Staff next addressed its estimation of the maximum magnitude event for the shallow zone of reservoir induced seismicity (upper 2 km). Staff reviewed several arguments presented which would

limit the maximum magnitude. First, the maximum magnitude shallow earthquake at the reservoir to date has been about M_L = 3.0. Tr. 5769. Second, in situ stress measurements of M. Zoback of the USGS at Monticello tend to indicate that the events with larger stress drop should occur in the upper few hundred meters. Staff updated testimony, ff. Tr. 5758, at 27. This is supported by the fact that the largest stress drops and the highest peak accelerations have come from events which occur in the upper few hundred meters and also from the fact that seismicity decreases with depth under the reservoir. Tr. 5769. This position was also influenced by the tendency of the frequency-magnitude curve to indicate saturation at about M_L = 3.0. Ibid.; Tr.5947, 5953.

59. Staff recognized Zoback's measurements in arriving at its conclusions with regard to maximum magnitude. Tr. 5891, 5897, 5901-02; Staff updated testimony, ff. Tr. 5758, at 41. According to Staff, Zoback's findings appeared to be borne out by the Applicants' calculation of stress drop for the strongest ground motion recorded at Monticello. Staff noted the Applicants' estimates of depths for these events ranging from 70 to 360 meters with the highest stress drops being associated with the earthquake of M_L = 2.4 and 2.8 at depths of 200 and 70 meters, respectively. Id. at 27.

60. Third, there has been an overall decline in the rate of seismic activity which suggests that stored strain is not being replenished. Id. at 28. Fourth, it referred to Dr. Nuttli's testimony which indicated that no earthquake greater than M_L = 4.0 has occurred at such shallow depths anywhere within the eastern U.S.

Fifth, the Staff's ground motion estimate is not dependent on the Applicant's ground motion model which includes uncertainties in source characteristics such as stress drop and interpretations of saturation of ground motion with distance. Tr. 5769. Sixth, the Staff has chosen to envelope recorded ground motions instead of choosing the 50th or an 84th percentile level of a suite of spectra. Ibid.

61. Based on the above, the Staff took the position that the best estimate of maximum magnitude for the shallow zone of seismicity is M_L = 3.0. Tr. 5883, 5914-15.

62. Portions of Applicants' case with regard to the maximum magnitude to be expected were unconvincing. Their argument with regard to heterogeneities in rock properties limiting the extent of a single fault movement to 1 km lends support to the proposed limit of M_L = 4.0 in the quantitative sense only through application of the Brune model. However, the in situ stress measurements and the 1 km source dimension estimate used to apply the Brune model to determine maximum magnitude cannot be relied upon to limit the magnitude to 4.0. See finding 34, supra. If the source dimension were doubled from 1 to 2 km, as might be reasonable under circumstances testified to by Applicants' witness (Tr. 5109-10), the magnitude would increase from 4.0 M_L to 4.6 M_L. Tr. 5876-77.

63. The Board concludes, from the evidence relied upon by Applicants and Staff, that a maximum magnitude of between 4.0 and 4.5 is reasonable. The Board further agrees that, if indeed an event between 4.0 and 4.5 were to be triggered by the reservoir at

Monticello, its depth would be the typical normal depth range of from 5 to 16 km.

64. However, the Board does not agree with Staff that the maximum magnitude shallow earthquake that might be expected at the reservoir will be about M_L = 3.0, similar to what had already occurred. The Board finds this inconsistent with the statement in the SER, with which the Board agrees, that "there is no reason to assume that the largest earthquake induced by Monticello reservoir has yet occurred." Stf. Ex. 1 at 2-26. In our opinion, the statement should apply also to the shallow earthquakes at Monticello. Staff's projection of a maximum 3.0 M_L earthquake does not give sufficient weight to Dr. Nuttli's upper limit to magnitude 4.0, rather than 3.0, for shallow earthquakes in the central and eastern United States. More importantly, it ignores two significant shallow earthquakes that the Board believes should serve as a conservative model for the expected maximum shallow event at Monticello: the Lake Jocasse 3.7 M_L RIS event in 1974 at a best estimate depth of 2 km, and the Illinois 3.8 M_L event of 1965 at a depth of 1.5 km. The Lake Jocasse event occurred six years after impoundment of a South Carolina reservoir. The largest RIS world-wide have occurred up to 10 years after impoundment. Tr. 5095-97, 5172; Nuttli testimony, ff. Tr. 5164, at 2, 4; Staff updated testimony, ff. 5758, at 15, 26-27.

65. The Board finds, on the basis of the evidence presented by Applicants and Staff, that a maximum magnitude for a shallow RIS event M_L = 3.8, approximately 1 full magnitude above what had already been experienced at Monticello and equal to the Lake Jocasse, South

Carolina and the Illinois events, would be a conservative and appropriate estimate. Any higher magnitude event would be expected to occur at normal tectonic depths.

E. Ground Motion

1. Deep Earthquakes

66. In their original presentation to the Staff and at the opening seismic hearings on June 22-24, 1981, Applicants defined the ground motion from a maximum magnitude 4.5 earthquake using the H-M adaptation of the Brune model, assuming hypocentral distance of 2.0 km and an rms stress drop of 25 bars. The resulting peak acceleration of 0.22 g was converted to a response spectrum using the 84th percentile (mean + one sigma) amplification ratios of Johnson and Traubenik. In its SER and the original hearing, Staff considered that spectrum and anchor point appropriate for use in evaluating the effects of a reservoir induced M_L = 4.5 earthquake upon the plant. See findings 10-12, 17, 23 supra.

67. At the further hearings in January 1982, Applicants continued to rely upon the H-M adaptation of the Brune model and the Johnson and Traubenik amplification ratios as the main support for its ground motion estimates. Staff revised its assumptions with regard to the expected depth of this maximum magnitude earthquake and the anticipated stress drop. It assumed that the event would occur at the typical tectonic depths of 5 to 16 km and an rms stress drop of 50 bars would be appropriate. It examined the sensitivity of these changed assumptions upon the Applicants estimate of 0.22 g and found that the

effects of the increase in stress drop upon the estimated peak ground acceleration was more than compensated for by the effect of the increase in distance. Since it also considered the use of the Johnson and Traubenik model acceptable at the increased distance and magnitude range, it concluded that the response spectra derived from the Applicants' use of their model to describe ground motion from the maximum magnitude 4.5 RIS is conservative. Staff updated testimony, ff. Tr. 5758, at 35.

68. In view of the unproven ability of the H-M adaptation to predict ground motion in the eastern and central United States and the uncertainties involved in applying that model, the Board cannot rely upon it to establish the ground motion parameters. We find the use of the Johnson and Traubenik amplification ratios less objectionable for use with the typical tectonic depth earthquakes of from 5 to 16 km than with shallow RIS (for which they would be unacceptable). We also find, however, that certain other methods for estimating ground motion utilized by Applicants and Staff in preparing for the further seismic hearings are preferable, and rely upon them instead.

69. At the further seismic hearings, Staff testified that it recently became aware of the availability of an extensive set of strong motion records recorded at an earthquake sequence near Mammoth Lakes, California in 1980. Thousands of records from over a thousand earthquakes in the magnitude 1 to 6 range were recorded. The Staff ask Applicants to evaluate the data set so as to determine whether site specific spectra suitable for use in determining the ground motion from

a M_L = 4.5 earthquake could be estimated. Id. at 36; Tr. 5907-08.

70. The earthquake sequence occurred predominantly within the Sierra Nevada, immediately to the south of Long Valley caldera. The site conditions within the caldera, where many of the seismographic instruments were deployed for reasons of accessibility and logistics, do not resemble site conditions at the V. C. Summer Nuclear Station. The McGee Creek site lying outside the caldera is more similar to the Summer site. It is situated on a few meters of glacial till underlain by metamorphosed rocks which are in turn draped over granite. All events from magnitude 4.3 to 4.8 recorded on the McGee Creek seismograph were selected for comparison. Tr. 5347-49. For events recorded at McGee Creek in the magnitude range 4.3 to 4.8, the average 50th and 84th percentile peak acceleration values are 0.11 and 0.18 g, respectively. Staff updated testimony, ff. Tr. 5758, at 36.

71. Based on its current knowledge, the Staff testified that this data represents the best source of data available to determine ground motion from an M_L = 4.5 earthquake in the 5 to 16 km depth range. Ibid.; Tr. 5765. The average hypocentral distance of 7.3 km associated with the data set used by the Applicants indicate that the resulting spectra would be a conservative estimate of ground motion within this range.

