From: "Williams, Dana M." <DANAWILL@SOUTHERNCO.COM>
To: "Christian Araguas" <CJA2@nrc.gov>,"William Burton" <WFB@nrc.gov>
Date: 10/15/2007 5:20:29 PM
Subject: SNC Letter AR-07-1773 transmitting the Response to Safety Evaluation Report (SER) Open Items_Part 1 of 2

> An electronic copy of Southern Nuclear's letter, AR-07-1773, dated October
> 15th, 2007 is attached. In addition, a hard copy has been transmitted to
> the NRC Document Control desk via FedEx.
>
> <<AR-07-1773 SER OI Resp Ltr Final part 1.pdf>>
>
> Thank you,
>
> Dana Williams
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> Nuclear Development
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>
>

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Subject: SNC Letter AR-07-1773 transmitting the Response to Safety Evaluation Report (SER) Open Items_Part 1 of 2
Creation Date: 10/15/2007 5:20:29 PM
From: "Williams, Dana M." <DANAWILL@SOUTHERNCO.COM>

Created By: DANAWILL@SOUTHERNCO.COM

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Security: Standard

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SOUTHERN COMPANY
Energy to Serve Your World℠

OCT 15 2007

Docket No.: 52-011

AR-07-1773

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

Southern Nuclear Operating Company
Vogtle Early Site Permit Application
Response to Safety Evaluation Report Open Items

Ladies and Gentlemen:

By letter dated August 30, 2007, the U.S. Nuclear Regulatory Commission (NRC) provided Southern Nuclear Operating Company (SNC) with the Safety Evaluation Report (SER) for the Vogtle Early Site Permit (ESP) Application with 41 open items (OIs). In that letter, the NRC requested SNC to respond to the OIs contained in the SER no later than October 15, 2007. The SER OIs involve the subject areas of Meteorology, Hydrology, Geology/Seismology, and Emergency Planning from SER Sections 2.3, 2.4, 2.5, and 13.3, respectively. This letter provides SNC's response to 27 SER OIs. As discussed with NRC project management, a schedule for OIs linked to additional COL or new ESP testing, analysis or modeling has been provided with the remaining 14 OIs.

The SNC contact for this OI response letter is J. T. Davis at (205) 992-7692.

Mr. J. A. (Buzz) Miller states he is a Senior Vice President of Southern Nuclear Operating Company, is authorized to execute this oath on behalf of Southern Nuclear Operating Company and to the best of his knowledge and belief, the facts set forth in this letter are true.

Respectfully submitted,

SOUTHERN NUCLEAR OPERATING COMPANY

J.A. Miller

Joseph A. (Buzz) Miller

Sworn to and subscripted before me this 15th *day of* October *, 2007*

Dana M. Williams
Notary Public

My commission expires: 12/29/2010

JAM/BJS/dmw

Enclosures:
1. Response to NRC Safety Evaluation Report Open Items on the Vogtle ESP Application
2. Proposed Revision to ESP Emergency Plan V2 Appendix 3 - Unit 3 ITAAC
3. Proposed Revision to ESP Emergency Plan V2 Appendix 4 - Unit 4 ITAAC
4. Letters of Agreement from Radiation Management Consultants
5. Revised Burke County Emergency Plan

cc: Southern Nuclear Operating Company
Mr. J. B. Beasley, Jr., President and CEO (w/o enclosures)
Mr. J. T. Gasser, Executive Vice President, Nuclear Operations (w/o enclosures)
Mr. T. E. Tynan, Vice President - Vogtle (w/o enclosures)
Mr. D. M. Lloyd, Vogtle Deployment Director (w/o enclosures)
Mr. C. R. Pierce, Vogtle Development Licensing Manager (w/o enclosures)
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Document Services RTYPE: AR01
File AR.01.01.06

Nuclear Regulatory Commission
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Mr. C. J. Araguas, Project Manager of New Reactors
Mr. J. E. Lyons, Director of Site and Environmental Review (w/o enclosures)
Mr. W.F. Burton, Chief – Environmental Technical Support (w/o enclosures)
Mr. M. D. Notich, Environmental Project Manager
Mr. G. J. McCoy, Senior Resident Inspector of VEGP (w/o enclosures)

Georgia Power Company
Mr. O. C. Harper, Vice President, Resource Planning and Nuclear Development (w/o enclosures)

Oglethorpe Power Corporation
Mr. M. W. Price, Chief Operating Officer (w/o enclosures)

Municipal Electric Authority of Georgia
Mr. C. B. Manning, Senior Vice President and Chief Operating Officer (w/o enclosures)

Dalton Utilities
Mr. D. Cope, President and Chief Executive Officer (w/o enclosures)

Bechtel Power Corporation
Mr. J. S. Prebula, Project Engineer
Mr. R. W. Prunty, Licensing Engineer

Tetra Tech NUS, Inc.
Ms. K. K. Patterson, Project Manager (w/o enclosures)

Southern Nuclear Operating Company

AR-07-1773

Enclosure 1

Response to

NRC Safety Evaluation Report Open Items

on the Vogtle ESP Application

SER Section 2.3.1 – Regional Climatology

2.3-1 Calculate the following AP1000 specific temperature site characteristics based on a 100-year return period.

- **Maximum safety dry-bulb temperature with a coincident wet-bulb temperature**
- **Maximum safety noncoincident wet-bulb temperature**

Response:

Maximum safety dry-bulb temperature with a coincident wet-bulb temperature

A 45-year data set from the International Station Meteorological Climate Summary for Augusta, GA was used to develop a dry-bulb to wet-bulb correlation curve. The dry-bulb temperatures ranging from 1^o F to 105^o F (the maximum value from the data set), were plotted in 2^o F intervals along with the maximum observed coincident wet-bulb temperature to obtain a correlation curve. The curve was extrapolated to 115^o F (the previously determined 100-yr return maximum dry-bulb temperature) to determine the 100-yr return coincident wet-bulb temperature of 77.7^o F. This site-specific maximum safety dry-bulb temperature of 115^o F and coincident wet-bulb temperature of 77.7^o F is bounded by the Westinghouse DCD maximum safety values of 115^o F dry-bulb / 80^o F coincident wet-bulb.

Maximum safety non-coincident wet-bulb temperature

The maximum safety non-coincident wet-bulb temperature was determined in a two-step process using hourly temperature data from the NCDC summaries for Augusta, GA:

- The maximum wet-bulb temperature that persisted for at least two consecutive hours was plotted for a 21-year period for which hourly data was available resulting in a curve fit equation.
- A 100-yr value was extrapolated from the equation utilizing the 21 years of maximum 2-hour sustained wet-bulb temperatures.

The 100-yr maximum safety wet-bulb temperature was determined from the equation to be 84.3^o F. Therefore, the VEGP site is bounded by the DCD maximum safety non-coincident wet-bulb temperature of 85.5^o F.

This information will be reflected in ESP Revision 3.

SER Section 2.4.8 – Cooling Water Canals and Reservoirs

2.4-1 The NRC staff reviewed the information provided by the applicant in the SSAR. The NRC staff concluded that as proposed in the application, the new VEGP Units 3 and 4 will not rely on any external water source for safety-related cooling water. The applicant did not propose any safety-related canals or reservoirs as a source for cooling water. However, there will be the need for safety-related water for initial filling and occasional makeup purposes. Therefore, the applicant should provide design parameters for these values.

Response:

As described in the Westinghouse DCD, Tier 1 Section 2.2.2 and Tier 2 Section 6.2.2, the AP1000 design utilizes a Passive Containment Cooling System (PCS).

The PCS performs safety-related functions related to delivering water from the passive containment cooling water storage tank (PCCWST) to the outside surface of the containment vessel. The PCCWST is incorporated into the safety-related shield building structure and nominally contains 800,000 gallons of water. A minimum storage volume of 756,700 gallons is verified by Technical Specifications every seven days. This stored volume provides water for short-term containment cooling for at least 72 hours following system actuation.

