From: Christian Araguas
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Presentation to the ACRS Subcommittee

Vogtle Early Site Permit Review Status

Section 2.5
Geology, Seismology and Geotechnical Engineering

October 24, 2007

Review Team for Section 2.5:

- Sections **2.5.1** & **2.5.3** Technical Reviewers
  - Dr. Gerry Stirewalt, Sr. Geologist
  - Meralis Plaza-Toledo, Geologist
  - Laurel Bauer, Geologist
  - Dr. Russell Wheeler and Dr. Anthony Crone, Geologists (USGS)
- Section **2.5.2** Technical Reviewers
  - Dr. Yong Li, Sr. Geophysicist
  - Dr. Clifford Munson, Sr. Geophysicist
  - Sarah Gonzalez, Geophysicist
  - Dr. Charles Mueller, Geophysicist (USGS)
- Section **2.5.4** & **2.5.5** Technical Reviewers
  - Tomeka Terry, Geotechnical Engineer
  - Zahira Cruz-Perez, Geotechnical Engineer
  - Dr. Weijun Wang, Geotechnical Engineer
  - Dr. Thomas Cheng, Sr. Geotechnical Engineer
  - Dr. Yong Li, Sr. Geophysicist
  - Dr. Carl Costantino, Geotechnical Engineer (Brookhaven N L)

AGENDA

- **Discussion of Key Issues & Open Items**
  - Section 2.5.1 Basic Geologic and Seismic Information (presented by Dr. Gerry Stirewalt)
    - The Pen Branch Fault
  - Section 2.5.2 Vibratory Ground Motion (presented by Sarah Gonzalez and Laurel Bauer)
    - Updated Charleston Seismic Source
    - Seismic sources not updated by the applicant