72. Staff acknowledged that questions arise with respect to the use of these data in estimating ground motion at an eastern site. These questions relate to regional differences in source characteristics and attentuation, and differences between the site

conditions at the Mammoth Lakes recording station and those at the Summer plant. The Staff did not believe, however, that these differences preclude use of the Mammoth Lakes data at the Summer plant. The Staff stressed that the primary difference between eastern and western U.S. is that ground motion from eastern U.S. earthquakes is larger at greater distances. Tr. 5899; Staff updated testimony, ff. Tr. 5758, at 37-38.

73. Applicants' analysis demonstrated that at frequencies less than 7 hertz the Applicant's model spectrum would exceed the Mammoth Lakes spectra for all frequencies. At frequencies greater than 7 hertz the Mammoth Lakes 84th percentile was approximately equal to the model spectrum except for a sharp exceedance centered about 8 to 9 hertz and a a slight exceedance at 15 to 20 hertz. Ibid. (See also figure 1.)

74. Staff regarded these peaks as consistent with those observed in the individual spectra and believed the peaks reflect the peculiar site conditions at the particular recording station. Staff took the position that the Mammoth Lakes site-specific spectrum verified the conservatism of the Applicant's model RIS spectrum for describing ground motion from an M_L = 4.5 earthquake for those structures at the Summer plant founded on rock. Id.; Tr. 5767. The Board finds this position both reasonable and convincing and supported by the weight of the evidence.

75. Applicants conducted an analysis of accelerograms recorded during aftershocks of the 1975 Oroville, California earthquake. Accelerograms recorded at five rock-like sites during the aftershock sequence were selected for analysis. RM-5, ff. Tr. 5042, at 1.

76. Forty-four components of horizontal motion were obtained at these sites from standard accelerographs. Magnitudes of these events vary from 4.0 to 5.2 with an average magnitude of 4.4. Focal depths of the forty four components vary between 6.3 and 12 km with an average of 9.4 km, and hypocentral distances are all less than about 15 km. The records were processed to retain all information in a frequency range from 0.65 to 46 hertz. Values of peak acceleration corrected for instrument response range from 28.7 to 204.6 cm/sec^2 (.03 g to .21 g). Id., at 1-2, Table 3; Tr. 5352-53.

77. Applicants also presented testimony from Dr. Nuttli that, for normal depth earthquakes in the eastern United States, peak horizontal accelerations in the near-source region of M_L = 5 earthquakes are estimated at 0.11 g, which is less than the SSE value. Nuttli testimony, ff. Tr. 5164, at 7. However, there were few data points in the curves on which he based his testimony, and all but one were concentrated around a distance of 100 km from the source. Furthermore, the curves were constructed for an assumed focal depth of 10 km. Dr. Nuttli indicate that he would not feel comfortable in using the curves for anything but far field earthquakes and that, even with those, an assumed focal depth of less than 10 km (such as 5 km) would require that the curves be pushed up to higher values. Id., at figure 2; Tr. 5475-76. Under these circumstances, the Board does not place any reliance upon Dr. Nuttli's curves to establish or support any ground motion parameter.

78. As an additional measure, the Staff compared the peak acceleration of 0.22 g proposed by Applicants with estimated peak

accelerations for an M_L = 4.5 earthquake derived most recently by other investigators using other techniques. Staff updated testimony, ff. Tr. 5758, at 38; Tr. 5907-08. This comparison with recent estimates of peak acceleration versus magnitude and distance for different locations around the world indicated a wide variation in estimates, with Applicants' assumed peak of 0.22 g exceeding almost all of these estimates. Id. at 41.

79. Board witness Dr. Luco agreed with the ground motion estimates made by Staff in its supplemental testimony with regard to normal tectonic depth earthquakes. For a maximum magnitude earthquake on the order of 4.5 at a depth of greater than 5-6 km, he found the mean + one standard deviation spectra for Mammoth Lake and Oroville to support the reasonableness of Applicants' 0.22 g RIS spectra for defining the maximum ground motion from these deeper events. Tr. 4728, 4973, 5596. Board witness Dr. Joyner also had no problem with the ground motion from the deeper events. Tr. 5733. The Board agrees that the ground motion from earthquakes up to 4.5 M_L at normal tectonic depths will not exceed Applicants' 0.22 g RIS spectra.

2. Shallow Earthquakes

80. In addition to relying upon the H-M adaptation of the Brune model (which the Board finds unreliable), Applicants also made ground motion estimates based upon scaling up the ground motion from 6 events at the Monticello reservoir to a 4.0 magnitude earthquake. Applicants' witness Dr. Robin McGuire scaled up the spectral amplitudes from these events directly, rather than scale the spectral shapes using a parameter such as peak ground acceleration. In Dr. McGuire's opinion,

although the data were inadequate for conclusive estimates, the comparison indicated that the Applicants' RIS spectrum was adequate in that it appeared to envelope the scaled values, except perhaps at high frequencies. Tr. 555-65 (including insert).

81. However, in addition to not being conclusive, the scaling was also defective. Dr. McGuire used a factor of 0.5 to represent amplification in the records, which the Board does not accept as having been established. Furthermore, had he used the correct exponent of 0.5, rather than 0.25, it would have resulted in the amplitudes at 4.0 magnitude being multiplied by a factor of 1.7. Tr. 5741-48. Consequently, the Board does not accept that analysis.

82. According to Staff, use of the Applicants' model is not appropriate to determine ground motion from shallow earthquakes at close distances. As it testified, the Johnson and Traubenik amplifications would not be appropriate where significant ground motion is expected at high frequencies such as have already been observed from nearby earthquakes at Monticello. In addition, the issue of saturation of ground motion with distance would have to be resolved if earthquakes at very close distances (within two source radii) were considered. Tr. 5912; Staff updated testimony; ff. Tr. 5758, at 41-42.

83. The peak acceleration at Monticello of 0.35 g, for the October 16, 1979 event, was recorded at a hypocentral distance of 0.8 km from a magnitude 2.8 earthquake at a depth of 70 meters. The Staff examined the effects an increase in magnitude would have upon ground motion estimates. Utilizing peak acceleration (that parameter most

related to spectral response at high frequencies), the Staff stated that one can estimate the ground motion at these frequencies. Assuming a scaling with magnitude recommended by Joyner and Fletcher and a typical scaling with respect to distance, it was indicated that 0.35 g for an M_L = 2.8 earthquake at 0.8 km would scale to the same value or less assuming an M_L = 4.0 earthquake at a distance of 2 km or more. Id. at 43.

84. If a larger event were to occur, Staff assumed it would be deeper and the resultant ground motion from this event would be enveloped by the envelope of existing ground motions and estimated RIS spectra. Staff found 2 km to be a very conservative estimate of hypocentral distance based on the distance of the plant to the earthquake clusters and Dr. Nuttli's estimate of 2.3 km as the shallowest depth at which an M_L = 4.0 event would occur. Thus, the larger but deeper events would have acceleration values that are the same or less. Ibid.; Tr. 5770, 5913.

85. Staff emphasized that the purpose of scaling peak acceleration was not to arrive at a definitive estimate of peak acceleration from an M_L = 4.0 at 2 km. Rather, the purpose was to provide some reasonable estimate as to the relative difference at high frequencies between the highest ground motion recorded so far at the Monticello dam abutment and the ground motion that may be recorded near the Summer plant from a postulated larger earthquake within the shallow zone of reservoir-induced seismicity. Staff updated testimony, ff. Tr. 5758, at 43.

86. The Staff concluded that the appropriate designation of the largest ground motion at the Summer site from the occurrence of RIS within the shallow zone of seismicity is the envelope of the response spectra from data that have been recorded at Monticello. Id. at 44; see figure 1. The Board finds this position both reasonable and conservative. This ground motion envelope exceeds the Applicant's proposed RIS spectrum at frequencies greater than 10 hertz.

87. In reaching the conclusion that the envelope of the response spectra from data recorded at Monticello can be relied upon, the Board relies heavily upon the agreement of Board witnesses Drs. Luco and Trifunac with this procedure. Dr. Luco recommended that the effects of scattering by the embedded foundation also be taken into account to the extent of any expected reductions of motion in the frequency range of from 5 to 30 hertz. Tr. 4711-12, 4982, 5596-97. The Board agrees that those effects should be taken into account in the further confirmatory tests. The Board also relies upon the testimony of Staff seismologist Dr. Andrew Murphy that larger magnitude events tend to occur at deeper depths for its conclusion that the maximum shallow earthquake postulated by Staff of M_L = 4.0 will occur at a distance of 2 or more kilometers from the plant. See Tr. 5781. The Board notes that its concern for shallow earthquakes extends only to a maximum of 3.8 M_L, as discussed earlier.