Prior to 72 hours after an event, operator actions are taken to align the passive containment ancillary water storage tank (PCCAWST), which is located outside the auxiliary building at ground level, to perform the nonsafety-related function of delivering cooling water to the PCCWST from hour 72 through day 7. An alternate water source can also provide water directly to the containment shell through an installed safety-related seismic piping connection. Water sources used for normal filling operations can be used to replenish the water supply. (Tier 1 Figure 2.2.2-1 shows the relationship of the tanks and water makeup connection to the containment vessel.)

It is clear from the descriptions in the DCD that the safety-related function of the external water supply is fulfilled by the PCCWST during the initial 72-hour stage of a containment cooling event. Technical Specifications ensure the availability of safety-related water. After 72 hours, operator actions are required to realign and re-supply the PCCWST from the nonsafety-related PCCAWST or the external water makeup connection. There are no DCD-imposed limitations on the source of the makeup water.

Since the DCD's inherent passive safety design and technical Specifications govern the safety-related cooling function, there is no requirement for any fill or makeup water to be classified as safety-related, and thus no design parameters are necessary. Further, since no site parameters related to external makeup water supply have been specified by Westinghouse in the DCD, there is not an identified need for any permit condition to restrict the use of any water supply that is otherwise of suitable quality to provide the nonsafety-related makeup function either prior to or after a design basis cooling event for the AP1000.

SER Section 2.4.12 - Groundwater

2.4-2 The applicant should provide an improved and complete description of the current and future local hydrological conditions, including alternate conceptual models, to demonstrate that the design bases related to groundwater-induced loadings on subsurface portions of safety-related SSCs would not be exceeded. Alternatively, the applicant can provide design parameters for buoyancy evaluation of the plant structures.

Response:

As described in the Westinghouse DCD, Tier 2, Section 2.4, Hydrologic Engineering, the AP1000 is designed for a normal groundwater elevation up to two feet below grade elevation (220 ft MSL for VEGP Units 3 and 4). DCD Section 3.4.1.2.1, External Flooding, further states that the base mat and exterior walls of seismic Category I structures are designed to resist upward and lateral pressures caused by high groundwater level. The minimum factor of safety for floatation is 3.7, as described in DCD Section 3.8.5.5.2, Floatation, and associated Table 3.8.5-2.

As described in the VEGP ESP Application, Revision 2, Section 2.4.12.4, Design Basis for Subsurface Hydrostatic Loading, groundwater elevations in the power block area are approximately 20 ft or more below the base slab elevation and approximately 60 ft or more below grade elevation. The significant difference between groundwater elevation and the base mat elevation (greater than 20 ft) suggests that the factor of safety for floatation essentially approaches infinity.

Therefore, the ESP Application demonstrates that the design bases related to groundwater-induced loadings on the subsurface portions of safety-related SSC's would not be exceeded.

SER Section 2.4.13 – Accidental Releases of Radioactive Liquid Effluents in Ground and Surface Waters

2.4-3 The NRC staff found the applicant's analysis in the SSAR to be incomplete; because it did not include consideration for the inevitable change in hydrology, and, hence, the potential change in flow direction within the Water Table aquifer for some release locations within the protected area (PA). The applicant's analysis provided no assurance that an adequate number of combinations of release locations and feasible pathways had been considered.

Response:

A numerical groundwater model is being developed to support resolution of Open Items 2.4-3 and 2.4-4. A two-dimensional single layer model is used to simulate groundwater flow in the Water Table aquifer. The base of the model is the low permeability Blue Bluff Marl which separates the water table aquifer from the underlying Tertiary aquifer. The boundaries of the model are selected to coincide with key physical features of the area. The northeast boundary of the model is a drainage boundary corresponding to the Savannah River. It is described by a series of drains accounting for groundwater discharge along the bluffs bordering the Georgia side of the river. The southwest and northwest boundaries are defined as no-flow boundaries, coinciding with the boundary of the local watershed, with the assumption that the groundwater divide coincides with the surface water divide. The southeast boundary was selected to coincide with Beaver Dam Creek and is treated as a constant head boundary. Drains are placed along ephemeral streams within the model domain. Several small ponds are included in the model and are treated either as constant head cells or as areas of increased recharge, where it is evident that they do not communicate with the water table.

Surficial geology maps are used to delineate the extent of the aquifer by identifying areas where the Blue Bluff Marl outcrops. Soil boring data from the Units 1 and 2 FSAR and the Units 3 and 4 ESP and COL subsurface investigations are used to define the top of the Blue Bluff Marl.

The model will be calibrated by varying the hydraulic conductivity and the rate of net gain of the water table aquifer due to aquifer recharge and leakage, and comparing modeled head values against observed head values. Aquifer recharge is varied across the model domain to account for variations in surficial geology, vegetative cover, and local land use patterns.

To predict post-construction groundwater flow conditions, the model will account for the different hydraulic conductivity value of the fill material associated with the excavated areas for Units 3 & 4, as well as changes in groundwater recharge due to building and parking lot construction, regrading, and assumed changes in vegetative cover patterns.

The model will be used to identify viable alternative conceptual models that include different assumptions regarding boundary conditions, communication of ponds with groundwater, geographic variation of recharge rates, and combinations of recharge rates and hydraulic conductivity values that produce acceptable agreement between simulated and measured water table levels.

Post-construction release points, groundwater pathways and discharge points will be evaluated using particle tracking for each viable conceptual model. In each case, particles are released from the auxiliary buildings of Units and 3 & 4, as well as from other points within the perimeter of the Protected Area surrounding the two new units (see DSER, Figure 2.4.14-1) and tracked to their potential discharge points.

The results of this modeling will be presented in ESP Revision 3, currently scheduled for late November 2007.

2.4-4 The NRC staff's review of the release location, migration, attenuation, and dilution of the radioactive liquid effluent inventory was incomplete because, as stated in Open Item 2.4-3, the applicant has not considered a sufficient number of alternate conceptual models to identify potential release points and pathways. Therefore, the applicant needs to specify the nearest point along each potential pathway that may be accessible to the public.

Response:

Refer to OI 2.4-3 response.

SER Section 2.5.2 – Vibratory Ground Motion

2.5-1 Provide additional justification to support the low weights for the larger M_{max} values for the Electric Power Research Institute (EPRI) seismic source zones that include the ESP site.

Response:

A response to this Open Item involves two issues: (1) the "process" for updating or revising the EPRI seismic source model; and (2) the technical basis or justification for updating or revising the EPRI seismic source model. These two issues are first described in general and then followed with specific justification for the weighting of Mmax values for the EPRI seismic source zones that include the ESP site.

(1) Process. Regulatory Guides 1.165 and 1.208 provide guidance to establish a stable process for developing a seismic source model for use in a probabilistic seismic hazard analysis (PSHA) for an ESP or COL applicant. The guidance allows the applicant to start with an accepted seismic source model, such as EPRI or LLNL, and to revise or update the source model based on new data or information. The EPRI source model was developed using a level of effort that would later be defined as a SSHAC Level 4 process. This SSHAC Level 4 EPRI study encompassed the range of informed professional opinion based on the data and information available at that time. In order to maintain stability in development of an acceptable seismic source model for use in a PSHA, the applicant is not responsible for re-defending the original EPRI source parameters or weights, unless new (post EPRI) data or information become available (i.e., a technical basis for revising or updating EPRI described below). Under the SSHAC process, it is not permissible to discount, re-weight, or alter the EPRI source model (without new data or information) simply because we might disagree with one or more of the Earth Science Teams (ESTs) or specific parameters of an individual team (such as probability of activity or Mmax). In addition, any revision to the EPRI source model based on new data or information similarly must be performed using a SSHAC process (Level 2, 3, or 4).