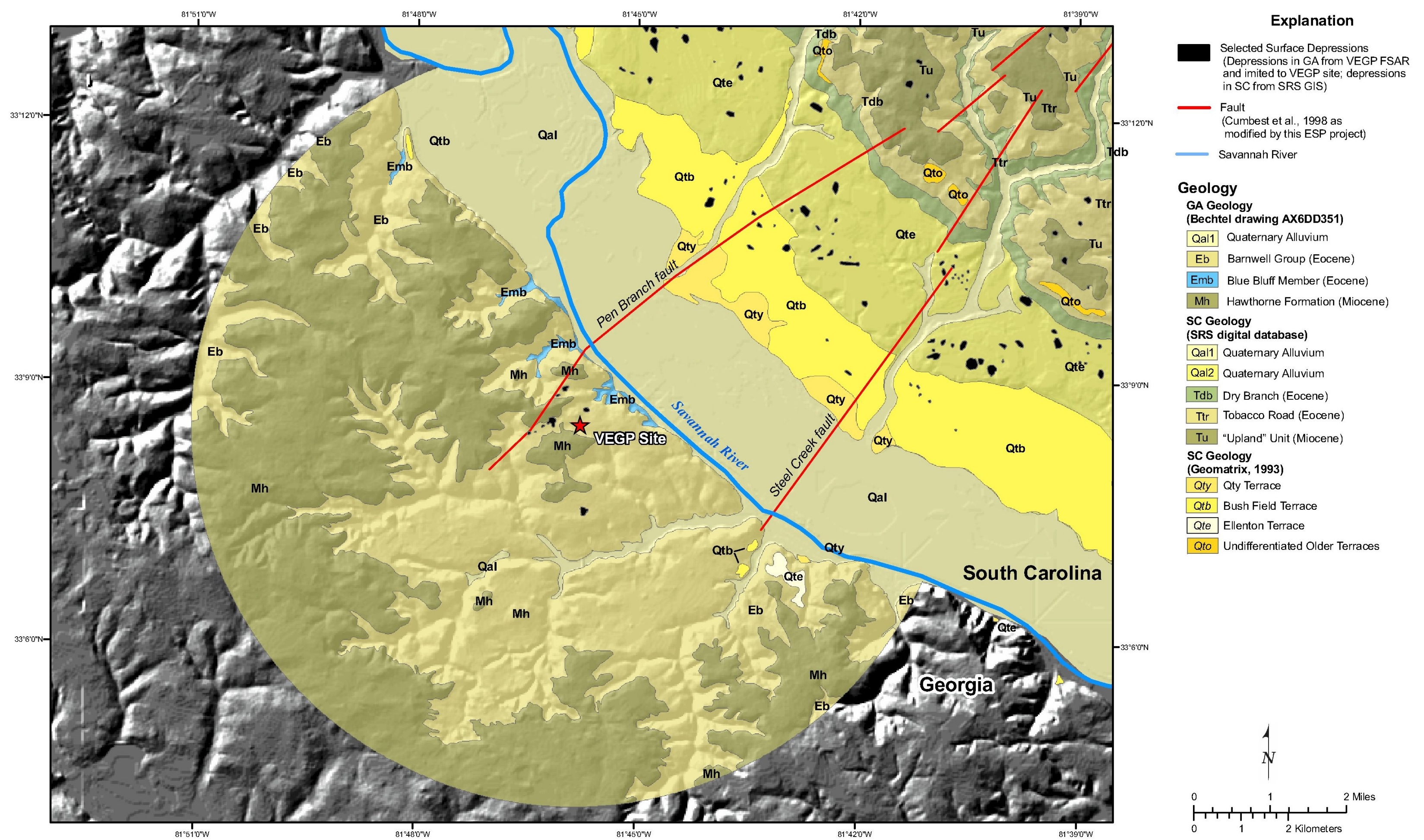
AGENDA

- **Discussion of Key Issues & Open Items**
  - Section 2.5.3 Surface Faulting (presented by Dr. Gerry Stirewalt)
    - Injected Sand Dikes
  - Section 2.5.4 Stability of Subsurface Materials and Foundations (presented by Dr. Yong Li)
    - Limited Site Investigations
    - Limited Laboratory Testing