88. The Board also notes that Board witness Dr. Joyner scaled ground motion from the August 1978 2.8 M_L event to higher magnitudes. Because he maintained hypocentral distances of less than 1 km for the higher magnitude events, which the Board finds would not likely occur within a depth of only 1

km, the Board does not accept his higher ground motion estimates. See Joyner report of November 12, 1981, ff. Tr. 4696, at Table 1.

F. Damage to Plant and Equipment

89. On the basis of the evidence adduced, Board witnesses Drs. Luco and Trifunac saw little danger to the nuclear plant structures themselves from the maximum magnitude earthquakes projected for the Monticello reservoir area. Tr. 4884, 4988. The Board agrees with that assessment. As a general proposition, none of the witnesses were aware of any damage to engineered facilities from an earthquake equal to, or less than, a magnitude 5. Tr. 4847-48, 4962-63, 5000, 5262, 5332. This lack of observations of damage should obviate any concern for damage to plant structures from the postulated maximum 4.5 M_L earthquake at normal tectonic depths. Furthermore, the maximum epicentral intensity for a Piedmont Province earthquake was Intensity VII, and for the Clark Hill earthquake, upon which the projected 4.5 maximum magnitude deep earthquake was primarily based, only about

Intensity V. Tr. 5947-48, 5960. By definition, an Intensity VII earthquake would not cause damage to engineered structures.9/

90. Similarly, while there have been few opportunities for observations of damage to engineered facilities from shallow earthquakes in the range of interest, Applicants' expert, Dr. Nuttli, has correlated the most damaging eastern United States earthquakes occurring at shallow depths with their epicentral intensities. Except for two earthquakes occurring in a region of intensive mining, in or above a mine itself, in which maximum intensity was VIII, the maximum intensity of the other earthquakes was Intensity VII. Tr. 5174-76. It is extremely unlikely that the historical maximum intensity of VII for a nonmining region for all shallow eastern U.S. earthquakes would be exceeded by an earthquake occurring at a shallow depth at Monticello.

9/ Intensity VII on the Modified Mercalli Intensity scale of 1931, the intensity scale utilized by the expert witnesses, is defined by United States Earthquakes, 1978 at 6, as follows:

> VII. Frightened all--general alarm, all ran outdoors. Some, or many found it difficult to stand. Noticed by persons driving motor cars. Trees and bushes shaken moderately to strongly. Waves on ponds, lakes, and running water. Water turbid from mud stirred up. Incaving to some extent of sand or gravel stream banks. Rang large church bells, etc. Suspended objects made to quiver. Damage negligible in buildings of good design and construction, slight to moderate in well-built ordinary buildings, considerable in poorly built or badly designed buildings, adobe houses, old walls (especially where laid up without mortar), spires, etc. Cracked chimneys to considerable extent, walls to some extent. Fall of plaster in considerable to large amount, also some stucco. Broke numerous windows, furniture to some extent. Shook down loosened brickwork and tiles. Broke weak chimneys at the roof-line (sometimes damaging roofs). Fall of cornices from towers and high buildings. Dislodged bricks and stones. Overturned heavy furniture, with damage from breaking. Damage considerable to concrete irrigation ditches.

91. More specifically, with regard to the spectral values of ground motion anticipated at Monticello, we see no likelihood of damage to the nuclear plant structures. To begin with, these structures have natural periods longer than those corresponding to the high frequencies discussed above, at 10 hertz or greater. The peak accelerations which might occur as random high frequency spikes on the acceleration time history, do not represent a significant energy input to the structures. The response of the structures would be essentially the same whether or not the peaks occur. The high frequency spikes do not contain sufficient energy to overcome the inertia of large structures and the frequency of the spikes is well above the response frequency of the power plant structures, thus precluding resonant response. Staff examined the effect of the spectral exceedances in question on the safety related structures. It testified that these structures all have fundamental frequencies below 10 hertz, significantly removed from the peak high frequency motions characterized by the free-field response spectra. Because of this difference in frequency, the response of major structures of the high frequency motion will be low and less than the response spectra predicted by use of the SSE response spectra. According to the Staff, the stresses induced in the structures are controlled by the SSE response spectra. Staff updated testimony, ff. 5758, at 63; Tr. 5772-73.

92. Applicants have demonstrated many conservatisms in the design and construction of the nuclear plant structures above and beyond the design response spectra to which the plant structures were built. Since the Board has found that spectral exceedances due to the

reservoir-induced events (both deep and shallow) fall in the range above the fundamental frequencies of the safety related structures, the conservatisms constitute additional reasons why the safety of the structures is beyond question.

93. With regard to safety related equipment and components, however, there is greater concern. Their natural frequencies range between 4.5 and 44.7 hertz, and they might be affected by the spectral exceedances above 10 hertz. Applicants have demonstrated that certain margins exist in the original design of the equipment and components that might accommodate ground motion exceedances over the original design spectra from reservoir induced seismicity. See Chen testimony, ff. Tr. 5324. Board witness, Dr. Luco, examined the safety margins and expressed some concern with regard to certain pieces of equipment or piping where the margins amounted only to approximately 30%. Tr. 4727, 4730, 4971-72, 4986-88, 5439. The Board agrees that, only with respect to equipment which the safety margins have been shown to be low, is there any concern.

94. Staff discussed the effect of spectral exceedances on systems and equipment mounted in the structures. These will be excited by the motion of the structure at the mounting location(s) of the various components. It noted that higher frequency motion (above 10 hertz) with little amplification will theoretically be present in excess of that predicted by the ground motion characterized by the SSE response spectra. In the judgment of the Staff, prudence suggested that any evaluation include the high frequency motions. Staff updated testimony, ff. Tr. 5758, at 63-64. The Board agrees. Systems and

equipment mounted on or near the foundation slab will experience the high frequency motions directly transmitted through the slab. According to the Staff, it is for this group of components that evaluation of the higher frequency motion are most significant. Ibid.

95. The equipment and components now installed in the plant have been qualified by tests and analysis to the SSE design level. The practicalities of much of the testing are such that this equipment has, in fact, seen excitation at the higher frequencies up to perhaps 40 hertz. As far as structural integrity, much of this equipment can take very high peak acceleration loads. Tr. 5774, 5796.

96. Further insight into the sensitivity of nuclear safety grade components to high frequency excitation (20 to 80 hertz and above) is available through the extensive requalification testing being performed for Mark II and Mark III boiling water reactors. The firms supervising the test program report that inputs less than 60 hertz rarely cause malfunction and that where malfunction has occurred, the mode has been primarily minor contact chatter. Staff updated testimony, ff. Tr. 5758, at 65.

97. Applicants have a present commitment to review all systems and components necessary for shutdown and continued heat removal to confirm that explicit margins exist for each safety component. Id. at 5, 65. Staff characterizes this effort as confirmation that the equipment with high-frequency response on the lower levels of the facility have appropriate margins to perform their intended function for the life of the plant. Staff Prop. Find. 164. The Staff testified that reservoir-induced ground motion employed for this evaluation should, to

the extent reasonable, take into consideration appropriate reductions in the free field spectra. Tr. 5774, 5787. The Board agrees. The ACRS advised, and the Staff concurred, that undertaking this confirmatory program need not prohibit plant operation. Tr. 5774-75. The Board agrees. The Staff believed this task could be completed during the early period of operation. Tr. 5787.

G. Charleston Eartnquake

98. At the construction permit stage, the NRC Staff concluded that the weight of the seismologic and geologic information supported the proposition that the seismicity in the vicinity of Charleston, S.C., including the Modified Mercalli intensity IX-X 1886 earthquake, was related to structures beneath the Coastal Plain province in the Charleston area and should not be assumed to migrate outside of immediate Charleston area. The Licensing Board presiding at that stage agreed. South Carolina Electric and Gas Co. (Summer Nuclear Station, Unit 1), LBP-73-11, 6 AEC 213, 218 (1973). Following the issuance of the construction permit, the then AEC contracted with USGS to perform an extensive geologic and seismologic investigation of the Charleston region. As the USGS investigation progressed, numerous working hypotheses evolved concerning the source mechanism of seismicity in that area. A summary of the USGS position on this matter is contained in a December 30, 1980 letter from J. F. Devine, USGS, to Dr. R. E. Jackson, NRC, which is included as Appendix E to Staff Exhibit 1. That letter concluded, in material part, that the concentration of seismicity in the Charleston earthquake epicentral area both before and after the 1886 event and the lack of post-Miocene faulting in the

evidence for localizing large earthquakes indicate that the likelihood of a Charleston size event in other parts of the Coastal plain and Piedmont is very low. Consequently, the report continued, earthquakes similar to the 1886 events should be considered as having the potential to occur in the vicinity of Charleston and seismic engineering parameters should be determined on that basis. Id., Tr. 1070-71. It continued with a recommendation that research on the sources of the Charleston and other east coast earthquakes should continue if a more definitive resolution of the problem is to be obtained.