(2) Technical Basis. There are no new data that would support revision to the EPRI seismic source model in the southeastern United States, with the exception of the Charleston seismic source [the Charleston seismic source was updated following a SSHAC Level 2 process as described in Bechtel (2006)]. For example, an updated seismicity catalog shows that there has been no change in the pattern, rate, location, or size of seismicity since the original EPRI 1986 study. In addition, with the exception of Charleston, there have been no new discoveries of geologic, tectonic, or geophysical features in the SEUS that would require revision to the basic seismotectonic setting known at the time of the original EPRI 1986 study.

However, since development of the EPRI 1986 seismic source model, several new re-interpretations of pre-existing data have been published in either peer-reviewed or "gray" literature. In this context, these studies may be viewed as "new information" although, in practice, these "new" interpretations reflect additional opinions of the informed professional community rather than a replacement of the EPRI 1986 EST opinions.

Maintaining the Mmax weights assigned to the EPRI source zones that include the ESP site is justified by the process, whereby regulatory guidance strives to achieve a stable source model that incorporates a broad range of uncertainty. There are also technical reasons, such as a recent seismic source characterization performed as part of the TIP study, that also support the EPRI weights of Mmax used for the Vogtle host zones.

From a process standpoint, the EPRI weighting of Mmax values for host zones is justified. The entire seismic evaluation process embedded in Regulatory Guide 1.165 begins with the EPRI source model. To change implementations of EPRI sources model strikes at the underpinnings of the stable and consistent process that the NRC and the industry have worked to develop over the years. Clearly, if new data or information has come to light since the EPRI model was developed that is not captured by the range of EPRI source parameters, sensitivity analyses and updates to the model should be performed. In order to maintain a stable source model and regulatory process between different nuclear sites, the assessment must start with an accepted model (e.g., EPRI) and changes must be made when demanded by new data. Updates or changes to the EPRI source model should utilize the SSHAC process in order to incorporate the composite range of views by the informed technical community. Consistency and stability cannot be achieved by individually "tweaking" elements of the EPRI source characterization without a minimum SSHAC Level 2 effort to update parameters or resolve certain technical issues. Disagreement with the implementation of the EPRI model does not, by itself, necessitate "new data" that warrants changes to the source model, such as how the Dames & Moore team decided to not include background zones in certain regions of the CEUS.

Regulatory Guide 1.165 clearly indicates that it is anticipated that future information will fall within the bounds of the EPRI source model, but will not necessitate changes to the model if the new information falls within the range of EPRI parameters. Regulatory Guide 1.165, E.3 Procedure and Evaluation (p. 39) states:

> *The EPRI and LLNL studies provide a wide range of interpretations of the possible seismic sources for most regions of the CEUS, as well as a wide range of interpretations for all the key parameters of the seismic hazard model. The first step in comparing the new information with those interpretations is determining whether the new information is consistent with the following EPRI and LLNL parameters: (1) the range of seismogenic sources as interpreted by the seismicity experts or teams involved in the study, (2) the range of seismicity rates for the region around the site as interpreted by the seismicity experts or teams involved in the study, and (3) the range of maximum magnitudes determined by the seismicity experts or teams. The new information is considered not significant and no further evaluation is needed if it is consistent with the assumptions used in the PSHA, no additional alternative seismic sources or seismic parameters are needed, or it supports maintaining or decreasing the site median seismic hazard."*
>
> *An example is an additional nuclear unit sited near an existing nuclear power plant site that was recently investigated by state-of-the-art geosciences techniques and evaluated by current hazard methodologies. Detailed geological seismological, and geophysical site-specific investigations would be required to update existing information regarding the new site,* ***but it is very unlikely that significant new information would invalidate the previous PSHA****.*

Regulatory Guide 1.165, E.3 Procedure and Evaluation (p. 40) also states:

> *It is expected that the new information will be* ***within the range*** *of the interpretations in the existing data base, and the data will not result in an increase in overall seismicity rate or increase in the range of maximum earthquakes to be used in the probabilistic analysis. It can then be concluded that the current LLNL or EPRI results apply.*

As pointed out in the DSER, the Dames & Moore team assigned low probabilities of activity (P_A) to some of its sources, such as source zones 41 and 53. Zone 53 (Southern Appalachian Mobile Belt) is a default zone for several Triassic rift basin sources, represents a host zone for the Vogtle site, and has a P_A = 0.26. The lack of a background zone beneath the region covered by source 53 results in a source-less area when

53 is "turned off." While the implementation of this aspect of the Dames & Moore source model has been the subject of debate, this is not an "error" or misinterpretation in their model. Statements in both the Dames & Moore EPRI report (1986) as well as recent discussions with James McWhorter, an original member of the Dames & Moore EST, indicate that Dames & Moore intended to represent the earthquake process in this fashion.

On page 5-3 of the Dames & Moore report (1986, volume 6), the discussion indicates they believe earthquake occurrence can be explained by tectonic reasons and that they do not use background zones as in other traditional seismic hazard assessments:

> *In our model, uniform seismicity is a consequence of a reasonable tectonic explanation for earthquake occurrence in the zone. To avoid muddling the tectonic aspect, our team does not use backgrounds. There is either a tectonic reason for a block of the earth's crust to be seismically active or there is not. So what we formerly called a "global background" no longer exists; the sources replacing it have a* P_A *reflecting our confidence in a tectonic reason for earthquake activity there.*

This implementation is different from the other ESTs, but it still represents the range of expert opinion in the EPRI SSHAC Level 4 study. From a process standpoint, it is not the responsibility of the applicant to defend the original rationale or implementation of the EPRI study, which has been approved by the NRC in Regulatory Guide 1.165 and forms the basis for evaluating sites across the CEUS. The individual teams were given latitude as to how to model seismic hazard in order to capture the full range of opinion for the poorly understood earthquake process in the CEUS. Without new data to invalidate the model, an individual team or model should not be reinterpreted or disregarded simply because their resultant hazard is less than the other EST source models.

From the technical perspective, the EPRI Mmax weighting of host zones is also supported. The ESP site lies near the boundary between Mesozoic extended Eastern Seaboard and Paleozoic Piedmont domains of Kanter (1994). The EPRI source zones that include the ESP site (host zones) are generally large source zones that include both portions of the Mesozoic extended crust as well as the Paleozoic Piedmont. The source zones listed below (with their minimum, weighted mean, and maximum values of their Mmax distributions) represent the EPRI host zones that contributed to 99% of the hazard at the Vogtle site.

EST	Source	Min	Weighted Mean	Max
BEC	BZ4	6.5	7.1	7.9
D&M	53	5.2	5.7	7.5
LAW	C09	6.8	6.8	6.8
RND	26	5.4	6.3	6.8
WES	26	5.7	6.0	7.5
WCC	29B	5.0	6.0	7.2

The broad range of magnitudes for these host zones adequately capture the range of more recent source characterizations by the USGS (Frankel, 1996; 2002), SCDOT (Chapman and Talwani, 2002), and the Trial Implementation Project (TIP) study (Savy et al., 2002). The EPRI maximum or upper bound values of Mmax have relatively low weights. The weighted mean of these six source zones range from M5.7 to M7.1 and the average of these six weighted means is about M6.3. While the EPRI source zones have relatively low weights associated with large magnitudes when compared to the USGS source model, they are not relatively low when compared to the TIP study, which represents a more in depth characterization of the Vogtle host zones than the USGS model.