2.5.1 Basic Geologic & Seismic Information

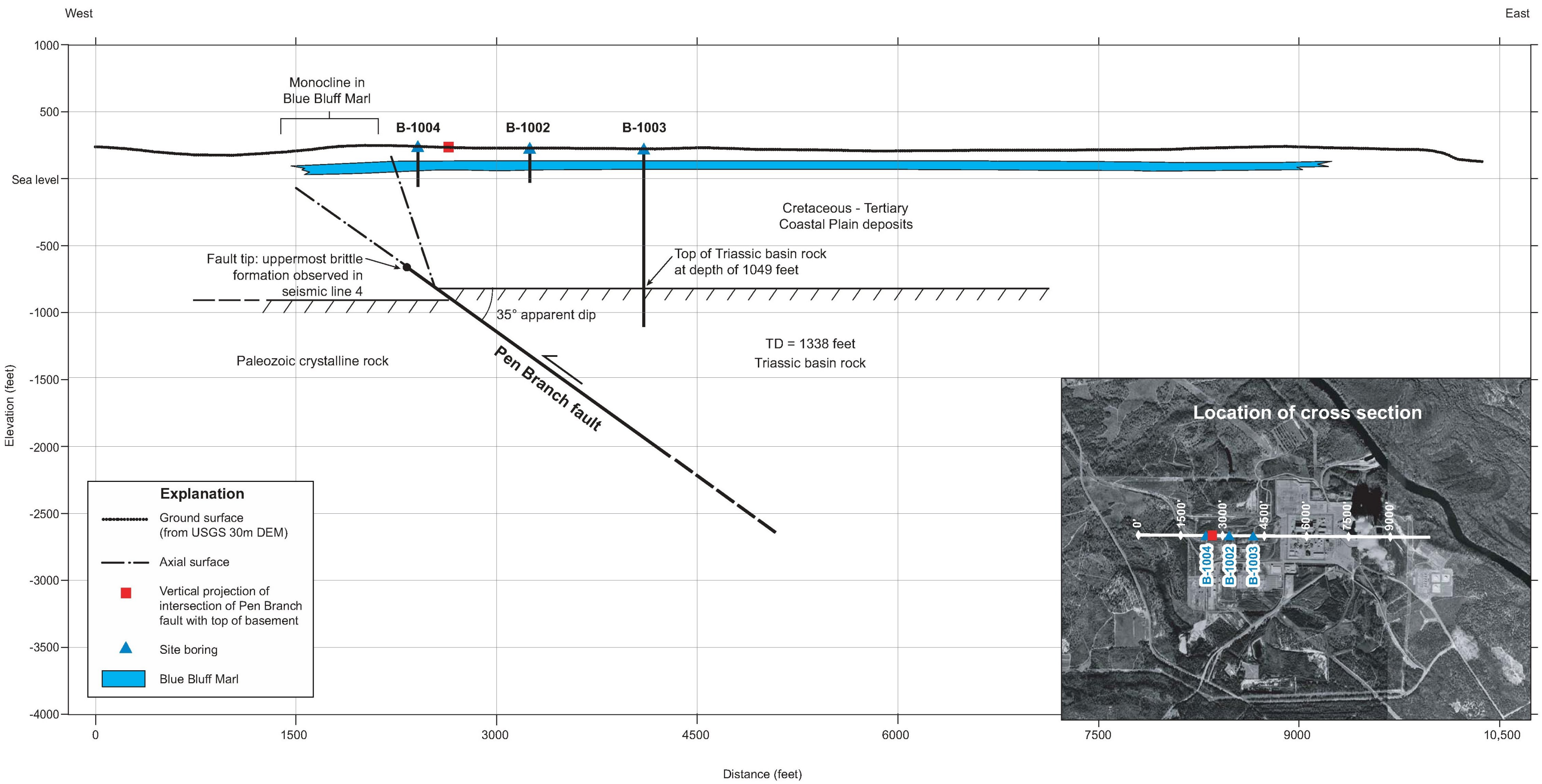
- **Pen Branch Fault**
  - ~25 mi. total length, strikes N46-66E, dips 60-75SE
  - Exhibits no expression of surface displacement
  - Exhibits no seismic activity

2.5.1 Basic Geologic & Seismic Information



The Pen Branch Fault extends beneath the ESP site based on subsurface geophysical data

2.5.1 Basic Geologic & Seismic Information



E-W Cross Section: Pen Branch Fault beneath VEGP site

- **Pen Branch Fault (Cont'd)**
  - No stratigraphic evidence of fault movement < 33.7 my old (post-Eocene)
  - Applicant evaluated Savannah River terraces for evidence of local fault displacement during the past 1.8 my (Quaternary)
    - Field evidence indicates that the Pen Branch is not a capable fault

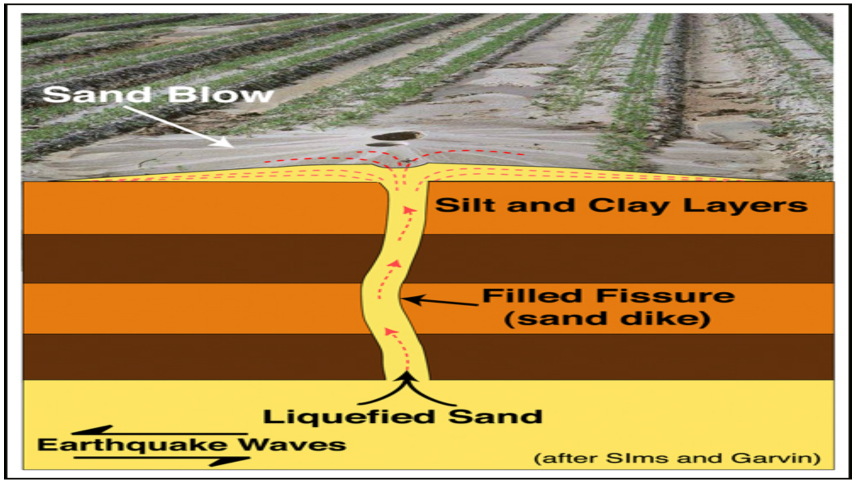
Quaternary Terrace Surface Overlying the Pen Branch Fault at the SRS

