To: Dana Powers, ACRS-NRC
From: William J. Hinze
Subject: **Safety Evaluation of the Early Site Permit Application in the Matter of Southern Nuclear Operating Company, for the Vogtle Early Site Permit Site**
Date: December 4, 2008

Introduction

The objective of this brief report is to summarize the salient points of my review of the report prepared by the Office of New Reactors, NRC entitled "Safety Evaluation of the Early Site Permit Application in the Matter of Southern Nuclear Operating Company, for the Vogtle Early Site Permit Site", dated November 2008. This report supplements and complements the attached report (Appendix A) which was submitted on October 12, 2007 on the Vogtle Early Site Permit Application (ESP) and NRC's draft Safety Evaluation Report (SER) on the application.

I have reviewed portions of NRC's Safety Evaluation Report (SER) in 2.4, Hydrologic Engineering; 2.5 Geology, Seismology, and Geotechnical Engineering; and portions of 3.7, Seismic Design. The emphasis of my review is on 2.5.1, Basic Geologic and Seismic Information; 2.5.2, Vibratory Ground Motion; 2.5.3, Surface Faulting, and to a lesser degree on 2.5.4, Surface Materials and 3.7, Seismic Design. In preparation for this task I have reviewed the ESP application, the NRC's request for additional information, the minutes of the ACRS Subcommittee that reviewed the ESP application and the NRC's draft SER on October 24, 2007, and participated in the ACRS review on December 3, 2008.

The results of the review are presented below indexed to the specific sections of the advanced (November 2008) NRC SER. In the interest of brevity, the information in the NRC SER is not summarized, but rather remarks are made on issues of concern and, where appropriate, questions are raised regarding the content.

My overall evaluation of the sections of the advanced SER that have been reviewed is that the NRC has prepared a comprehensive and insightful review and evaluation of the ESP application for the Vogtle Electric Generating Plant (VEGP) submitted by Southern Nuclear Operating Company (SNC) and the limited work authorization (LWA) activities for which SNC has requested approval.

However, I do have comments, questions, and different views than those specified in the advanced SER that may be useful to you and your subcommittee as the ACRS reviews the Vogtle ESP Application and the advanced SER. These are listed below.

In addition, reports have been prepared which are attached that describe the current status of VEGP site seismic source zones (Appendix B) and a review of the status of open items related to geology, seismology, and geotechnical engineering (section 2.5) of the Vogtle Early Site Permit application (Appendix C).

Hydrologic Engineering (2.4)

1. Section 2.4, Hydrologic Engineering, is very comprehensive and insightful of the hydrologic concerns at VEGP; however, frequently in evaluating the methodologies of the applicant, the NRC describes these as being "generally" acceptable. The term "generally" is not definitive and, thus, its use could lead to misunderstanding. I suggest that use of this term be reconsidered.

2. Probable Maximum Tsunamis Hazards (2.4.6) The potential risk to oceanic coastal areas from a tsunami has received increasing attention since the destructive impact of the 12/26/04 Indonesian earthquake and the resulting tsunami in the Indian Ocean region. The NRC and applicant agree that the hazard from a tsunami to the VEPG site is negligible considering the elevation of the site and its distance from the Atlantic Ocean Coast. The largest historical tsunami to impact the Atlantic Ocean Coast in the vicinity of the VEPG was from the 1755 Great Lisbon earthquake. Modeling suggests the wave height from this tsunami was approximately 3 m on the eastern shore of the US.

The primary origin of tsunamis is from disruption of the ocean floor as a result of earthquake activity either by direct displacement of the floor or by initiation of submarine landslides activated by the vibratory motion of the quake. However, tsunamis may also be caused by massive landslides into the ocean especially from volcanic islands. Recent predictions of catastrophic landslides from volcanic islands in the Atlantic Ocean have led to predictions from modeling of tsunami wave heights of the order of 25 m on the eastern shore of the US. Although these predictions are disputed based on available geological evidence and there are concerns regarding the assumptions and parameters of the models, these hypothetical tsunami events need to be considered in evaluating the hazard to proposed nuclear plants closer to the shore and at a lower elevation than the VEGP site. Intuitively, the probability of these catastrophic tsunamis is very low, but they must be considered, likely in a probabilistic manner. Numerous parameters must be considered in this evaluation. One important source of data is the identification, location, and dating of debris deposits originating from tsunamis along the eastern coast of the US. None of these deposits have been identified from pre-historic events in the region of the VEGP.