The EPRI Earth Science Teams (ESTs) were aware that extended Mesozoic crust produced the largest earthquakes in stable cratons worldwide, even though the Johnston et al. (1994) study of global stable continental regions (SCRs) was not final at that time (Coppersmith et al. 1987). The study of global SCRs began as an effort to support the ESTs, by replacing space for time in assessing the maximum magnitude earthquakes in stable cratons, such as the CEUS. One of the most significant findings was the observation that the world's largest SCR earthquakes of M>7 were limited to Mesozoic extended crust. This information was part of the database of knowledge that the ESTs used to formulate their source characterizations for the CEUS and is supported by the statement in Johnston et al. (1994):

> *The results of this study lend support to the preliminary indications from this work (Coppersmith et al., 1987) that were used in the assessments of maximum magnitude for seismic source zones in the EPRI SOG seismic hazard methodology.*

In response to Open Item 2.5-2, we were requested to review the TIP study, which provided a trial implementation of the SSHAC process. This more recent TIP study (2002), which was based on workshops held in 1997 and 1998, also had the benefit of the final Johnston et al. (1994) results of worldwide seismicity and implications for Mmax. The TIP study assigned a wide range of Mmax values for the Vogtle host zones covering the South Carolina-Georgia Piedmont and Coastal Plain region and are much more similar to the EPRI range of magnitudes than the 1996 and 2002 USGS source model that assigned a uniform M7.5 to the entire eastern seaboard. The USGS source model uses a high probability for a large magnitude (M7.5), but this characterization does not capture the range of opinion expressed by the informed technical community. The TIP study does not report discrete magnitudes and weights to represent Mmax distributions, but rather provides tabulated minimums, maximums, and modes of the distributions as well as graphical representations of the distributions. For the Vogtle host zones, the composite Mmax distributions (representing the combined characterizations of the five experts) are characterized by a bimodal distribution, with each mode having similar probabilities. The TIP host zone Mmax distributions are summarized below:

Source Zone	Min	Low Mode	High Mode	Max
3a	5.0	5.5	7.0	7.5
3B-3a	4.5	5.5	6.5	7.2
3c	5.0	5.5	6.3	7.0
3b-3c	4.8	5.0	7.0	7.5

The Mmax distributions for the four TIP source zones that include the Vogtle site range from a minimum of M4.5 to a maximum of M7.5, which is very similar to the EPRI host zone range of M5.0 to M7.9. The bimodal distributions of Mmax for the TIP source zones (shown graphically on pages F-8 throught F-11 in Savy et al., 2002) reflect mean Mmax values on the order of a low magnitude 6. The TIP study represents a more recent assessment of the host zones for the Vogtle site and supports the EPRI characterizations of Mmax. While the geometries of the TIP host zones differ from the EPRI host zones, the hazard at the ESP site should not be sensitive to the boundaries of these generally large source zones. However, the TIP Mmax ranges are similar to the EPRI characterizations and therefore, support the weighting of Mmax values by the EPRI ESTs.

In summary, without new data to invalidate the model, an individual team or model should not be reinterpreted or disregarded simply because their resultant hazard is less than the other EST source models. Otherwise this would create instability in the regulatory process in regards to consistent application of the PSHA. In addition, the weights of magnitudes for the EPRI source zones that include the ESP site are supported by the recent TIP study that specifically addressed the host zones in detail. The TIP study, which we were requested to evaluate in Open Item 2.5-2, supports the magnitude ranges and weights of magnitudes used by EPRI, since both studies have similar weighted mean magnitude values on the order of ~ M6 to 6.5.

2.5-2 Provide an evaluation of any information contained in the Trial Implementation Project (TIP) study that is relevant to the seismic source characterization of the ESP site.

Response:

First, we respond by reiterating our position that the Trial Implementation Project (TIP) study was primarily an exercise in implementation of the SSHAC process. As such, the seismic source model developed in the TIP study should be evaluated with this in mind. The purpose and objectives of the TIP study are clearly spelled out in numerous locations within the text and some of these are listed below.

- Abstract, page iii: *The present study is a trial implementation of the SSHAC guidance.*

- Executive Summary, page xi-xii: *The scope of TIP was to test the recommendation of the SSHAC on the characterization of the seismic sources, and to finalize the development of ground motion attenuation models for eastern North America started by SSHAC.*

- Section 1.2, page 1: *Implementation Project has the purpose of improving our ability to quantify and reduce uncertainties in seismic hazard estimation. The objectives of this study are to exercise the process improvement recommended in the SSHAC report specifically for seismic source characterization and to implement the methodology in a manner designed to achieve optimum stability in the PSHA results.*

- Section 4.2.7, p. 28: *Recalling that the purpose of this project is to produce a guidance document for performing a PSHA, the role of this feedback was to get some insights of the aspects of the process with which the EVA felt comfortable and those with which they did not, and to understand what worked and what did not.*

The fact that all final seismic source model parameters and weights are not presented in the TIP report also support that this study focused primarily on implementation of the SSHAC process as opposed to the development and publication of a new source model for the southeastern US. The absence of a complete set of parameters and weights in the TIP study also makes it difficult to replicate the entire source model and directly compare with some of the specific EPRI model parameters. The TIP report provides tables and figures that illustrate how the individual EVA's (experts) evaluated or weighted certain issues or parameters, but the report does not provide a final tabulation of all source parameters and weights that were used in the computation of hazard in the TIP study.

However, the TIP study does address some key issues and provides assessments of these issues by the five experts assembled (Bollinger, Chapman, Coppersmith, Jacob, and Talwani) that can be evaluated and compared, in a more general sense, to the EPRI EST source model parameters. The TIP study included multiple workshops to define, clarify, and elicit expert opinion on several critical issues relating to the source characterization process and specific technical questions on seismic sources that were judged to be significant to the hazard at the Vogtle and Watts Bar sites.

An evaluation of the TIP study reveals that several aspects of this recent seismic source characterization, fall within the range of EPRI source models and also the new Updated Charleston Seismic Source (UCSS) model. The information in the TIP study that is relevant to the seismic source characterization of the ESP site includes the following issues summarized below. Specific examples of how the TIP study supports the ESP seismic source characterization are also presented in responses to Open Item 2.5-1, 2.5-3, and 2.5-5.

- **Charleston earthquake source**. On the issue of whether the Charleston earthquake process should be restricted to a local Charleston source or allowed to float over a broader region, the experts in the TIP study heavily favored a local Charleston source and assigned a weight of nearly 80%. Three of the experts assigned weights of 100% to the local Charleston source and another gave it a weight of 90%. Only one expert favored a regional Charleston source. The local Charleston source zones developed in the TIP study are very similar in extent to the geometries of the UCSS that was developed to replace the EPRI Charleston source zones in the ESP seismic source model. As described in the response to Open Item 2.5-5, David Amick at a TIP study workshop indicated that he has found no paleoliquefaction evidence for strong ground shaking in the inland Bowman microseismicity zone, thus further supporting a local Charleston source.

- **Local source zone issue for the Vogtle site**. A key issue addressed by the TIP study was how to treat Vogtle local source zones, namely the Pen Branch fault and Dunbarton basin. The composite weighting of the experts favored a regional source (67%) over a local source (33%). The EPRI Bechtel and Dames & Moore ESTs included local Dunbarton basin sources with probabilities of activity of 10% and 28%, however, these sources did not belong to the final set of the EPRI sources that contributed to 99% of the total site hazard. Recently, more definitive studies of the Pen Branch fault have demonstrated that this fault, which bounds the Dunbarton basin, is not a capable tectonic source and therefore, need not be considered in the seismic source model. Therefore the TIP study's weighting of this issue is in general agreement with the ESP seismic source characterization.

- **Mmax weighting of Vogtle host zones.** As described in the response to Open Item 2.5-1, the TIP study supports the magnitude ranges and weights of magnitudes used by EPRI, since both studies have similar weighted mean magnitude values on the order of ~ M6 to 6.5 for the sources that include the ESP site.

- **Eastern Tennessee seismic zone (ETSZ)**. It was recognized in the TIP study that defining the Mmax distributions is a critical issue for the Watts Bar site in Tennessee. The composite Mmax distributions for each of the eight ETSZ sources defined in the TIP study are represented by modal magnitudes of M6.3 or M6.5, and are described in more detail in the response to Open Item 2.5-3. The greatest weights assigned to moderate magnitudes in the TIP study supports the EPRI ETSZ broad range of Mmax values rather than the heavily weighted large Mmax values in the USGS source models (Frankel et al., 1996, 2002). The TIP magnitude distributions for ETSZ also support the idea that the ETSZ does not contribute significantly to the total hazard at the ESP site.