99. Applicants also performed a reassessment of the impact of Charleston seismicity on the Summer site in light of the new data compiled by the USGS since the construction permit stage. Applicants' assessment is contained in its Exhibit 1. Applicants' position on the Charleston earthquake was summarized in the prefiled testimony of Dr. Alexander. It concluded from the extensive work done by USGS, evaluations of the most prominent hypotheses, the probabilities of future occurrences and the historical record of seismicity in the Charleston area, that there was no observational evidence to indicate that an earthquake comparable to the 1886 event will reoccur in any location except in the Charleston vicinity. Dr. Alexander further testified that a reoccurrence of such an event in the Charleston area will not generate ground motions that exceed the Summer design basis. Alexander testimony, ff. Tr. 728, at 16. See Tr. 921-22.

100. Staff reviewed the results of the USGS study of the Charleston region, the working hypotheses formulated as a result of that work, and the analyses of the Charleston region performed by the Applicants.

Based on its consideration of this information, the Staff concluded that the position held at the construction permit stage is still valid, namely, that there is no basis to assume that an earthquake equivalent to the 1886 Charleston earthquake is likely to occur anywhere but in the general vicinity of Charleston, South Carolina. Staff took the position that the 1886 Charleston earthquake can be reasonably related to the complex geologic structure unique to the region and in consideration of the recurrent seismicity in the area should not, in developing the earthquake design basis for the facility, be assumed to occur at the Summer site. However, because a clear association between structure and seismicity has not been demonstrated, it recommended that geological and seismological research be continued in the Charleston area. Stf. Ex. 1 at 2-38 to 2-39. It reaffirmed this position at the hearing that there was no basis to migrate the Charleston earthquake to other parts of the Coastal Plain or Piedmont provinces. Tr. 1063, t

1070-71, 1155. s

101. The Board has reviewed the evidence presented and finds that i supports the reasonableness of the construction permit Licensing Board'o conclusions that the 1886 Charleston earthquake can be localized to the local Charleston area. The Board, therefore, concludes that there is n new information that warrants reopening this matter at this operating license stage for a re-determination on the merits.

H. Wateree Creek Fault

102. Subsequent to the impoundment of the Monticello reservoir and the ensuing increase in local seismic activity, the USGS contracted the services of Dr. Donald T. Secor, Jr., Department of Geology, University

of South Carolina, to conduct an intensive geologic investigation of the general area surrounding the reservoir. During the course of the investigation, Dr. Secor mapped a previously unrecognized fault within the Chapin quadrangle which he named the Wateree Creek fault. Alexander testimony, ff. Tr. 728, at 16-18. The Applicant testified that, on the basis of its review of the findings of Dr. Secor to date, the fault had been traced northward to a point approximately 2 km northeast of Peak, South Carolina and there was no observational evidence of northward continuation of the fault to the vicinity of the Monticello reservoir. Further, there was no geological evidence to suggest that the fault is capable nor has any seismicity been associated with it. Id. at 18-19. Accordingly, Applicants did not believe this factor was of concern to the safety of the facility. Ibid.

103. The Staff took the position in the Safety Evaluation Report that, on the basis of the information then known, it was reasonably assumed that the Wateree Creek fault may be presently adjacent to the Monticello reservoir, that there is no historic seismicity associated with that fault, and that there is no geological evidence for capability of the Wateree Creek fault. Stf. Ex. 1 at 2-26 to 2-27. Thus, the Staff concluded that the Wateree Creek fault did not pose a hazard to the site. The Staff did consider it prudent, however, for Applicants to continue to monitor the ongoing mapping of that fault. Id. at 2-39.

104. In order to explore the matter further, the Board sought the appearance of Dr. Secor to explain the state of knowledge about the Wateree Creek fault. Dr. Secor explained the status of his mapping efforts and testified that he found no evidence that the Wateree Creek

fault extended into the Monticello quadrangle (Tr. 793), that the fault had not moved in "roughly one hundred million years" (Tr. 794) and that the attitude of the fault was not "particularly favorable for reactivation" (Tr. 796). Dr. Secor professed his general agreement with the conclusions drawn by Applicants from his work. Tr. 795. Dr. Secor further testified that there was no unknown area that would cause him to have reservations about the Wateree Creek fault upsetting the conclusions of the USGS or NRC Staff so far concerning the site. Tr. 799. Finally, Dr. Secor testified that the reservoir-induced seismicity was unrelated to the Wateree Creek fault (Tr. 801) and that the Wateree Creek fault would not likely be activated by reservoir-induced seismicity (Tr. 803).

105. Applicants felt that Dr. Secor's testimony strengthened their earlier testimony. Tr. 980. In addition, on the strength of Dr. Secor's testimony, the NRC Staff expressed less certainty about its earlier position on the possible northward continuation of the Wateree Creek fault. Tr. 1063. It observed that the fault was older than it had previously thought. Tr. 1092. On the basis of the entire evidence on this matter the Board finds that the Wateree Creek fault poses no hazard to the Summer site.

I. Continued Microseismic Monitoring

106. The final seismic issue concerned Intervenor's contention that seismic monitoring should continue until the end of 1983. The NRC Staff indicated its intention to impose a license condition whereby the Applicants must continue to monitor seismicity until the end of 1982 and may not terminate such program unless prior written approval is received from the Staff. Stf. Ex. 1b at 18-3. The Staff believes that this

continued monitoring is desirable in order to detect any possible event larger than that experienced to date. Stf. Ex. 1 at 2-23; Tr. 1069. Applicants testified that it believed that the largest or approximately largest reservoir-induced event had already occurred at the site--magnitude 2.8. Tr. 886-888, 909.

107. The Board agrees with the Staff that continued microseismic monitoring is desirable. Considering that the Board also agrees with the SER's statement (Staff Exhibit 1 at 2-26) that "there is no reason to assume that the largest earthquake induced by Monticello reservoir has yet occurred;" that the largest reservoir-induced earthquakes generally occur up to 10 years after impoundment; and that the maximum event at Lake Jocasse, S.C. occurred about six years after water level approached full pond, we cannot see how the elimination of seismic monitoring before the end of 1983 can be justified. Full pond elevation occurred on February 8, 1978. Id. at 2-22. Staff could not explain why the same reasons that require monitoring until the end of 1982 would not also require monitoring to continue at least until the end of 1983. Tr. 1146-49.

IV. Principal Findings

108. The maximum magnitude potential earthquake at normal tectonic depths (5-16 km) at the Monticello reservoir is M_L = 4.5.

109. The maximum magnitude potential earthquake at shallow depths (0-3 km) at the Monticello reservoir is M_L = 3.8.

110. The ground motion model (the H-M adaptation of the Brune model) relied upon by Applicants in the FSAR and the opening hearings

on seismicity (June 22-24, 1981), and approved by Staff in the SER, is unreliable. Because of its uncertain parameters, a conservative application of that model would result in a peak acceleration anchor point 3 or 4 times as great as the 0.22 g anchor point predicted by Applicants. For the earthquakes occurring on October 27, 1978 and October 16, 1979, rms stress drops for each event were conservatively calculated at from 2 to 4 times the 25 bars utilized by Applicants in their application of the H-M model. The H-M model is too unpredictable to be used for estimating ground motion.

111. The Johnson and Traubenik amplification ratios used by Applicants to construct response spectra, upon which Applicants relied in their SER and the opening seismic hearings and which was approved by Staff in the SER, are inappropriate for the shallow reservoir induced seismicity expected at Monticello reservoir.

112. Applicants have failed to demonstrate that the high peak horizontal acceleration readings for the August 1978 and October 1979 earthquakes of 0.25 g and 0.35 g, respectively, reflected any amplification of ground motion as the waves propagated from the underlying bedrock to the surface where they were recorded. In particular, Applicants have failed to demonstrate that there was any amplification due to soil, topography, or accelerometer pad-soil interaction. It is likely, however, that the ground motion exhibited in the free field during an earthquake would be reduced as it is transmitted to the nuclear plant structures embedded in rock because of a scattering of the waves and the rigidity of the foundations.

113. Through use of ground motion estimates and response spectra derived from earthquakes at Mammoth Lake and Oroville, California,

Applicants and Staff have demonstrated that the ground motion from the maximum magnitude earthquake postulated for normal tectonic depths (5-16 km), utilizing the appropriate damping values, will not exceed the motion predicted by Applicants' SSE design response spectra. For that reason, and on the basis of empirical observations with regard to epicentral intensities and damage from other tectonic events, Applicants and Staff have demonstrated that there will be no damage to the nuclear plant structures or equipment from a maximum magnitude earthquake occurring at normal tectonic depths.