Basic Geologic and Seismic Information

The following items concerning Section 2.5 serve to support and expand on the comments made in the previous report to the ACRS that is included as an attachment.

1. The following are comments related to faulting at and near the VEGP site that is treated in Item #3 of Appendix A:
    a. At the October 24, 2007 meeting Scott Lindvall of WLA answered a question from Dr. Powers that the Millet fault was now discredited and that the appropriate fault near or at the southwestern margin of the Dunbarton

basin is the Martin fault. Despite this the discredited fault is named in the advanced SER on pages 2-191, 2-192, and 2-224. Should these references to the Millet fault be changed to the Martin fault?

b. The Martin fault as mapped at the Savannah River Site appears to mark the southwestern edge of the Dunbarton basin. If this fault is listric could it extend sufficiently far to the northwest to underlie the VEGP site location? Why is this fault not included in the list of potential Quaternary faults on page 2-219?

c. The SER has properly noted that the Pen Branch fault which makes the northwestern margin of the Triassic Dunbarton basin may be either a listric or a high-angle fault, but they do acknowledge that the current information does not differentiate between these types of faults. Despite this, is it useful to consider the implications of these two types of faulting to the depth of earthquake hypocenters that could be anticipated and the relevance of these depths to vibratory motion at the site?

d. The overall impression of the analysis of movement along the faults of the VEGP site is that the focus is on vertical movement. This is not stated explicitly but is the inference that can be made from the treatment of the subject matter. This appears to be the case for the study of the Ellenton terrace (Qte), borehole logging, and seismic reflection studies. The possibility of strike-slip movement associated with the regional stress pattern which has the maximum horizontal compressive stress oriented ~N50^{o} to 70^{o}E is largely neglected. The Pen Branch fault which has an orientation of roughly N45^{o}E and N34^{o}E would not be subject to the maximum shearing stress at this orientation, but strike-slip movement can occur along faults ranging in orientations from 10^{o} to 40^{o} from the regional maximum horizontal compressive stress. Thus although ideally oriented to the regional stress, strike-slip movement may be permissible along this fault. If these boundary conditions are accepted, is it possible that strike-slip movement may have occurred along the Pen Branch fault in Quaternary time without evidence in observable vertical movements?

e. The 1 m detection level of disruption of the Ellenton Terrace is accepted in the advanced SER as "…a reasonable limit based on measured variability detected in elevation of this terrace surface due to erosion and dissection of the terrace." [page 2-213] Does this mean that vertical movements at the surface along the Pen Branch fault of less than 1 m would not be detected? What are the implications of this to evaluating earthquake hazard from this fault?

2. As reported in Section 2.5.1, Item 5 of Appendix A, there is a need to define the areas of the greater VEGP region where surveys have been made for paleoliquefaction features and where the subsurface conditions are susceptible to liquefaction. The lack of identification of paleoliquefaction features without this additional information seriously qualifies the use of the negative evidence. This item is not analyzed in the advanced SER. Perhaps a positive approach should be used by outlining the area of the greater VEGP region for which paleoliquefaction surveys produce credible results.

3. In Item 6 of section 2.5.1 of the Attachment A explores the potential usefulness of strain measurements made by repeat Global Positioning Satellite (GPS) measurements in the Charleston seismic source region. Although, the Atlantic Ocean coastal plain is not ideal for stable bench marks and the length of the time over which measurements have been made is less than a decade, some consideration should be made of the GPS measurements that have been made by the University of South Carolina in the Charleston region that at least in part have been supported by the NRC.

Vibratory Ground Motion

The following items serve to support and expand on the comments made in the previous report (Appendix A) to the ACRS that is included as an attachment.