The TIP study was designed as a trial implementation of the SSHAC Level 4 process by formally incorporating expert judgment and uncertainty into the seismic source characterization and PSHA for the Vogtle and Watts Bar sites. This report does not present a complete documentation of the source model parameters, which makes it difficult to replicate the TIP seismic source model. However, the TIP report does present logic trees, tables, and plots that summarize different aspects of their seismic source characterization and uncertainty in several key parameters. Therefore, the report is instructive in illustrating how an expert elicitation characterized seismic sources and uncertainties in the late 1990's. Several of the key issues addressed in the TIP study support the wide range of uncertainty expressed in the EPRI EST seismic source characterizations for the ESP site.

2.5-3 Provide additional justification to support the low weights for the larger M_{max} for the Eastern Tennessee seismic zone. In addition, provide additional information to show that the Eastern Tennessee seismic zone does not significantly contribute to the hazard at the ESP site if larger M_{max} values are considered.

Response:

The Eastern Tennessee seismic zone (ETSZ) lies between the New York-Alabama and Ocoee aeromagnetic anomalies in what Kanter (1994) has classified as non-extended crust. Wheeler (1995; 1996) has defined this region associated with Eastern Tennessee seismicity as Late Proterozoic/early Paleozoic Iapetan extended crust. Based on the Johnston et al. (1994) study of stable continental cratons, the global seismicity database indicates that the largest historic earthquakes (M>7) are limited to Mesozoic extended crust. The Johnston et al. (1994) data base show that Paleozoic non-extended crust has a mean Mmax of M6.4. Therefore, based on the global database, there is no analog to suggest that the ETSZ portion of the crust should fail in large (M>7) events.

The Trial Implementation Project (TIP) study (Savy et al., 2002) identified the ETSZ as a key issue in assessing hazard for the Watts Bar site in Tennessee. While this study was primarily a trial implementation of the SSHAC process, the NRC has requested in Open Item 2.5-2 that we more closely examine information contained in the TIP study that is relevant to the seismic source characterization of the ESP site. The TIP study defined eight source zones to represent uncertainty in the geometry of the ETSZ and defined composite Mmax distributions for each source zone using the weighting schemes from each of the five experts. The composite Mmax distributions are presented graphically (pages F-12 through F-19 of the TIP study) for each of the ETSZ source zones, and are summarized in the table below with values of the minimum, maximum, and mode of the distributions.

Source Zone	Min	Mode	Max
4a1	4.5	6.5	7.5
4a1+2	5.0	6.5	7.5
4a1+2+3	5.0	6.5	7.5
4b1	5.0	6.5	7.5
4b2	5.0	6.3	7.5
4c	5.0	6.3	7.5
4d	5.0	6.3	7.5
4e	5.0	6.3	7.5

The magnitude distributions for all ETSZ source zone representations in the TIP study ranged from as low as M4.5 to as high as M7.5, with a mode of either M6.3 or M6.5 for each distribution. The modal values represent the greatest weight of the distributions, indicating that the experts participating in the trial implementation of the SSHAC Level 4 process felt that the majority of the weight belonged in the moderate magnitude events as opposed to the largest magnitudes. The broad distribution of the TIP study is similar to the distribution of M4.8 to M7.5 in the EPRI source zones.

The modal Mmax value for each of the TIP characterizations of the ETSZ is either M6.3 or M6.5. Even though the TIP study does not present discrete magnitudes and weights, the modal magnitudes suggest a mean magnitude on the order of ~M6.5 or less for the ETSZ.

There is no new evidence for the ETSZ that would suggest larger Mmax values than used in the EPRI study. The process-oriented TIP study published in 2002 has reassessed the ETSZ as part of a trial implementation of the SSHAC methodology. If the scientific conclusions of the TIP study were to be adopted, the ETSZ would still contribute less than 1% of the total hazard at the ESP site.

According to the sensitivity study presented in DSER Figure 2.5.2-11, a mean magnitude of M6.5 or less for the ETSZ would contribute less than 1% of the total hazard at 1 Hz for ground motions critical for design levels (0.1 g and higher). Therefore, the TIP study, which represents a SSHAC level 4 trial implementation effort to better define the ETSZ source model, supports the higher weight given by EPRI for moderate magnitudes, justifies the EPRI Mmax distributions and, in turn, the negligible contribution to hazard at the Vogtle site from the ETSZ.

Since no new data or evidence has been developed to imply large magnitude earthquakes in the ETSZ since the EPRI study, there is no basis for rejecting the Mmax interpretations of the EPRI teams, which cover the range of Mmax employed in more recent seismic source characterizations. Therefore additional calculations of seismic hazard with larger Mmax values for the ETSZ would be purely speculative and could not form a basis for conclusions.

2.5-4 Because the staff received the requested information from the applicant on June 18, 2007, it requires additional time to complete its review of the applicant's response to Request for Additional Information (RAI) 2.5.2-4. In addition, the staff requests that the applicant explain why only two of the four members of the Technical Advisory Group (TAG) panel reviewed and approved written copies of the engineering report describing the Updated Charleston Seismic Source (UCSS), as stated in it response to RAI 2.5.2-4.

<u>Response</u>:

The Updated Charleston Seismic Source (UCSS) model was presented to the entire Technical Advisory Group (TAG) panel in meetings on April 12-13, 2006. As such, the TAG performed participatory peer review of the UCSS, including reviewing the approach (i.e., SSHAC Level 2), data, and results of the updated model. The TAG panel consisted of three seismologists and one structural engineer. It was decided that it would be in the best interest of the project to also have a detailed review of UCSS engineering report by members of the TAG. The two seismologists most familiar with the tectonics and seismicity of the southeastern US, Dr. Martin Chapman and Dr. Carl Stepp, were requested to review written copies of the engineering report and provide comments.

2.5-5 Provide supporting evidence to rule out the occurrence of large inland earthquakes.

<u>Response</u>:

Providing direct evidence to conclusively support a negative finding (i.e., an earthquake has not occurred) is difficult in the earth sciences. Thus, many large areal source zones in the EPRI source model, including the host zones described in the response to Open Item 2.5-1, allow for the possibility of a large magnitude (M7+) event in the southeastern US.

The preponderance of evidence, however, suggests that Charleston-type earthquakes (i.e., large-magnitude events combined with a recurrence on the order of 500 years) are restricted to the South Carolina coastal zone, as indicated by four recent Charleston seismic source characterizations shown in Figure 2.5-5A: the Trial Implementation Project (TIP; Savy et al. 2002), the U.S. Geological Survey (USGS) seismic source model (Frankel et al. 1996, 2002), the South Carolina Department of Transportation (SCDOT) source model (Chapman and Talwani 2002), and the Updated Charleston Seismic Source (UCSS) model developed for the Vogtle ESP application.

Various researchers (e.g., Amick et al. 1990, Obermeier 1996) have published maps depicting the geographic distribution of 1886 liquefaction and paleoliquefaction sites in coastal South Carolina and along the eastern seaboard. These researchers do not, however, thoroughly document their reconnaissance of the rivers and drainage ditches that lack features indicative of strong ground shaking inland from the Charleston meizoseismal area, other than to say none was observed inland. The Edisto River sites [sites 117, 119, 120, and 121 from Amick et al.'s (1990) Table 1; also shown on Obermeier's (1996) Figure 7.6] appear to be the liquefaction sites that are located farthest inland. These four Edisto River sites likely record both 1886 and prehistoric strong ground shaking (S. Obermeier, pers. comm., 4/4/2007). It is instructive to note that these Edisto River liquefaction sites are closer to the Charleston meizoseismal area (<40 miles) than are the liquefaction sites up and down the coast that experienced liquefaction during the 1886 event (~100 miles). These observations indicate that the local Charleston source is capable of producing the observed inland liquefaction features along the Edisto River.