114. By utilizing the envelope of response spectra from data already recorded at Monticello, Staff has demonstrated that the ground motion from the maximum magnitude postulated shallow event, at the proper damping values, will exceed Applicants' SSE design response spectra only at frequencies greater than 10 hertz. For that reason, and based upon empirical observations with regard to epicentral intensities from other shallow earthquakes in the eastern United States and from observations of damage from other earthquakes, Applicants and Staff have demonstrated that the maximum magnitude shallow earthquake postulated for the Monticello reservoir (3.8 M_L) will not damage the nuclear plant structures.

115. Because some of the safety related equipment and components have natural frequencies above 10 hertz, and some of the systems and equipment are mounted on or near the foundation slab where they will experience high frequency motions transmitted directly through the slab, Applicants have committed themselves to reviewing the systems and equipment necessary for shutdown and continued heat removal to confirm

that explicit safety margins exist for each component. The Board agrees that this review may take into account appropriate reductions of ground motion attributable to the embedment of the foundations in rock and that the Summer plant can commence operations prior to the completion of the confirmatory program. The Board, however, does not agree that the confirmatory program can rely upon any of the evidence adduced in this proceeding as establishing amplification factors in the ground motion recordings due to soil, topography, or accelerometer pad-soil interaction.

116. The existence of the Wateree Creek fault does not pose any danger to the Summer nuclear plant.

117. No evidence has been adduced which would warrant reopening the finding of the construction permit Licensing Board that the 1886 Charleston earthquake should be localized to the immediate Charleston area.

118. It is likely that the maximum magnitude earthquake from RIS at Monticello will not occur until 6 to 10 years after impoundment, which took place in February of 1978.

V. Conclusions of Law

Based upon the entire evidentiary record of this proceeding, and upon the foregoing findings of fact, the Board concludes that with regard to Contention 4: a) the FSAR was inadequate with respect to the description of seismic activity in the area of the Summer plant site. However, the inadequacies were cured by the full record in this proceeding; and b) site seismicity must be monitored at least until the

end of 1983, and Staff should consider further monitoring at that time as an additional licensing requirement.

The Board concludes further that, if the licensing conditions set forth below are implemented, the seismic safety of the Summer nuclear plant will be assured.

VI. Licensing Conditions

In the event that the other issues are resolved in favor of plant operation (with or without further conditions), the Licensing Board will require the following conditions to the granting of the operating license:

1. That seismic monitoring be continued at least until December 31, 1983, and that Staff reevaluate at that time the need for further monitoring to be made an additional licensing requirement; and

2. That Applicants successfully complete during the first year of operation the confirmatory program on plant equipment and components, within the guidelines established in the Findings, to demonstrate to Staff's satisfaction that explicit safety margins exist for each component necessary for shutdown and continued heat removal in the event of the maximum potential shallow earthquake.

VII. Order

IT IS ORDERED, in accordance with 10 CFR §§ 2.760, 2.762, 2.764, 2.785, and 2.786, that this Partial Initial Decision shall become effective and shall constitute, with respect to the matters covered

herein, the final decision of the Commission 30 days after the date of issuance hereof, subject to any review pursuant to the above cited Rules of Practice. Exceptions to this decision may be filed within ten (10) days after service of this Partial Initial Decision. A brief in support of such exceptions may be filed within thirty (30) days thereafter, forty (40) days in the case of the Staff. Within thirty (30) days after service of the brief of appellant, forty (40) days in the case of the Staff, any other party may file a brief in support of, or in opposition to, such exceptions.

ATOMIC SAFETY AND LICENSING BOARD

G. A. Linenberger

Gustave A. Linenberger, Member
ADMINISTRATIVE JUDGE

Frank F Hooper/HG

Dr. Frank F. Hooper, Member
ADMINISTRATIVE JUDGE

Herbert Grossman

Herbert Grossman, Chairman
ADMINISTRATIVE JUDGE

Bethesda, Maryland
July 20, 1982

VIII. APPENDIX

Procedural Context of Our Calling Board Witnesses

Unlike the other parties to the proceeding, Staff did not accept the Board's decision to call independent experts as Board witnesses. It moved for directed certification of this ruling, primarily on the grounds that we had not adequately explained or articulated our reasons for calling these experts. Staff Motion for Directed Certif., August 7, 1981, at 1, 3, 12. Staff suggested that the Board Chairman had certain "precise questions" relating to his areas of concern that he had not posed to Staff. Id. at 2. It suggested that the Appeal Board "instruct" the Licensing Board to refrain from calling its experts without attempting to elicit this desired information from the witnesses profferred by the parties (Id. at 4), and asked for a rule that would require a licensing board to make a finding of "exceptional circumstances" before calling its own experts (Id. at 9, 12, 14).

Apparently acting upon Staff's representations that this Board had failed to explain adequately its reasons for calling Board experts, the Appeal Board requested our full explanation. Appeal Board Memorandum of August 10, 1981, 14 NRC at 1159. We responded, indicating that we had explained our position at transcript pages 3790-3817. Memorandum of August 11, 1981. We indicated further that the inadequacies surmised by us did not relate to Staff's testimony but, rather, to the Staff's

review as disclosed by the testimony - a matter that did not lend itself to correction merely by adducing further Staff testimony. We described the choices before us as having been (1) to close the record on the evidence already received, (2) to schedule a further hearing involving only the previously-heard witnesses (whose further testimony might still be inadequate for a satisfactory record, necessitating a further delay to retain independent experts) or (3) to attempt to arrange for independent experts and further hearings with all deliberate speed. We pointed out that we had not discouraged further testimony by Staff's witnesses but had indicated that the parties would be given full opportunity to respond to any positions that might be taken by the Board witnesses and encouraged the parties to make full use of that opportunity. Finally, we offered that the experts we had selected should be in a good position to critique the Applicant and Staff's choice of modeling methods and data, about which the Board had expressed some concern (i.e., the Hanks and McGuire adaptation of the Brune model and the stress drop inputs).

In response to our memorandum, the Appeal Board ordered that responses to the Staff's motion be filed and served no later than August 21, 1981 and that, on or before that same date, the Staff might file a supplemental paper in support of its pending motion, confined to the content of the Licensing Board's memorandum. Staff filed that supplement on August 21, 1981 and shifted its focus to criticisms of the Board chairman's supposedly pejorative thoughts and accusations. We discussed Staff's criticisms in our Memorandum and Order of October 15,

1981, LBP-81-47 14 NRC 886, 870, and will not repeat it here. Staff's memorandum also indicated that it would present the further prefiled testimony of its seismic panel by September 15, 1981.

On August 25, 1981, the Appeal Board ordered that the Staff file its supplemental testimony no later than September 15. The Appeal Board conjectured that, following the Licensing Board's consideration of that supplemental testimony, the Licensing Board might no longer find it necessary to call the independent experts. The Appeal Board's Order indicated that it would issue a further memorandum elaborating upon the matter.

On August 27, 1981, the Appeal Board issued an unpublished memorandum in which it indicated that it had not yet undertaken a review of the testimony of the parties. Appeal Board Memorandum of August 27, 1981, fn. 1 (later published in an Appendix to ALAB-663, 14 NRC 1140 (1981) at 1161.) By merely scrutinizing the Board Chairman's remarks, without referring to the evidence adduced, the Appeal Board determined that any evidentiary deficiencies would appear to be amenable to resolution through further Staff review and testimony, and that the dichotomy drawn by the Licensing Board between the Staff's testimony and the Staff's review was a distinction without a difference. With a view towards the Licensing Board's reviewing the expected Staff prefiled testimony due on September 15, 1981, the Appeal Board laid down a standard to be applied to the calling of Board experts. The Appeal Board opined (14 NRC at 1163) that "such an undertaking * * * [the calling of Board experts] should be reserved for the most extraordinary situation in which it is demonstrated beyond question that a Board

simply cannot otherwise reach an informed decision on the issue involved."

Moreover, even before reaching the point at which that suggested general rule might be applied to determine whether Board witnesses could be called, the Appeal Board suggested options that must be explored if the Licensing Board had been persuaded for one reason or another that certain of the evidence is unreliable. As stated by the Appeal Board, "among other things, the [Licensing] Board can (1) simply reject that evidence and decide the issue without regard to it (i.e., on the basis of the other evidence of record); or (2) require the sponsoring party to produce supplemental testimony which is not subject to the same infirmities." Ibid.