1. Some of the teams in the EPRI – SOG connected together the seismicity of the Charleston area with seismicity to the northwest, principally in the Bowman seismic zone located 80 km northwest of Charleston. It is significant that there is no geological or geophysical data that supports a through-going seismic structure from Charleston to the Bowman area and perhaps beyond and, thus, a northwesterly-striking seismic zone from the Charleston area is not a viable hypothesis. Rather the seismicity of the Charleston area, the results of paleoliquefaction studies, and geological investigations strongly suggest that Charleston seismic zone is limited to a much smaller area immediately associated with mapped faults, particularly near the intersection of the Ashley and Woodstock faults.
2. Jeff Munsey of the Tennessee Valley Authority has identified new sources of information on historical seismicity and events especially in the southeaster US. Have these events been incorporated into the present seismicty catalog? Are any of these newly identified events proximal to the VEGP site? A magnitude 4.5 event of 4/5/1888 has been identified in the Newberry, SC area. Does this have an impact on the evaluation of the seismic hazard at VEGP?
3. Does the current seismicity of the Charleston seismic source zone area follow the exponential decrease in number of events of Omori's law suggesting that these events may be aftershocks of the Charleston event? If so, what are the potential implications to seismic hazard from the Charleston seismic zone?
4. Paleoliquefaction features have been mapped roughly 100 km from the shoreline in the South Carolina/Georgia region likely showing that significant magnitude earthquakes are not limited to the coast line region where there are prominent paleoliquefaction features. However, there has been inadequate mapping of paleoliquefaction survey regions to establish that those areas without mapped features are devoid of significant earthquakes.
5. The 320 km radius region of importance to mapping seismic zones includes the continental margin and highly extended region at the margin of the continent. What is the implication of this to seismic hazards at VEGP? Basham and Adams in studying the seismicity of the continental margin of the Atlantic Ocean in Canada suggest that earthquake magnitudes of the order of 7.2 may be associated

with the contact between continental and oceanic crust. Is this a credible seismic zone to be considered in evaluation of the VEGP site? What is the maximum magnitude earthquake that could occur on the continental margin off shore Georgia that would not be noticed or recorded on land?

Surface Faulting

1.. The results from surveys of surface faulting would be enhanced by an evaluation of the sensitivity of the various methods of measuring fault displacement. This evaluation should consider subsurface methods of measurement as well.

Appendix A

To: Dana Powers, ACRS-NRC
From: William J. Hinze, ACNW&M
Subject: **Review of Vogtle Early Site Permit Application and NRC's Safety Evaluation Report for the Vogtle Application**
Date: October 12, 2007

Introduction

The objective of this brief report is to summarize the salient points of my review of the Vogtle Early Site Permit (ESP) Application (Rev. 2, April 2007) prepared by the Southern Nuclear Operating Company and the Safety Evaluation Report (SER) for this application prepared by the NRC Office of New Reactors (August 30, 2007).

Specifically at your instruction I have focused my review on Section 2.5.1, Basic Geologic and Seismic Information; Section 2.5.2, Vibratory Ground Motion; Section 2.5.3, Surface Faulting; and Appendix 2.5 B, High Resolution Compressional Seismic Survey Field Report. Sections dealing with Geotechnical Engineering as well as other sections of the Application and SER, 2.5. 4-6 were briefly perused.. I was aided in my review by my experience as a member of the Rondout Earth Science Team (EST) that participated in the EPRI Probabilistic Seismic Hazard Analysis (PSHA) of eastern North America that was published in 1986. The EPRI-1986 PSHA updated according to current regulations was used as the basis for the seismic analysis presented in the Vogtle ESP Application.

The results of the review of are presented below indexed to the specific sections of the ESP Application and the SER. In the interest of brevity I have not summarized the information presented in the sections, but rather commented on issues of concern.

My overall evaluation of Sections 2.5.1 -3 of the ESP Application is that in general it presents and analyzes the information required in the applicable regulations 10 CFR 52.17(a)(1)(vi), 10 CFR 100.23(c), and 10 CFR 100.23(d) and that the SER is a comprehensive and insightful review of the Application. However, I do have comments, questions, and different views than those specified in the Application and SER that may be useful to you and your subcommittee as the ACRS reviews the Vogtle ESP Application. These are listed below.

Basic Geologic and Seismic Information (Section 2.5.1)

1. The hypotheses dealing with the origin of the potentially seismogenic features of the Vogtle region are relatively mature and notably advanced over the status of geologic and tectonic knowledge of the region at the time of the EPRI-1986 study. These advances have been incorporated in the description of the geology and tectonic structures and their origin in the Application and SER.