A recent implementation of the SSHAC process was performed for the TIP study (Savy et al., 2002), which addressed whether Charleston-type earthquakes are restricted to a local Charleston source or could occur over a much broader region. The TIP study states:

> *The hazard at the Vogtle plant will be sensitive to the northwestern and western extents of the Charleston source. There appears to be no compelling reason to extend the source to the northwest from the 1886 epicentral area by connecting the Summerville-Middleton Place and Bowman zones of microseismicity. Dave Amick has found no paleoliquefaction evidence for strong ground shaking in the Bowman area, and the microseismicity there is much shallower than in the epicentral area. (p. 19)*

The experts participating in the TIP study place a high probability (~80%) of restricting large, frequent earthquakes to a local Charleston source represented as five source zones shown in Figure 2.5-5A. Other recent Charleston source characterizations place a 100% weight on large, frequent earthquakes occurring within a local Charleston source zone. These include the SCDOT study (Chapman and Talwani, 2002) and the USGS model (Frankel et al., 1996; 2002). Each of these source models, including the UCSS, has similar inland extents (Figure 2.5-5A). None of the source zones associated with these four Charleston models include either (1) all of the inland Edisto River liquefaction locations or (2) the inland Bowman seismic zone.

The UCSS model used to describe the Charleston seismic source in the Vogtle ESP application is similar to three other, recent Charleston source characterizations that restrict (with a weighting of 80-100%) the occurrence of Charleston-type earthquakes to coastal South Carolina where the preponderance of data support recurring large earthquakes.

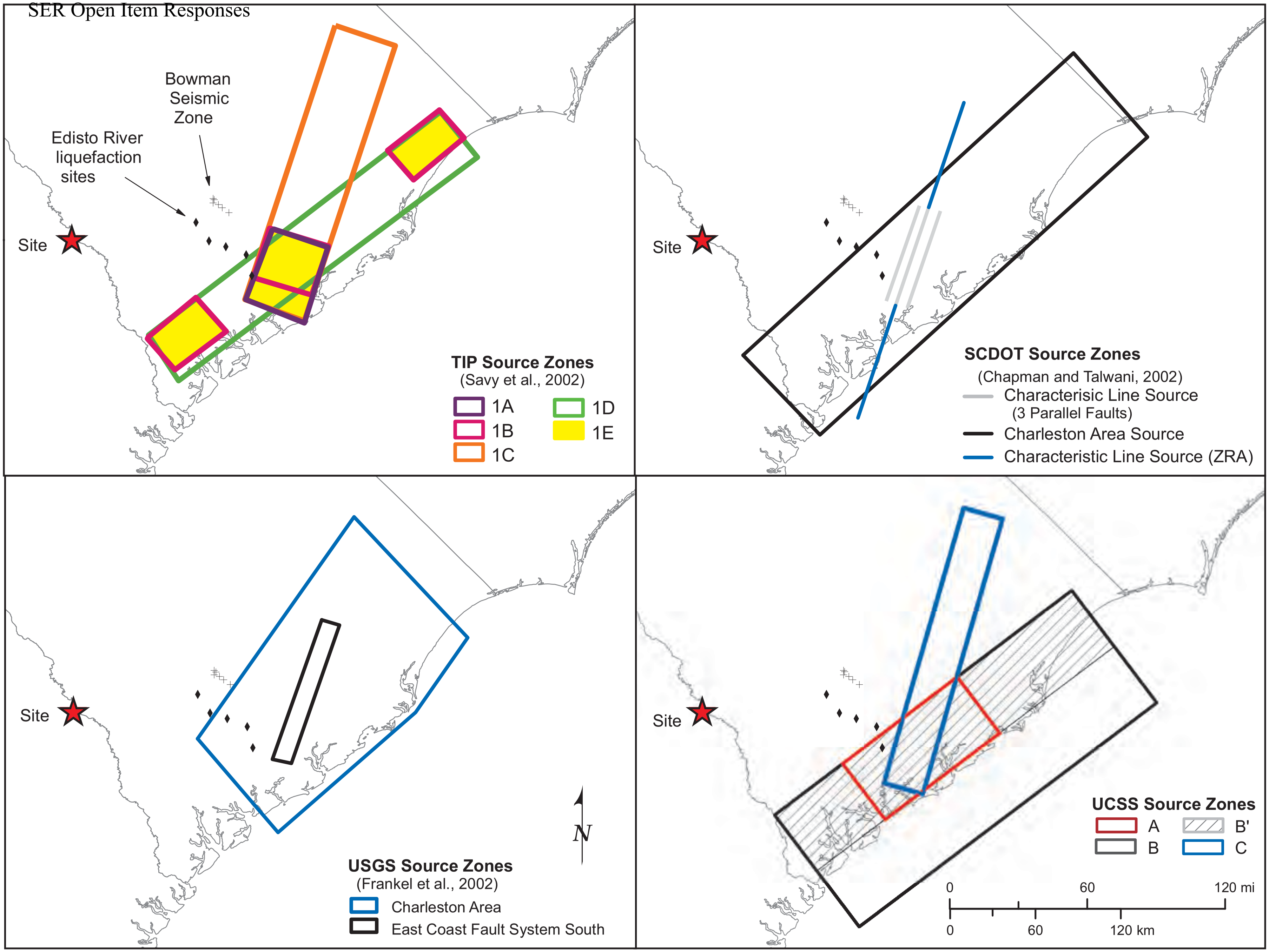


Figure 2.5-5A. Comparison of Charleston Source Zone Models

2.5-6 Because the staff received the requested information from the applicant on June 18, 2007, it requires additional time to complete its review of the applicant's supplemental response to RAI 2.5.2-19. In addition, address the differences between the Step 6 of the site response methodology description provided in response to RAI 2.5.2-19 with the information provided in the SSAR.

Response:

Step 6 of the site response methodology description provided in response to RAI 2.5.2-19 was followed in the SSAR. This is consistent with the description of Step 6 in the SSAR. A simplified description of Step 6 is as follows:

> The uniform hazard response spectra at MAFEs of 10-4 and 10-5 at the control point location are calculated as follows. Starting from the 10-4 and 10-5 spectral acceleration (SA) hard rock values (from the hazard calculations described in 2.5.2.4) at the seven structural frequencies (call these "anchor frequencies"), interpolation is performed between those SA values using the spectral shapes from NUREG/CR-6728, and anchoring those shapes to the SA values at the anchor frequencies to obtain 10-4 and 10-5 SA values at the 300 structural frequencies. The interpolation is done as follows. At each intermediate frequency, an SA is estimated from the next higher of the anchor frequencies, by scaling the spectral shape to the SA value at that anchor frequency. Another SA is estimated from the next lower of the anchor frequencies, in the same manner. Then these two estimates are weighted, using weights based on the inverse logarithmic difference between the intermediate frequency and the next higher and lower anchor frequency. For each MAFE (10-4 and 10-5), two rock spectra are created: a HF spectrum and a LF spectrum. Note that the spectra shown in Tables 2.5.2-20a (for HF) and 2.5.2-20b (for LF) in the columns labeled "Hard rock input motion" are not these spectra, but are the HF and LF spectra used to represent rock motion for site response calculations.
>
> From the HF and LF rock spectra for each MAFE, **a single spectrum is created by using the HF rock spectrum for high frequencies and the LF rock spectrum for low frequencies. The frequency at which the transition is made is described below. This procedure corresponds (within several percent) to the envelope of the two motions and maintains the consistency of using HF earthquakes to represent the HF part of the spectrum and LF earthquakes to represent the LF part of the spectrum.** This results in one rock spectrum for each MAFE.
>
> Soil spectra for each MAFE are calculated as follows, using the 10-4 rock spectrum as an example. The 10-4 rock spectrum is multiplied by the mean amplification factor (AF) from Step 5C for the 10-4 soil motion for each of the 300 structural frequencies, creating a 10-4 soil spectrum. This mean AF is the average of the columns marked "EPRI" and "SRS" in Table 2.5.2-20a for frequencies above 8 Hz, and is the average of the columns marked "EPRI" and "SRS" in Table 2.5.2-20b for frequencies below 5 Hz. In between 8 Hz and 5 Hz the soil spectrum is interpolated to achieve a smooth spectrum and avoid an artificial spectral valley. Table 2.5.2-21 shows the 10-4 rock SA and the 10-4 soil SA, calculated in this way. The rock SA values at the anchor frequencies are consistent with the values shown in Table 2.5.2-16. The soil spectrum for 10-5 is created in a similar way, except that interpolation for 10-5 is done between 6 Hz and 4 Hz to achieve a smooth transition between the HF and LF controlled parts of the spectrum, resulting in a smooth 10-5 soil spectrum.
>
> These soil spectra for 10-4 and 10-5 are used to calculate the GMRS for the site, as shown in Table 2.5.2-22.