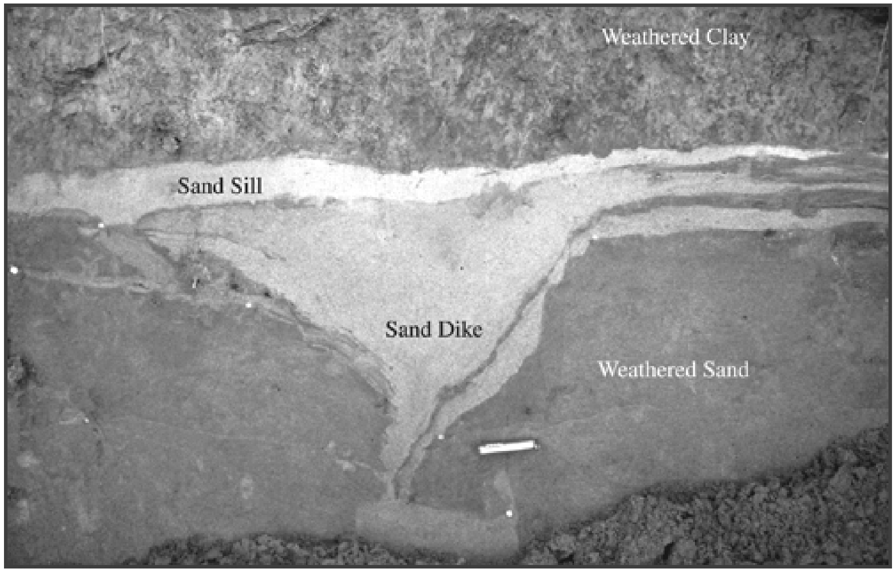
2.5.2 Vibratory Ground Motion

- **UPDATED Charleston Seismic Source Zone**
  - Applicant's update of the 1986 EPRI source model involved significant changes in geometry, and maximum magnitudes (M_{max}), and recurrence interval
  - Average recurrence interval of M_{max} earthquakes decreased significantly, increasing the overall hazard
  - Update based on liquefaction features from historic and prehistoric earthquakes

Liquefaction

- Liquefaction features occur in response to strong ground shaking
- Liquefaction susceptibility is a function of site characteristics
- Liquefaction features commonly occur in the form of sand blows





- **Charleston Liquefaction Features**
  - Abundant liquefaction features from historic and prehistoric earthquakes were mapped for ~130mi. NE-SW along the South Carolina coast and >65mi. inland from coast
  - Paleoliquefaction features formed during prehistoric earthquakes