2. The principal potentially seismogenic geological features of the region are: (1) the Charleston seismic zone that was the site of the ~7 (6.7-7.3) magnitude earthquake of 1886, (2) the Eastern Tennessee seismic zone that is the second-most (to the New Madrid seismic zone) seismically active region in the eastern United States, and (3) the early to middle Triassic (~175 Ma) basins which form the basement beneath the coastal plain Cretaceous and Tertiary sediments of much of the States of Georgia and South Carolina. There is no specific evidence that faults of the Triassic basins which were formed during extension of the continental crust during the early stages of the formation of the Atlantic Ocean during the breakup of the supercontinent Pangea are seismogenic, but several authorities have noted that the normal faults of the basins are likely candidates for reactivation in the current stress pattern of the eastern United States. These potentially seismogenic features are adequately described and discussed in the Application and analyzed in the SER. There are numerous other Precambrian (>~615 Ma) faults and others formed during the subsequent Appalachian mountain building periods that are potential sites for reactivation in the current stress regime, but no evidence suggests a correlation of these faults with specific historical earthquakes.

3. The Vogtle site is underlain by the north-northeasterly striking Dunbarton Triassic basin which has been identified by drilling through the roughly 300 m of overlying sediments and geophysical studies. The basin is associated with the much more extensive and well-developed South Georgia Triassic basin. The data suggest that the Dunbarton basin is a half-graben with the greatest development of the basin along a normal fault on its northwestern side. This fault has been at least locally reactivated in Tertiary time and is recognized as the Pen Branch fault in the Savannah River Site (SRS) with a southwestern extension into the Vogtle site. There is no evidence that this fault has been active in the last 2 million years and is appropriately analyzed as a non-capable fault in the Application and SER. Its orientation as recognized in the detailed geological/geophysical investigations of the SRS is incorrectly oriented for reactivation in the current stress field (see item 4.). Several other faults of the SRS which may extend across the Savannah River into Georgia have a similar general orientation.

   The southeastern edge of the Dunbarton basin may also be fault controlled. The Martin fault (Figure 2.51-16 of the ESP Application) that has been mapped in the SRS may be the surface extension of that fault. This fault which occurs some 30 km southeast of the Vogtle site unfortunately has not been the site of high resolution surface geophysical studies. It should be noted that the Martin fault appears to be identified on Figure 2.5.1-21 of the ESP Application as the Millet fault. Are the Martin and Millet faults the same fault? And if so why is this not made clear in the Application discussion?

4. The information available to the EPRI-1986 EST on the stress regime of the eastern United States is essentially equivalent to the currently available data except that regional perturbations in the stress field that were interpreted by some ESTs are not warranted by the current information. Additionally, most of the stress measurements are from the relatively near-surface (<~ 300 m) and thus are not in the seismogenic region of the crust where earthquakes of the region occur. The maximum horizontal compressive stress is derived from ridge-push forces originating in the Mid-Atlantic Ridge and is generally directed in an N60^{o}E direction. Accordingly, in general faults oriented at roughly 45^{o} to this direction are subject to strike-slip movement depending on the coefficient of friction, while orthogonally oriented faults are subject to reverse faulting. This information and its implications are well treated in the Application and SER.

5. The relatively short historical seismic record and the low recurrence interval of earthquakes in the Vogtle region inhibit comprehensive characterization of the seismicity of the region. A significant development since the EPRI-1986 study is the mapping of paleoliquefaction features as a useful methodology for identifying the site of past earthquakes, especially in the last 10,000 years. These features occur in friable sediments where the groundwater table is close to the surface and are caused by liquefaction of soils during the passage of seismic waves originating from earthquakes that generally have a magnitude of greater than 6. Dating of carbonaceous material in these features permit approximate dating of the earthquake. Mapping and studying of paleoliquefaction features in the Charleston seismic zone has been essential to furthering our knowledge of the nature of the 1886 Charleston event.

   The ESP Application and the SER note that the mapping of paleoliquefaction features has been conducted over an extensive region of the southeastern United States including the Vogtle site vicinity. These studies have failed to identify liquefaction features in the Vogtle site vicinity, however, no information is provided on the stream valleys that have been studied and those that have conditions suitable for liquefaction during the passage of strong seismic waves. I consider this to be a significant omission of critical data. There is a need for confidence that the paleoliquefaction studies have been sufficiently detailed and have covered the appropriate regions in the vicinity of the Vogtle site. What are the implications of this omission to our understanding of the seismicity of the Vogtle vicinity?