With regard to this standard, we must state at the outset that we did not fully understand it. Nor did we take it to be a rule imposed on this Board. To begin with, as we later pointed out in LBP-81-47, 14 NRC 866, 874 (1981), we did not see how that standard could ever be satisfied in an operating license proceeding. Since the burden is on the applicant to establish that the safety issues should be resolved in favor of plant operation, we thought that where a Board simply cannot otherwise reach an informed decision on the issue involved, imposition of the standard would logically require a denial of the license. Consequently, we thought our reading of the Appeal Board's standard would place that standard in conflict with a number of NRC cases in which the respective licensing boards had called their own experts (see cases cited at LBP-81-47, supra, at 14 NRC 873) and the heretofore prevailing standard announced by the Appeal Board in Consumers Power

Company (Midland Plant, Units 1 and 2), ALAB-382, 5 NRC 603, 608 (1977), that "the decision to call or not to call a witness for the Board must rest and does rest ultimately in the sound discretion of the tribunal alone." Moreover, the apparent prohibition against a board's calling its own expert would be contrary to the Federal Rules of Evidence, all existing judicial authority, and accepted administrative practice, as later discussed in LBP-81-47, supra, 14 NRC at 872.

In addition to our not being able to reconcile the Appeal Board's standard with established practice, the procedural context in which the standard was announced persuaded us that it was not intended as a ruling imposed upon this Board. As we read the standard, it appeared to track the relief requested by Staff in its motion for directed certification, that the Board be required to make a finding of "exceptional circumstances" before calling its own experts. Staff motion at 9, 12, 14. However, if the Appeal Board were deciding the matter before it, it would be expected to read the evidentiary record concerning that matter, which it indicated it had not. Memorandum of August 27, 1981 at fn. 1, 14 NRC at 1161. Furthermore, the Appeal Board had announced in both its August 25 and August 27 memoranda that it was not deciding Staff's pending motion for directed certification and was holding it in abeyance. 14 NRC at 1160, 1164. Finally, we did not believe that the Appeal Board intended to issue a ruling that would, in effect, grant the Staff's motion to reverse our actions, based upon a new standard that apparently revoked its prior standard, in a manner that would effectively preclude Commission review of its action. If we then were

to apply that new standard and decide not to call the experts, the matter might never reach the Commission.10/

In the context of the substantive and procedural anomalies just discussed, we were uncertain of the meaning and application of the Appeal Board's pronouncements. In the very next hearing session, in fact, the Licensing Board Chairman expressed his uncertainty, as follows (Tr. 387-88):

> Mr. Knotts [Applicants' counsel], if you would care to expound upon what the procedures are and what the obligations are with regard to the Appeal Board's memorandum [of August 27, 1981, supra], we'd be glad to hear from you but I don't think at this point that we're prepared to say anything about it and as I indicated in the conference call, there are some procedural problems and substantive problems with regard to that memorandum, but to the extent that you want to offer your positions we'd be glad to hear them, or any other party before we decide on what we ought to do further, that is orally here at hearing. We are not asking for any further briefs.

Applicants' counsel responded (Tr. 388) by indicating that he "didn't really have anything to add in that regard," and none of the other parties offered an interpretation.

As we finally interpreted the Appeal Board's actions (mistakenly, it now appears), they were designed to give us a strong indication that the Appeal Board was inclined to disagree with us as a matter of initial impression without reviewing the record, and was affording us an

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10/ We do not discuss this matter to suggest any impropriety in the Appeal Board's handling of this matter. We accept the Appeal Board's authority to determine the propriety of its own actions vis-a-vis the Licensing Board. We merely raise the procedural aspects of this matter to demonstrate that there was considerable foundation to our considering the new standard as a suggestion rather than an unannounced order.

opportunity to reverse our own actions without risking a formal reversal. The Appeal Board's actions we thought, were taken to permit us to withdraw gracefully from a position that otherwise would likely be reversed upon a full review of the record. We found support for our view in the statements made in the Appeal Board's August 25, 1981 memorandum, that it was "possible that, following . . . [our] consideration [of the Staff's supplemental testimony], the [Licensing] Board will no longer find it necessary to resort to the independent consultants" and, "[s]hould that contingency materialize, the pending Staff motion will, of course, become moot." 14 NRC at 1160.

Staff submitted its proposed further prefiled testimony on September 15, 1981. We read that testimony and reviewed the evidentiary transcripts. We saw nothing in the further testimony that resolved our concerns with regard to the critical aspects of the seismic issues. As we read the evidentiary transcripts, we noted that, contrary to Staff's persistent assertions throughout its August 7, 1981 and August 21, 1981 submittals to the Appeal Board that any insufficiency in the record was attributable to the failure of the Board to ask appropriate questions of Staff's witnesses, we had examined Staff's and Applicants' witnesses critically and in depth on the areas of concern, without satisfaction. We had questioned critically the ground motion figures actually recorded near the site (Tr. 757-63), and the basis for Staff's acceptance of Applicants' theory that there had been an amplification of ground

motion from bedrock to the Jenkinsville accelerometer because of soil and topographical characteristics (Tr. 1141-46). We had, as indicated above, suggested a further examination into the USGS records and reports regarding the Jenkinsville accelerometer (Tr. 3799). We had examined, repeatedly and critically, all of the testimony we had heard with regard to the exclusive reliance by Staff and Applicants on the H-M model and the critical input of a stress drop of 25 bars, based upon a conservative projection of a 17 bar calculation for a prior event, to calculate expected future ground motion (i.e., the zero period acceleration point at which to anchor the response spectra). Tr. 861-77, 933-37, 940-46, 971-74, 1004-07, 1018-19, 1122-34, 1136-37, 1186-90, 1207-13, 1221-22.

Acting upon our mistaken view that the new standard laid down by the Appeal Board was a preliminary view based upon a cursory review of the record that might be subject to change upon the Appeal Board's full and formal consideration of Staff's pending motion for directed certification, we issued our Memorandum and Order, LBP-81-47, supra, reaffirming our intention of calling independent experts. With the purpose in mind of persuading the Appeal Board to reverse what we assumed to be a preliminary position and ultimately decide the issue in our favor, we marshalled authorities to support our legal position and urged the Appeal Board to reconsider its "suggested" new standard in light of the evidentiary record. As the Licensing Board then stated (at 875):

> We have no doubt that if the Appeal Board were to consider the Licensing Board's decision to call expert witnesses in the context of the live facts of this case, as would be disclosed by its reading the transcript of hearing, it would reconsider proposing that new standard and would affirm this Board.

We had set these matters before the Appeal Board as respectfully as we knew how, and indicated that "we recognize the authority of the Appeal Board to decide these matters contrary to how we view them and to reverse our actions." Id. at 876. And, although we reaffirmed our intention of calling the Board witnesses at a further hearing, we did not schedule such a hearing pending a further issuance by the Appeal Board. Ibid.

We could not at that time hope to, nor did we even attempt to, comply with the standard proposed by the Appeal Board. On the basis of an uncontradicted record (later proven to be unreliable) to the effect that there had been a full disclosure to the Board of pertinent ground motion recorded near the Summer site, that the maximum ground motion recorded was 0.25g, that the 0.25g reading was an amplification by a factor of 2 of the bedrock motion because of soil and topographical effects, that the H-M adaptation of the Brune model was a reliable formula to determine ground motion which could be relied upon exclusively for that purpose, and that a maximum stress drop of 25 bars could be assumed for that area, we could not hope to demonstrate beyond question that we could not reach an informed decision based upon that evidence. Nor, even though we believed that evidence to be unreliable, did we see how we could apply the other two options proposed by the

Appeal Board in its August 27, 1981 memorandum (14 NRC at 1163), to wit:

> 1) simply reject that evidence and decide the issue without regard to it (i.e., on the basis of the other evidence of record); or 2) require the sponsoring party to produce supplemental testimony which is not subject to the same infirmities.

We could not simply reject that evidence, even though we considered it unreliable, because it was uncontradicted and had been reaffirmed repeatedly by the experts. Even if we could reject it, there was no other evidence of record on ground motion on which we could base our decision. Nor were there any "infirmities" that we thought could be cured by the sponsoring party's supplemental testimony. It was, as we had earlier suggested to the Appeal Board, the analysis (i.e., "Staff's review") we thought deficient, not the testimony.