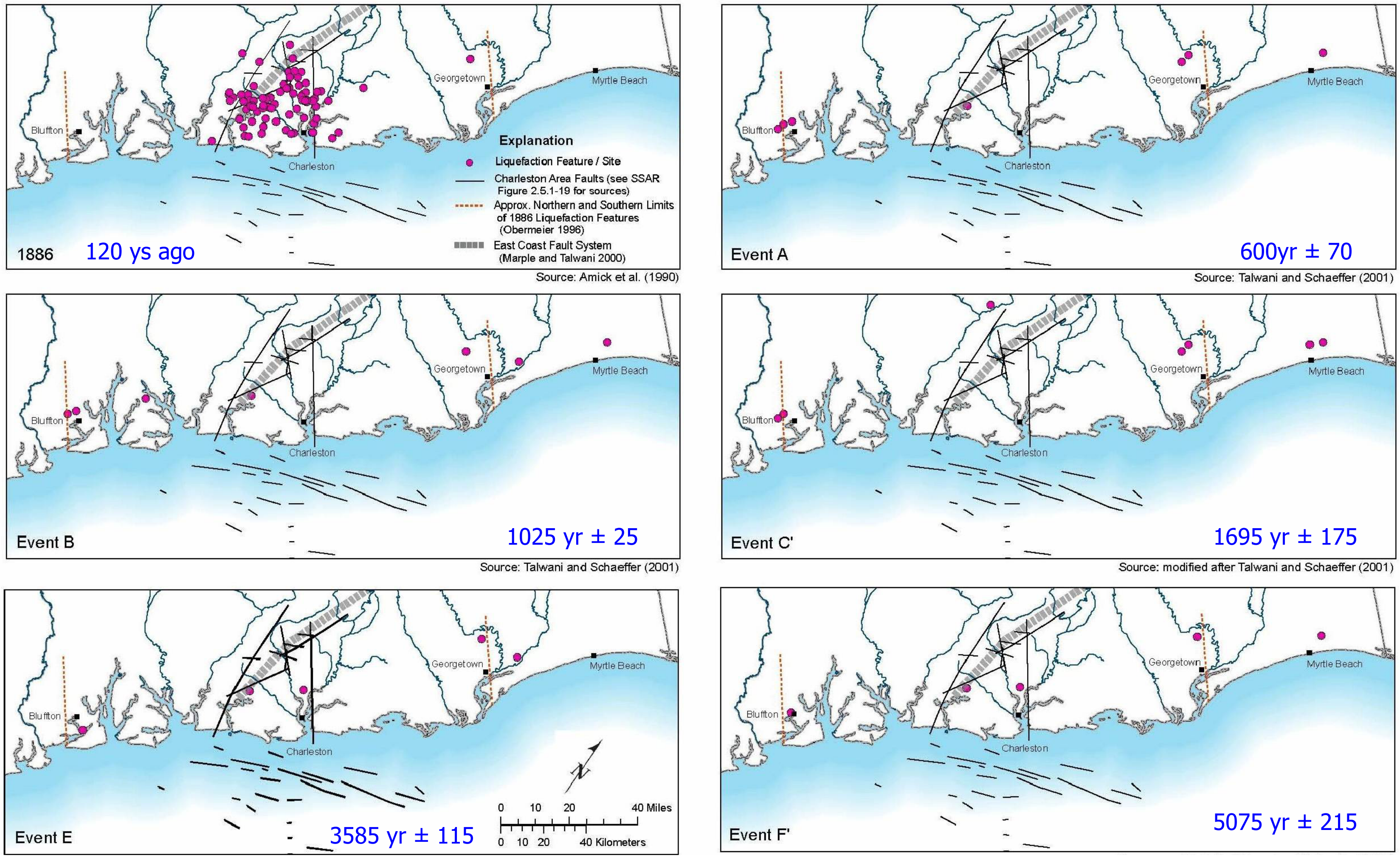
2.5.2 Vibratory Ground Motion

Illustrations of historic 1886 liquefaction features from the Charleston Area

Charleston Paleoliquefaction Features

- Paleoliquefaction features, documented since the 1989 EPRI study, contributed to the update of the Charleston source zone
- Liquefaction features represent 5 similar magnitude earthquakes (in addition to 1886) during the past ~5000 years
- Estimated repeat times for large earthquakes in the Charleston area:
  - 500-600 years, based on a complete 2,000 yr history
  - 900-1000 yrs, based on a complete 5,000 yr history