6. Small long-term ground measurements using location observations from Global Positioning Satellites (GPS) have become a major source of information related to potential seismic events. Ground movements in southeastern United States are likely to be at the margin of resolution of GPS observations. Nonetheless, it is important to identify any potentially useful GPS measurements in the region that could bear on seismic activity. Trenkamp and Talwani (2007)[1] have a manuscript

[1] ***Trenkamp, R., and Talwani, P., 2007., GPS strain and strain zonation near Charleston, South Carolina, Journal of Geophysical Research, manuscript in revision.***

on GPS strain measurements that is listed in the publications of Pradeep Talwani in his personal web page at the University of South Carolina site. A search of the literature on strain measurements in southeaster United States should be performed and all pertinent information included in the application.

7. In response to RAI 2.5.1-7 the applicant rejected the Grenville front as a potential seismic feature because it is of Precambrian age. However, there are numerous Precambrian faults throughout the eastern and central United States that are potentially seismogenic as a result of reactivation in the current stress field. Furthermore, one of the seismogenic regions of the eastern United States, the Anna, Ohio seismic zone (Figure 2.1-15 of the Application), has been identified as the location of the intersection of a Precambrian rift with the Grenville front (tectonic zone). See for example Hinze and Hildenbrand (1988)[2].The treatment of this topic in the Application is inadequate on this point.

8. The applicant has correctly recognized the potential for distant large earthquakes in the central and eastern United States to contribute to ground-motion hazards at the Vogtle site. The applicant and the SER identify the New Madrid seismic zone as the most significant to the seismic hazard characteristics of the site and the only distant seismic zone that needed updating since the EPRI-1986 study. The updating indicates the need to lower the generally accepted recurrence interval in this zone to roughly 500 years. The treatment of this topic is handled well both in the Application and the SER. However, there is no mention of the concern with "far-field triggering" of earthquakes. Recent studies and publications take note that large earthquakes may trigger earthquakes at distances of several hundreds of kilometers distance. This topic was also raised with respect to the ESP of the Clinton site. The possibility of far-field triggering of earthquakes should be noted in the Application and its implications with regard to seismic hazards considered.

9. *To summarize, in general the Application and the SER fully describe the current state of information regarding geology and seismicity of the Vogtle site region and I concur with the conclusions (2.5.1.4) of the SER with the exceptions noted above. The Pen Branch fault should not be considered a capable fault based on the current evidence. The seismic characteristics of the Charleston seismic zone control the Safe Shutdown Earthquake (SSE) ground motion.*

Vibratory Ground Motion (Section 2.5.2)

1. In the PSHA it is clear that the primary sources of ground motion in the region are the Eastern Tennessee and Charleston seismic zones. The Eastern Tennessee zone, which is included even though it occurs immediately outside the 300 km distance, is associated with unknown faults that likely strike northeasterly in the

[2] ***Hinze, W.J., and Hildenbrand, T.G., 1988, The utility of geopotential field data in seismotectonic studies in the eastern United States, Seismological Research Letters, 59, 289-297.***

Precambrian and Cambrian rocks which underlie the folds of the Valley and Ridge geomorphic province. The Eastern Tennessee seismic zone lies between the geophysically identified New York-Alabama lineament, which has been related to a Precambrian or early Paleozoic strike slip zone, and the Appalachian Clingman-Ocee geologic lineament. This is a zone of major release of earthquake energy but historic earthquakes do not exceed a magnitude of ~4.6 and no earthquake epicenter has been identified with a specific fault. This information has not changed in a significant manner since EPRI-1986 study. It is appropriately identified in the Application and SER as of only minor significance to ground motion at the Vogtle site.

2. Significant new information has been obtained about the Charleston seismic zone since the EPRI-1986 study which has been incorporated into the Application and appropriately reviewed and analyzed in the SER. The new information has come about as a result of geophysical studies, liquefaction investigations, microseismicity compilations, and continued analysis of the integrated data. It is significant to note that the 1886 Charleston event has not been identified with a particular fault in the area, but the best evidence is that it occurred near the intersection of the NNE extending Woodstock fault and the Summerville cross fault. The Woodstock fault has been related to the East Coast fault zone which is interpreted to extend NNE from the Charleston area.