We were not surprised, however, to discover later that each of our concerns on these critical (to the analysis then relied upon) matters was fully justified. Although the magnetic tapes from the USGS instruments had been available to Applicants' experts (and presumably to Staff if it had requested them) through April of 1980 (Tr. 3414-16; Talwani, ff. Tr. 3407, at 2), by the July 16, 1981 hearing session, a significant event that occurred on October 16, 1979 had not been reported to the Board. The accelerometer data from that event indicated that there had been peak accelerations recorded of 0.35g, 0.36g and 0.18g for the two horizontal and one vertical components, respectively, dwarfing the 0.25g recording of the August 27, 1978 earthquake that had caused so much concern. The later event was not reported to the Board

until we received a "Board notification" from Staff, dated October 20, 1981, following by one day the Appeal Board's Order of October 19, 1981 permitting us to proceed with our calling the Board experts.11/

Moreover, explosive tests and soil modelling by Applicants' experts, testified to during the later hearings in January of 1982, demonstrated that, at the frequency range from 20 to 25 hertz at which the peak accelerations for the August 1978 and October 1979 events had been recorded, there was very little possibility of amplification due to soil or topography. Finds. 36-49. With regard to the stress drop figure to be used in the H-M model, Applicants and Staff calculated stress drops from some of the newly acquired, processed accelerometer records for six events occurring after August of 1978. Using Applicants' root mean square (rms) calculation of stress drops, Staff recalculated stress drops of approximately 12, 19, 23, 42, 7 and 48 bars for the six events. Find. 27. For October 1978 and October 1979 earthquakes, stress drop estimates by Applicants and the Board experts vary from 50 to 65 bars if no amplification of the accelerometer reading is assumed. Find. 29. These calculations contradict not only the "conservative" limit of 25 bars based upon the calculation of 17 bars

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11/ In its ALAB-663, supra, fn. 38, 14 NRC at 1157, the Appeal Board refers to this accelerometer data as "new seismic information" that the Staff brought to the Board's attention. The event had occurred more than two years prior to the Board notification and only the USGS's processing and the notification to the Board were new at the time. The unprocessed accelerometer records, which indicated peak acceleration values of 0.35g, 0.33g and 0.15g for the two horizontal and one vertical components, were available long before then. Board notification (BN-81-32), October 20, 1981; Tr. 3415-16.

for the August 1978 event, but also the assumption fundamental to the use of stress drops (and hence the H-M model) to calculate ground motion, that "stress drops appropriate for estimating strong ground motion do not vary over a range of magnitudes." Appl. Ex. 4 at 4. Staff now concludes that 50 bars (the approximate maximum it calculated thus far at Monticello) is the appropriate rms stress drop to be used in estimating ground motion.12/ Staff updated testimony, ff. Tr. 5758, at 33-34. Staff's ultimate conclusion with regard to the H-M model that it is "physically reasonable but needs to be treated with caution" (Id. at 35), differs markedly from Staff's original, exclusive reliance upon Applicants' use of that model, of which the Board was so critical, to calculate the zero period acceleration anchor point. At the further seismic hearings in January 1982, Staff's main seismic witness retreated from any reliance upon the H-M model. After hearing the bulk of the seismic testimony, he concluded that it was not possible to come to any definitive results using Applicants' model or to

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12/ To avoid confusion, we note that the Brune model is relatively insensitive to changes in stress drop inputs when used to calculate expected magnitudes. Increasing the 25 bars, used by Applicants to arrive at a 5.0 magnitude, to 100 bars, resulted in a 5.3 magnitude, for only a .3 difference. Tr. 1230, 5015. However, when used to calculate ground motion, the Brune model is highly sensitive to variations in stress drop as demonstrated by Chinese strong motion figures. For events at the Hsinfengkieng reservoir with calculated stress drops of approximately 10 bars, the peak accelerations were approximately one-half those calculated for the Monticello reservoir at 25 bars. Appl. Ex. 4 at 5, 12. See Tr. 5922.

determine which parameters are to be used in applying the model. He recommended that the Board look at other approaches. Find. 28.

Similarly, at the further hearings, Staff concluded that Applicants' response spectra were not appropriate for shallow RIS. Finds. 35, 82.

Although we were not surprised later that the further hearing with the participation of the Board experts thoroughly discredited the analyses of which we had been critical, we were surprised by the Appeal Board's response to our decision to proceed further in calling the Board experts. Although we set forth the basis for our determination in a respectful manner and held our proposed action in abeyance until the Appeal Board could review the matter, the Appeal Board viewed that as an "open and flagrant disregard of . . .[its] instructions," and an uninvited and inappropriate "critique" of its prior memorandum. Order of October 19, 1981, 14 NRC at 1166. The Appeal Board followed with its memorandum of December 14, 1981, ALAB-663, supra, in which it viewed us further as having "an apparent and vexatious lack of understanding regarding the relationship of licensing and appeal boards in the administration of this Commission's adjudicatory process." As the Appeal Board explained it, (14 NRC at 1149-50), we had disregarded its instructions which it had issued under the authority conferred by Sections 2.718(i), 2.785(a) and 2.785(b)(1), by which the Appeal Board was authorized to direct the certification of questions arising in proceedings before the licensing boards. According to the Appeal Board,

it had issued the August 27 memorandum within this adjudicatory framework pursuant to a specific request for relief which the Staff was authorized to make and upon which the Appeal Board was empowered to act. Ibid.

Nowhere in this reasoning is there mention of the fact upon which we had relied in our reaffirmation order that, although Staff was authorized to request relief and the Appeal Board was empowered to grant it, the Appeal Board had explicitly declined to exercise its authority within the adjudicatory framework by accepting for ruling Staff's motion for directed certification. Under the adjudicatory framework referred to by the Appeal Board, the Appeal Board can accept a requested certification to review our rulings and in turn be reviewed by the Commission. We did not question that authority. To our regret, we did not know it had been exercised.

Beyond these fundamental matters, we see certain inaccuracies in ALAB 663 that cast us in an unfavorable light. It suggests that we arbitrarily attempted to dictate the methods to be used in the expert reports; that we denied Staff a chance to articulate its views; that we did not explain ours; that we decided to call independent experts to review the Staff, rather than the merits of a novel seismological issue; that we singled out the Staff for criticism; that we relied upon inapposite cases; that we misstated the law because we ignored a

relevant authority; that we defied the Appeal Board by disobeying a clear order to us; that we professed an inability to handle the merits of the case; and that we forced the Appeal Board to allow us to follow a procedure that is entirely unjustified. We will attempt to clarify the record:

1. We never "declined to permit the Staff to justify its position or explore [any] matter," as stated at 14 NRC 1144. The page (Tr. 3791) cited for that proposition contained a statement, taken out of context, to the effect that we did not care to have the Staff come on "now." The preceding page, Tr. 3790, makes it clear that we merely wanted to first state the Board's position. As we stated there: "We want to discuss what it is that the Board has in mind and what the parties have to say about it." (Emphasis added.) The Staff followed the Board's discussion with its own comments at Tr. 3803-05, 3816-17.

2. We never stated that "the Staff should have relied on" certain means and data to determine g values, as also represented at 1144. As the page (Tr. 3793) cited for that proposition indicates, we were not satisfied that the Staff had made a determination of the best means and data to use. We asked Staff to look at other data, but admitted that, with regard to the particular kind of data that we suggested, "Maybe [they are] not good enough data to use." Ibid.

3. We never suggested that we intended to defy the Appeal Board and schedule a hearing with the Board witnesses testifying, to which the Staff counsel objected, as the Appeal Board suggests at 1147. Our

concern was whether to voluntarily adopt a standard we thought was improper or, as we eventually did, issue an order setting forth what we believe to be proper and give the Appeal Board time to rule on the matter. The discussion with the Staff at Tr. 3888-90 related to whether the Staff could tell us when it would be prepared to put its witnesses on if the Appeal Board were to give us the green light. Staff took the position that it could not even tell us when it would be prepared until the Appeal Board decided its motion for directed certification. Nowhere did we suggest that we would actually put the witnesses on without first permitting the Appeal Board to render its decision.

4. We never suggested in the record or in any order we issued that the purpose for calling the independent witnesses was to "audit," "pass independent judgment upon," or "apprais[e]" the Staff's review, testimony or evidence, as the Appeal Board states throughout. 14 NRC at 1152, 1155, 1156. We asked the Board experts "to critique the Applicant and Staff's choice of modelling methods and data [i.e., the H-M model and the data inputs to that model] about which the Board had expressed some concern" (Licensing Board Memorandum of August 13, 1981 at 3) - not to critique the Staff. In order to move the proceeding, the Board experts were asked to not begin their analyses from scratch, but to take the record as it then stood. See Tr. 4683-84. Although this procedure has been characterized as "auditing" Staff and questioning Staff's credibility, it was adopted to expedite matters and apparently succeeded in doing so, except for delays caused by Staff and the Appeal Board.

5. We never "professed [an] inability" to decide the merits of the seismic issue, as stated at 1157. As our Memorandum and Order, LBP-81-47, indicates (at 14 NRC 874), because of the burden of proof a Licensing Board can always decide the issue before it on the evidence adduced. Our position was more properly characterized by another statement at 1149 that we had given the "distinct impression" that we could reach an informed decision on the seismic issue. See, also, p. 1155.