2.5-7 Provide further justification to support the claim that the equivalent-linear approach is suitable for higher strain levels.

Response:

EPRI (EPRI TR-102293, Guidelines for Determining Design Basis Ground Motion Estimation, November 1993) presents a comprehensive study comparing the equivalent linear method with the nonlinear methods for seismic site response analysis. The study was performed for three sites (Gilroy 2, Treasure Island, Lotung Taiwan) and included the equivalent linear method using RASCAL/SHAKE and the nonlinear methods with the programs SUMDES and TESS (see EPRI TR-102293, Volume 2, Appendix 6.B for details and references). The solution obtained from each method of analysis was compared with the recorded motion for each of the three sites. The sites comprised of soil layers ranging from sand and gravels to soft silts and stiff clays and had recordings of both high- and low-strain ground motions. The comparison of the results showed reasonably good agreement among the three methods. To extend the study to higher ground motions (maximum input accelerations ranging from 50%g to 125%g), a generic soil profile for Eastern North America was also analyzed using the same three programs. This study also confirmed that the amplification factors obtained from the equivalent linear method is in general agreement with the fully nonlinear methods. The predicted peaks at resonance frequency tend to be conservative using the equivalent method.

At the Vogtle site, the input rock motion is low compared to the range of the motions used in the EPRI study and the site is generally stiffer. Therefore, the conclusion of the EPRI study applies, confirming the equivalent linear method is adequate for the site response analysis at the Vogtle site.

2.5-8 Because the staff received the requested information from the applicant on June 18, 2007, it requires additional time to complete its review of the applicant's response to RAI 2.5.2-3. No additional information is requested from the applicant for this open item.

Response:

None required.

2.5-9 Provide further justification regarding the applicability of the Lee (2001) and the NUREG/CR-6728 V/H ratios to the ESP site. In addition, provide justification for the use of an approximate envelope of the Lee (2001) and the NUREG/CR-6728 V/H ratios.

Response:

Estimating earthquake ground motions in central and eastern US [CEUS] has always been a challenge due to the lack of empirical data. For hard rock CEUS sites EPRI (2004) considers 12 models to capture a robust estimate of the median horizontal ground motion and its uncertainty to capture the range of opinion of the technical community. Estimating vertical motions for CEUS sites, particularly soil sites, is even more challenging.

Regulatory Guide 1.60 presents both horizontal and vertical design response spectra from which V/H can be determined. In developing the V/H for SSAR Section 2.5.2 – similar to what has been presented for other ESP applications – it is our intent to develop a V/H function that considers more recently recognized parametric dependencies [e.g., magnitude, distance, site conditions].

NUREG/CR-6728 recommends V/H as a function of binned peak ground acceleration – as a simplified proxy for magnitude and distance – for generic rock sites in western US [WUS] and CEUS. The NUREG does not, however, recommend specific V/H for soil sites, but rather refers to an appendix [Appendix J] wherein a complex approach is described using empirical WUS V/H and ground motion modeling to develop a WUS-to-CEUS transfer function to obtain the desired CEUS V/H [$V/H_{CEUS,Soil}$]:

$$V/H_{CEUS,Soil} = V/H_{WUS,Soil,Empirical} * [V/H_{CEUS,Soil,Model} / V/H_{WUS,Soil,Model}] \quad \text{Eq. 1}$$

In this approach the first term on the right side is developed from readily available empirical WUS attenuation relations. The second term on the right requires ground motion modeling for both generic WUS soil sites [$V/H_{WUS,Soil,Model}$], assumed consistent with the empirical ground motion relation [$V/H_{WUS,Soil,Empirical}$], and "site-specific" CEUS site [$V/H_{CEUS,Soil,Model}$]. Ground motion modeling – that is, estimating earthquake ground motions from theoretical and limited empirically-based parameterization of earthquake source, path, and near-site crustal and soil characteristics [e.g., see EPRI, 1993] – requires numerous assumptions and specifications of uncertainties [both epistemic and aleatory]. The complexities of modeling is why $V/H_{WUS,Soil,Empirical}$ / $V/H_{WUS,Soil,Model}$ is not simply 1.0, and it is intended that in the transfer function the "noise" of modeling cancels out, leaving a useful WUS-to-CEUS transfer function. The development of this transfer function, however, is not prescriptive and it is not unique.

Given the complexities, uncertainties, and non-uniqueness in applying Eq. 1, the SSAR considers the implementation of the NUREG approach [Eq. 1] – accepted by the NRC in the DSER – in two cases as a guide for recommending a V/H for the Vogtle project site. One case considers transfer functions presented in the NUREG Appendix J itself where the CEUS soil model is that of a generic "deep soil" [500 feet] site. The second case, also following the NUREG approach, uses an evaluation of V/H for a facility at the nearby Savannah River Site [SRS] (Lee, 2001). The subsurface shear-wave velocity profiles and depths to water table are similar at Vogtle and at the SRS facility.

While the results from SRS [second case] may seem arguably the most applicable for the Vogtle site, the generic nature of the first case is consistent with the generic character of the rock V/H recommendations of the NUREG. Therefore, both results are considered in the SSAR.

The second half of this Open Item asks about the apparently arbitrary way in which the two cases are enveloped. Like Reg. Guide 1.60 and the recommended V/H functions for rock sites in the NUREG, the intent is to derive a V/H that is relatively simple and smooth, but that reflects the general features of the results obtained above. The results from the two cases suggest the following general features:

1) similar to Reg. Guide 1.60 and the NUREG V/H for rock, V/H is higher at high frequncies than at low frequencies;

2) the two cases evaluated suggest that a relatively flat V/H value at high frequencies, slightly lower [~0.9] than that given by Reg. Guide 1.60 [1.0];

3) both cases suggest a lower V/H value [0.5] than that given by Reg. Guide 1.60 [2/3] in the lowest frequencies;

4) the envelope of the two cases suggests that the transition between the higher V/H at high frequencies and the lower V/H at low frequencies is more gradual than the relatively abrupt transition in Reg. Guide 1.60; and

5) the V/H at high frequencies is sustained at its high value longer toward lower frequencies [flatter] than suggested by CEUS rock V/H from the NUREG.

Given the complexities, assumptions, and uncertainties of developing CEUS, deep soil V/H for the Vogtle site, as well as the desire to develop a smooth function, a conservative envelope of the V/H for the two cases is developed. The three discrete accelerations intervals for which rock V/H is defined in the NUREG also suggests approximate evaluations of V/H. Therefore, some peaks are cut [e.g., ~1.3Hz] and valleys are filled [e.g., 2.5Hz], but these are not considered significant relative to other uncertainties in ground motion evaluations. One aspect of the approximate envelope that may be highlighted, however, is in the frequency range of about 0.3 to 1.0Hz. Here, the envelope of the two cases would suggest a noticeable dip in V/H as low as 0.25 or less. One explanation of this is resonances in the vertical and horizontal ground motions when using simple velocity models, and would be reduced if the profiles had been randomized [NUREG Appendix, p. J-12]. Regardless of the cause, it is our judgement that this low of V/H is not reasonable, so V/H was kept to a minimum value of 0.5.

SER Section 2.5.3 – Surface Faulting

2.5-10 Provide a more detailed description of the geometry and appearance of the injection sand dikes and their spatial association with dissolution depressions (including photographs of this feature, if available).