   The Charleston seismic zone is particularly important to the ground motion studies of the Vogtle site because of its proximity and the large magnitude of the 1886 Charleston earthquake. The recent interpretations of the Charleston seismic zone suggest a decreased recurrence interval. Based on dating of paleoliquefaction features over the past few thousand years the recurrence interval is of the order of 500 years with an uncertainty of perhaps no more that 50 years. Furthermore, there is much clearer information on the configuration of the seismic zone. In the EPRI-1986 study information on faulting in the Charleston area was only becoming available. As a result the ESTs differed considerably in their specification of the zonal boundaries. These boundaries are now much more constrained and have been used appropriately by the applicant.

3. Although microseismicity, paleoliquefaction, geologic, and geophysical investigations have identified a complex pattern of 9 faults in the Charleston seismic zone associated with 1886 Charleston earthquake, there is no generally acceptable hypothesis to explain why this combination of geologic structures has been repeatedly active with large earthquakes in the past. Without this explanation restricting seismicity to the Charleston seismic zone, it is questionable that this is the only such set of geologic structures in the region that could cause large earthquakes. Could there be other similar structural regions that have not been identified because of the lesser intensity of investigations and the lack of microseismicity and paleoliquefaction features? A positive answer to this remains a possibility but the lack of other areas in the Vogtle site region that have experienced similar large earthquakes, particularly in view of the 500 year

recurrence interval of the Charleston seismic zone, suggest that the probability of this possibility must be very low.

4. In view of the paucity of information on earthquakes in the region of the Vogtle site, the relatively long recurrence interval, and short historical record, it appears likely that an earthquake may occur anywhere in the region, the so-called controlling earthquake. If indeed this is the case what is the maximum magnitude earthquake that could occur anywhere in the area and how is this "floating" earthquake magnitude established in the region?

5. The Application is based on ground motion as determined from PSHA using updated EPRI information. The applicant did not choose to use the LLNL methodology as permitted in the regulations. Why did the applicant choose the EPRI methodology over the LLNL approach? This is not discussed in the application. What are the implications to the results of the seismic hazard from the use of the EPRI methodology?

6. As noted in the SER there is inconsistent data regarding the shear wave velocity of the sediments underlying the Vogtle site. This inconsistency needs to be explained and the shear wave velocities should be verified.

7. The staff's conclusion that the site is located within the Mesozoic passive margin which includes Triassic rift basins leading to Open Item 2.5-1 is thoroughly justified. The source of the difference between the applicant and the SER needs to be explained.

8. SER's Open Item 2.5-3 regarding the possible contribution of the larger magnitude earthquakes in the Eastern Tennessee seismic zone is significant and needs to be answered by the applicant.

9. Open Item 2.5-5 of the SER dealing with limitations in the regional paleoliquefaction studies is consistent with the concerns of 2.5.1, item 5 above. This is a particularly significant open item.

10. *To summarize, the Application and the SER do a credible job of evaluating 2.5.2. The conclusions of the SER on this topic given in 2.5.2.4 are germane. However, I have some concerns as indicated above. I concur with all of the Open Items identified in the SER.*

Surface Faulting (Section 2.5.3)

No specific comments are required for this section, but,, in summary, the SER appropriately treats the Application in dealing with the potential for surface faulting and Open-Item 2.5-10 is justified.

Stability of Subsurface Material and Foundation (Section 2.5.4)

This section was only briefly reviewed, but the conclusions of the SER (Section 2.5.4.4) are appropriate and the concern with insufficient supporting information is warranted.

Stability of Slopes (Section 2.5.5)

This section was only briefly reviewed, but the evaluation of this section of the Application is appropriate.

Embankments and Dams (Section 2.5.6)

This section was only briefly reviewed, but the evaluation of this section of the Application is appropriate.

High Resolution Compressional Seismic Survey Field Report (Section Appendix 2.5 B)

1. There is ambiguity in the interpretation of the results of the reflection seismic survey because the survey is 2-dimensional in nature requiring interpolation of the strike and nature of the Pen Branch fault between the individual survey lines. This is inevitable in a 2-dimensional survey such as conducted at the Vogtle site especially where *en echelon* faults may be present.. This problem could have been minimized by conducting a 3-dimensional survey. The resources needed for acquiring and processing a 3-dimensional survey are considerably greater than for a 2-dimensional survey. However, the importance of achieving the higher resolution in the study of this strategically located fault suggests that the state of the technology methodologies should have been considered for this important study.