6. We never stated that a trial tribunal's decision to call its own expert is "totally beyond appellate scrutiny" or ignored a court case to the contrary, as suggested at 1153. Any time that a party appeals an issue, no matter how flimsy the appeal, it is subject to appellate scrutiny. However, we read the case we supposedly overlooked, United States v. Weathers, 618 F.2d 663 (10 Cir. 1980) as approving, rather than criticizing, a district court for appointing its own expert. The question before the 10th Circuit was whether the district judge's appointment of the expert established the existence of a reasonable doubt in the judge's mind of the criminal defendant's sanity. The Court of Appeals upheld the trial court and held that it did not. In a footnote, the Court of Appeals commented on the fact that, although the judge did not follow the prescribed procedures under Rule 706 of the Federal Rules of Evidence, this did not affect its decision affirming him. While Rule 706 does not directly apply to us, we believe that we have substantially complied with it. See Tr. 3814.

7. We did not cite Public Service Co. of Oklahoma (Black Fox Station, Units 1 and 2), LBP-78-26, 8 NRC 102, with regard to the

calling of an NRC Staff geologist or the Oklahoma officials, as the Appeal Board believes at 1153, but with regard to U.S. Army Corps of Engineer witnesses, whom we understand were called as independent Board witnesses.

8. We did not purposely ignore a material difference between this case and Diablo Canyon,[13] Seabrook,[14] Midland,[15] and San Onofre,[16] to wit, that in those cases the Board called witnesses that the intervenors wanted to have heard. 14 NRC at 1154-55. We believed that element of those cases to be a negative factor in weighing the propriety of calling the experts because it implied the Boards' use of this device to circumvent the prohibition on offering financial assistance to intervenors. It was despite this element that the Boards' decisions to call the experts as Board witnesses were considered proper -- because the Boards themselves wanted to hear the witnesses. We considered our case as stronger, not weaker, because of the difference.

9. We never abandoned our position that there were deficiencies in the Staff's seismic review, contrary to the Appeal Board's "reasonable

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13/ Pacific Gas and Electric Co. (Diablo Canyon Nuclear Plant, Units 1 and 2), ALAB-644, 13 NRC 903 (1981).

14/ Public Service Company of New Hampshire (Seabrook Station, Units 1 and 2), ALAB-667, 15 NRC __ (March 3, 1982).

15/ Consumers Power Company (Midland Plant, Units 1 and 2), ALAB-382, 5 NRC 603 (1977).

16/ Southern California Edison Co. (San Onofre Nuclear Generating Station, Units 2 and 3), LBP-82-3, 15 NRC 61 (January 11, 1982).

inference" that we had. 14 NRC at 1151. Although we referred to Staff's seismic experts in LBP-81-47 as "highly competent and credible," we indicated that their expertise did not extend to the "highly complex modelling required . . . in this unique situation involving extremely shallow reservoir-induced seismicity in the Eastern United States." Id. at 868-69. We did not wish to be drawn into insulting Staff's experts in order to justify our calling Board experts.

10. We see nothing in LBP-81-47 which could justify the Appeal Board's suggestion that we might not have fairly appraised the evidence before us if we had been ordered not to call the Board experts. ALAB-663, supra, at 1158. Although it may appear otherwise from ALAB-663, the tenor of our issuance was respectful -- to both Staff and the Appeal Board. We do not consider a public expression of intellectual disagreement with what we believed to be a suggested standard and a skepticism about the reliability of certain expert testimony (which later proved false), to warrant questioning the integrity of this Board. If the Appeal Board believed that its new standard for calling Board experts was proper and would survive a direct challenge before the Commission and the courts, it could have reversed us with the full confidence that we would carry out its orders, fairly and to the letter, as we had indicated we would (14 NRC at 875, 876).

In the final analysis, we see only two matters discussed in the Appeal Board's December 14, 1981 memorandum as offered in support of the statement in the Order of October 19, 1981 that there had been an "open and flagrant disregard of [Appeal Board's] instructions": 1) that we intended to defy the Appeal Board by scheduling a hearing with the Board

witness testifying, of which we have demonstrated there is no record support (see numbered paragraph 3 above); and 2) that this Board "set forth . . . virtually no explanation respecting why an informed decision on the seismic issue could not be reached on the basis of testimony of the parties." 14 NRC at 1149. Considering that the Licensing Board had stated that "we cannct . . . claim to have satisfied the new standard" of demonstrating beyond question why we could not reach an informed decision (LBP-81-47, supra, at 874), we do not see how we can be faulted for not offering those non-existent reasons.

In our opinion, there is a wide area between "the most extraordinary situation in which it is demonstrated beyond question that a Board cannot otherwise reach an informed decision on the issue involved" and "intuition and vague doubts about the reliability of the Staff's presentation" (ALAB-663 at 31), into which this case (and probably every other case in which a Board is not satisfied with uncontradicted expert testimony) falls. Here, we were skeptical of the evidence adduced with regard to the completeness of the accelerometer information, soil and topographical amplification of accelerometer readings, the reliability of the Brune model, and the data inputs to the model (primarily the stress drop limitation of 25 bars), and had expressed our skepticism repeatedly throughout the testimony in the form

of persistent and critical Board examination.17/ Our skepticism was not borne of "intuition and vague doubts," but, rather, was based upon the many years of experience and training that led us to question whether the testimony on these matters was complete and reliable, and could be improved by these same witnesses. We did not see then, nor do we see now, how these concerns could have been articulated in the context of the interlocutory posture of the case and the uncontradicted testimony with which we were not satisfied. Although even a close reading of the transcripts would lose some of the flavor of the actual hearing, we urged the Appeal Board "to consider the Licensing Board's decision to call expert witnesses in the context of the live facts of this case, as would be disclosed by its reading the transcript of hearing." LBP-81-47 at 875. That the critical matters testified to proved unreliable, thereby confirming our initial skepticism, does not surprise us. We still believe that if the Appeal Board had relied less upon the allegations of Staff concerning our actions, and more upon the evidentiary record, "it would [have] reconsider[ed] proposing [its] new standard and would [have] affirm[ed] this Board." Ibid.

17/ See Board Finding 15, supra, for a discussion of, and record citations to, the extensive questions raised by the Board regarding Applicants' ground motion model.

On June 11, 1982, the Commission voted not to review ALAB-663, and issued separate views of certain Commissioners.18/ CLI-82-10, 15 NRC __. We wish to clarify a matter discussed in the separate views of a Commissioner regarding the opinion of the Chairman of the Licensing Board Panel on the Licensing Board's motivation for calling its own witnesses. In our view it would have been improper for the Licensing Board to have discussed its motivation with the Panel Chairman or any other person not on the Licensing Board. The Panel Chairman's impression of the Licensing Board's views in the matter referred to was undoubtedly based upon the views we expressed in LBP-81-47, 14 NRC 866, 874 (1981), regarding the Appeal Board's new standard--not upon any personal discussions with us. A close reading of our discussion in LBP-81-47, supra, at 874, however, would indicate an agreement with the Commissioner's position that if the applicant, who has the burden of proof, cannot establish the safety of the plant, a licensing board must deny the operating license -- not resurrect it through calling its own

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18/ Undoubtedly the Commission is aware that a failure to review an interlocutory matter does not close the issue. Even Commission action on an interlocutory matter is only a final disposition if the Commission so desires. As a fundamental legal principle, all interlocutory matters, whether or not ruled upon, are subject to review at the time an appellate body reviews the final decision. Especially in this case, where the Appeal Board accepted the decision of the Licensing Board to call its own witnesses, albeit reluctantly, a Commission decision not to review the ruling need only be considered tentative by the Commission. The Commission may wish to review the question of our calling independent witnesses on a complete record, while reviewing the initial decision.

witnesses. We also reiterate for that Commissioner our view, as fully discussed above, that we did not disregard the Appeal Board's directives.

We also submit that our actions were consistent with the separate views of another Commissioner that the Licensing Boards should not conduct an independent technical review and should resolve the issues in dispute using first the resources of the parties. We are certain that on reading the complete record the Commissioner will recognize the concerted effort made by the Licensing Board to ascertain the validity of Applicants' ground motion model and the parameters utilized therein, through repeated questioning of Applicants' and Staff's witnesses, before we resorted to calling independent Board witnesses. That Staff's further testimony filed on September 15, 1981 again attempted to justify the ground motion model and parameters, which later proved to be so unreliable, can only confirm the correctness of the Licensing Board's contemporaneous opinion that there was nothing further to be gained by continued reliance upon Applicants' and Staff's witnesses in that regard.