<u>Response</u>:

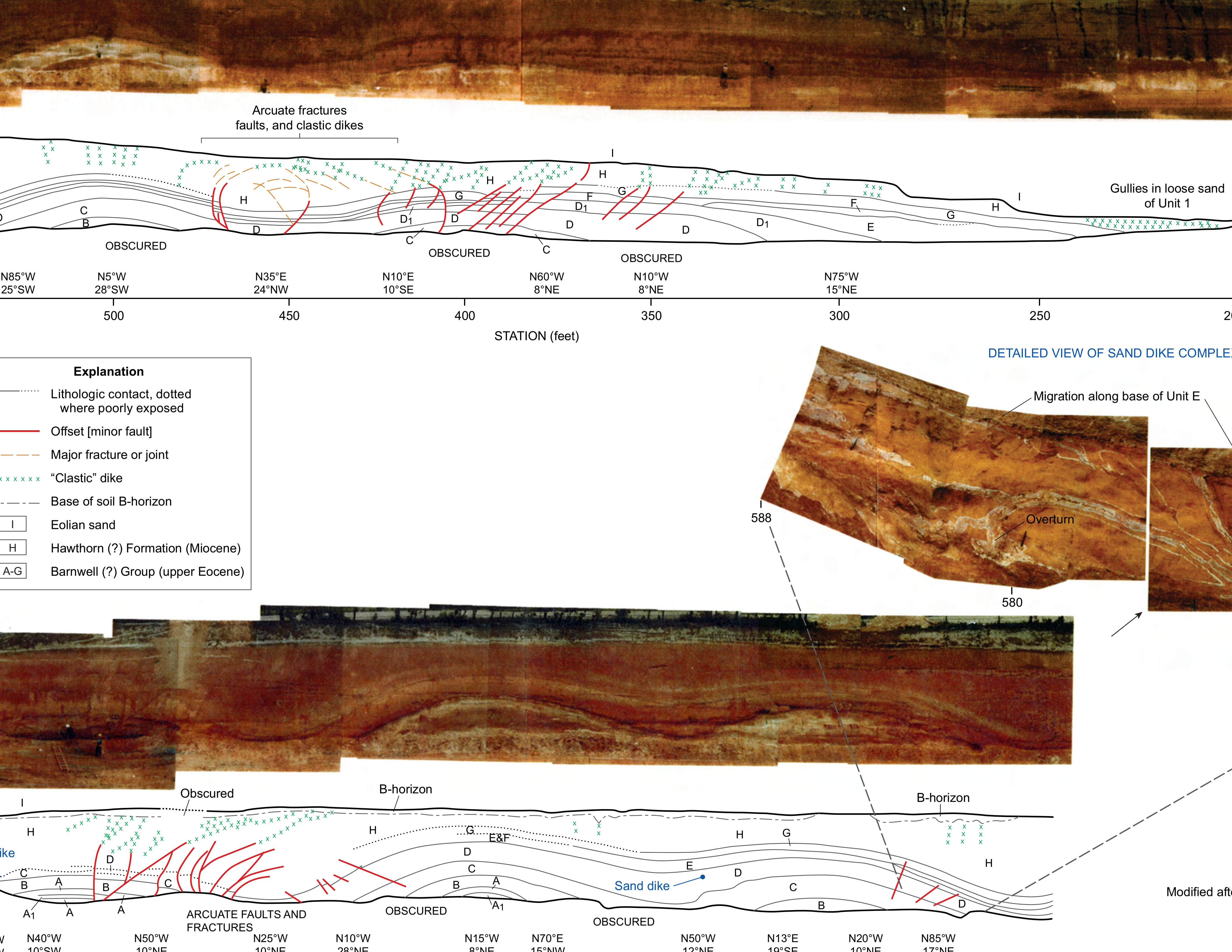
The injected sand dikes occur at three localities in the Bechtel (1984) trench (Figure 2.5-10A). These sand dikes were not observed at any other location either on or off the VEGP site during the ESP mapping effort. Within the trench, the sand dikes are only located within the upper Eocene Barnwell Group and as identified by Bechtel (1984), consist of lavender, loosely consolidated, well sorted, very fine, clean quartz sand and are confined to a single unit (Unit D) within the trench. These dikes were likely formed by fluid or plastic injection of sand from a source in underlying sand beds of Unit C. The sand dikes are locally mapped along the up-dip contact with Unit E, but do not penetrate Unit E (Figure 2.5-10A). As the dikes were mapped downward, they became irregular and indistinguishable as they entered/emerged from Unit C (Bechtel, 1984).

As described in Bechtel (1984), the orientation of the dikes varies greatly. At each location they dip steeply down the limbs of large depressions and appear to have a source within Unit C at the base of the depression. The dikes flatten upward toward the crest of arches (Figure 2.5-10A).

The sand dikes are plotted on the contour and 3-dimensional surface grid from Bechtel (1984, Figure 5) (Figure 2.5-10B). As shown on Figure 2.5-10B, the upper Eocene Barnwell Group is deformed into a series of irregular depressions that form an 'egg-carton' or 'dimpled' pattern. The depressions are not aligned or elongated in any preferred orientation, and are most likely the result of dissolution of the underlying Utley limestone and collapse of overlying strata. The injected dikes are concentrated in the area of greatest 'dimpling' and are absent from the area of least 'dimpling'. Bechtel (1984) identified only one large complex of sand dikes and this complex plots in a depression (Station 570 to 590, Figure 2.5-10B). The remaining two, single, laterally discontinuous, thin sand dikes plot along margins of depressions (Stations 642 and 830, Figure 2.5-10B). The close spatial association of the sand dikes with limbs of the depressions suggests that the liquid injection resulted from development of the depression. Subsequent deformation and faulting of the sand dikes (for example at Station 575) show that the sand dikes pre-date later phases of sediment collapse and formation of the depressions.

As described in Bechtel (1984) and reviewed by the USNRC (1985), variation in orientation of the depressions and associated dikes supports a local control for their formation versus a regional tectonic control that would produce more coherent orientations. The spatial relation of the sand dikes with the dissolution depressions supports the hypothesis that the sand dikes were created in response to increased overburden pressure during an early phase of sediment collapse. The sand dikes are further deformed and faulted by continued later phases of sediment collapse and formation of the depressions.

The age of the injected sand dikes, therefore, is related to the age of the collapse depressions. The depressions deform the overlying Miocene Hawthorne Formation but do not deform an erosion surface or an extensive paleosol that developed on the erosion surface. Mature, well-formed pedogenic "clastic dikes" have developed within the paleosol suggesting significant age as shown on Figure 2.5-10A. The paleosol is, in turn, overlain by Pleistocene to Holocene eolian sand (Figure 2.5-10A). Given the significant paleosol development on the erosion surface and extensive subsequent erosion of this former surface prior to eolian deposition on the modern landscape, Bechtel (1984) interpreted the erosion surface and paleosol to be late Miocene to Pliocene in age. Lack of deformation of the erosion surface or of the paleosol suggests that development of the depressions and related injection of the sand dikes likely occurred in the late Miocene or Pliocene.



Arcuate fractures
faults, and clastic dikes
Gullies in loose sand
of Unit 1
OBSCURED
N85°W 25°SW
N5°W 28°SW
N35°E 24°NW
N10°E 10°SE
N60°W 8°NE
N10°W 8°NE
N75°W 15°NE
500
450
400
350
300
250
STATION (feet)
DETAILED VIEW OF SAND DIKE COMPLE
Migration along base of Unit E
Overturn
588
580
Explanation
Lithologic contact, dotted where poorly exposed
Offset [minor fault]
Major fracture or joint
"Clastic" dike
Base of soil B-horizon
I Eolian sand
H Hawthorn (?) Formation (Miocene)
A-G Barnwell (?) Group (upper Eocene)
Obscured
B-horizon
Sand dike
ARCUATE FAULTS AND FRACTURES
N40°W
N50°W
N25°W
N10°W
N15°W
N70°E
N50°W
N13°E
N20°W
N85°W
Modified aft