2. The seismic reflection survey was limited to the Vogtle site. Consideration should have been given to extending the survey to the southeast where the basement equivalent of the Martin fault may bound the southeastern margin of the Dunbarton Triassic basin. Reactivation of the Pen Branch fault suggests that the Martin fault which is only 30 km from the site may too have been reactivated in more recent time. A seismic reflection study of this fault could have been useful in determining if this fault was active in more recent time. This is important because of the proximity of the southeastern border fault to the Vogtle site.

Appendix B

To: Dana Powers, ACRS
From: William J. Hinze
Subject**: Status of VEGP Site Seismic Source Zones**
Date: December 4, 2008

Numerous tectonic elements have been mapped within the VEGP site region (radius of 320 km) dating from Precambrian (>550 Ma) to Holocene (< 10 Ka) time. However, only one seismic source zone has been clearly identified in this region. Seismic zones are defined largely on the basis of seismic flux in historic time and thus the Charlestown area with its destructive earthquake of 1886 and subsequent seismicity is clearly defined as a seismic zone. Additional seismic zones occur beyond but in proximity to the VEGP site region, but only one of these, the Eastern Tennessee Seismic Zone (ETSZ) is considered as a VEGP site seismic zone based on its seismic activity and location at the 320 km boundary. Faults associated with the Triassic Dunbarton basin and particularly the Pen Branch fault on the northwestern edge of the basin occur within the VEGP site area, but available evidence indicates no seismic activity along these faults in Quaternary (<1.8 Ma) or Holocene time. Thus only two seismic source zones are considered in the VEGP site region, the Charleston and Eastern Tennessee Seismic Zone. The current status of knowledge of these two zones is summarized below referenced to the changes that have occurred since the EPRI Seismic Owners Group (SOG) study in 1986.

Charleston Seismic Zone

Studies of the seismicity and tectonic features of the vicinity of the 1886 Charleston earthquake were relatively immature at the time of the EPRI SOG study. Accordingly the SOG study teams of experts described a range of locations of the zone and its characteristics. However, since the mid-1980s the site of the 1886 earthquake has been the subject of numerous successful investigations. In particular, microseismicity, subsurface geological studies, and mapping and analysis of paleoliquefaction features identified in the region have provided critical new evidence.

The majority of the microseismicity occurs in the vicinity of the intersecting Ashley and Woodstock faults which is also an area of significant paleoliquefaction features derived from the 1886 earthquake as well as previous seismic events of magnitude exceeding approximately 6. However, despite the much improved knowledge of the Charleston seismic zone, major questions remain regarding the limits of the zone. Accordingly, four different boundaries delimiting the zone have been identified. However, all four are much more restricted in areal extent than the zones defined by the expert teams in the EPRI SOG report. In particular, on the basis of current evidence the zone is no longer projected to the northwest into the interior of Georgia and into the proximity of the VEGP site. One suggested zone continues into the Atlantic Ocean coastal

region because of faulting identified in nearby marine seismic reflection studies, but this zone is accorded limited weight compared to the other three zones.

Paleoliquefaction studies of previous major earthquakes in the zone over the past several thousand years indicate a recurrence interval of approximately 550 years for magnitude 7 earthquakes. Current analyses suggest that the 1886 earthquake had a magnitude in the low 7s and likely the maximum magnitude for this zone is of this order.

Eastern Tennessee Seismic Zone

A region of intense, northeasterly-striking seismic activity occurs in eastern Tennessee very near the boundary of the VEGP site region. This area has been subject to continuing seismic activity of less than magnitude 5 earthquakes originating in the Precambrian basement rocks below the Paleozoic sedimentary rocks that form the bedrock in the region. The geologic feature associated with this seismic zone is not known, but the seismic zone parallels major features associated with Appalachian Mountain tectonics.

Despite being one of the most active seismic regions of the central and eastern United States no paleoliquefaction features have been identified in this zone to suggest larger magnitude earthquakes in the immediate past or the recurrence interval for earthquake activity. As a result there is limited improvement in knowledge of this seismic zone since the EPRI SOG study. Estimates of the maximum magnitude of earthquakes in this region are as high as 7.75 in the EPRI SOG study. The significance of this zone to the vibratory motion anticipated at the VEGP site is considered significantly less than from the Charleston seismic zone because of the greater distance between the zone and the VEGP site.

The VEGP applicant comprehensively reviewed the evidence for the seismic source zones and identified creditable seismic source zones of the VEGP site region and the characteristics of these zones. Further, the NRC staff's technical analysis and evaluation of the applicant's information and conclusions was complete and accurate from both a regulatory and scientific viewpoint.

Appendix C:

To: Dana Powers, ACRS
From: William J. Hinze
Subject: **Review of Status of Open Items Related to Geology, Seismology, and Geotechnical Engineering (Section 2.5) Of the Vogtle Early Site Permit Application**
Date: December 4, 2008

The responses of the Vogtle ESP applicant to the 22 Open Items identified by the NRC staff in their review of the Early Site Permit Application have been comprehensively analyzed by the NRC staff. The staff finds that the responses to concerns about the procedures and methodologies used to determine the seismic hazard and the properties of the VEGP site pertinent to seismic response answer their concerns and, thus, considers these items to be closed. A review of the responses and the staff's review of them are found to be satisfactory. The open items should now be considered closed.

A brief review of the Open Items and the applicant's and the NRC staff's findings regarding the applicant's response is presented below:

Open Item 2.5-1 – The staff requested justification for the low weights for larger M_{max} values in the estimate of one of the EPRI SOG expert teams (Dames and Moore) pertaining to the seismic hazard at the VEGP site. The contribution to the seismic hazard is insignificant (<5%) at the VEGP site if this estimate is excluded from the analysis, thus the staff closed this item.

Open Item 2.5-2 – This item concerns the significance of the Trial Implementation Program (TIP). The applicant and the NRC staff have now agreed that in addition to illustrating methodology that the results of TIP are useful and significant to analyzing the seismic hazard at the VEGP sit. This item is now closed.

Open Item 2.5-3 – This item concerned the significance of the Eastern Tennessee Seismic Zone (ETSZ) to the seismic hazard at the VEGP site. The applicant and the NRC staff agree that there is no significant new information about this zone since the EPRI SOG study and that the results of this study indicate that because of the distance between the zone and the site that the effect of this zone is insignificant (~1%) at the VEGP site.

Open Item 2.5-4 – This item was based on a concern about the adequacy of the Updated Charleston Seismic Source (UCSS) study. With further information about the procedures used in this study the NRC staff determined that the applicant adequately performed a SSHAC Level 2 study to update the Charleston seismic source zone. As a result this item is closed.

Open Item 2.5-5 – This item was focused around the NRC staff's need for supporting evidence to rule out large earthquakes inland from the Atlantic Ocean coastal region including the Charleston area. The applicant provided a detailed treatment of the evidence regarding inland earthquakes and supporting documentation of a localized

Charleston earthquake source which satisfied the staff's concerns. This open item is now closed.

Open Item 2.5-6 – This item concerned the need for additional information from the applicant on the procedures used to establish the soil surface spectrum for the VEGP site and time to perform an evaluation of this information. The applicant explained the use of amplitude functions to modify the spectrum for a hard rock site to the soil site at the VEGP which satisfied the NRC staff's concern leading to this open item. This item is now closed.

Open Item 2.5-7 – This item dealt with the differences in methodologies for seismic site response analysis and justification for the equivalent linear approach method at higher strain levels. The applicant provided supporting information from a relevant EPRI document that satisfied the NRC staff's concern. This item is now closed.

Open Item 2.5-8 – This item concerned the need for additional time for the NRC staff to review 6 PSHA hazard curves recently received in response to a RAI. This item with the staff's review is now closed.

Open Item 2.5-9 – This item involves the methodology to study the seismic response of the soil at the VEGP site. The staff requested further justification for the methodology used by the applicant which was furnished to the satisfaction of the staff and thus the item was closed.

Open Item 2.5.10 – In this open item the NRC staff requested additional information regarding the sand dikes and their spatial association with dissolution features. This information was provided by the applicant and was therefore closed.

Open Items 2.5.11 – 2.5.22 – These open items concern the need for better descriptions of procedures and for increased number of measurements of the properties of the Blue Bluff marl and soils of the VEGP site. Accordingly, the applicant has made numerous additional borings, measurements of samples, and related tests that satisfied the concerns of the NRC staff in these items. These items are now closed.