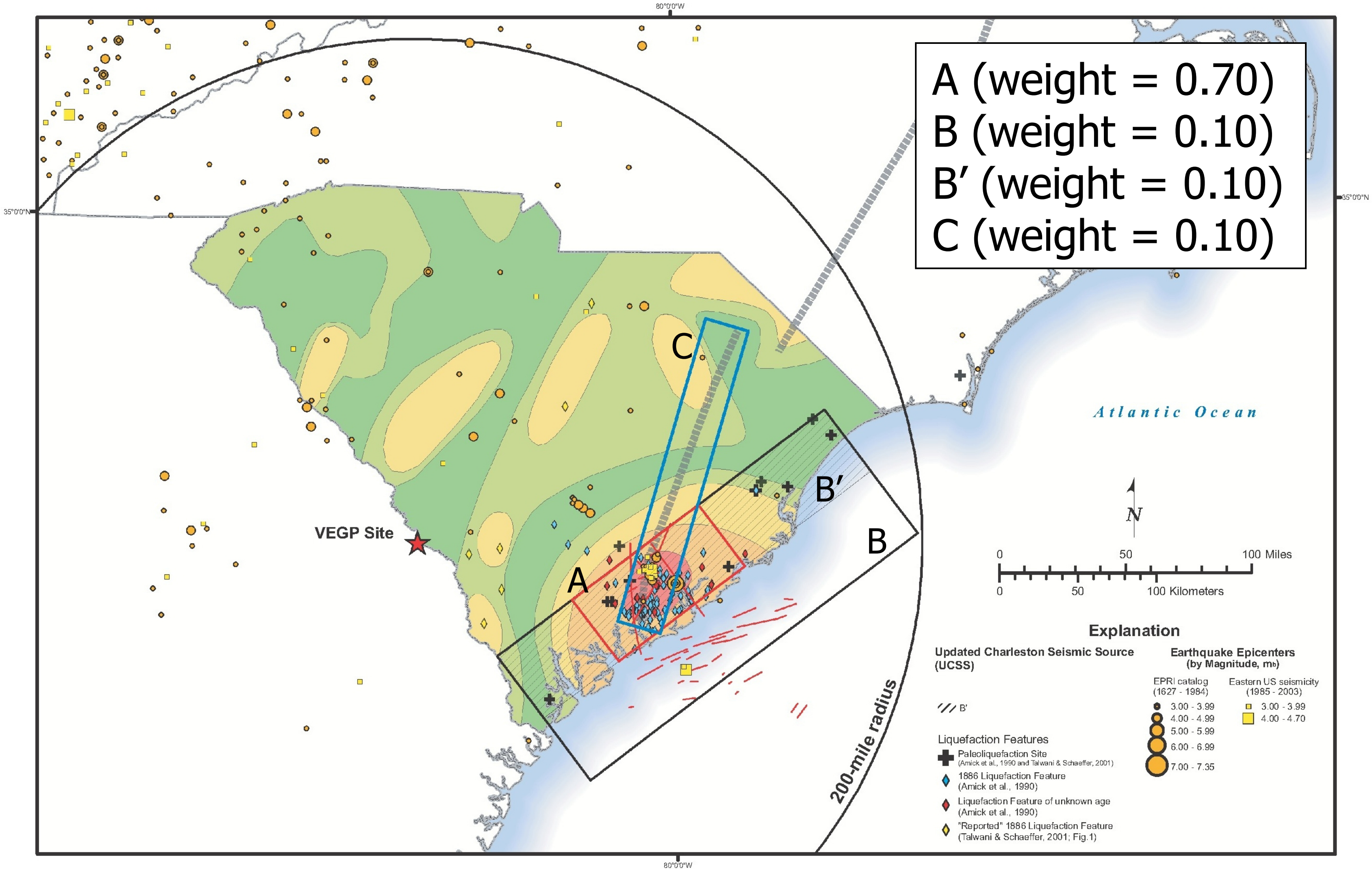
2.5.2 Vibratory Ground Motion



Distribution of Charleston Source Paleoliquefaction Features

- **Charleston Paleoliquefaction (Cont'd) (OI 2.5-5)**
  - NRC Staff concluded that the applicant did not provide sufficient paleoliquefaction evidence to rule out the occurrence of large inland earthquakes (OI 2.5-5)
  - The occurrence of a large earthquake, inland from the coast, may necessitate a different Charleston source zone model

2.5.2 Vibratory Ground Motion



Updated Charleston Seismic Source

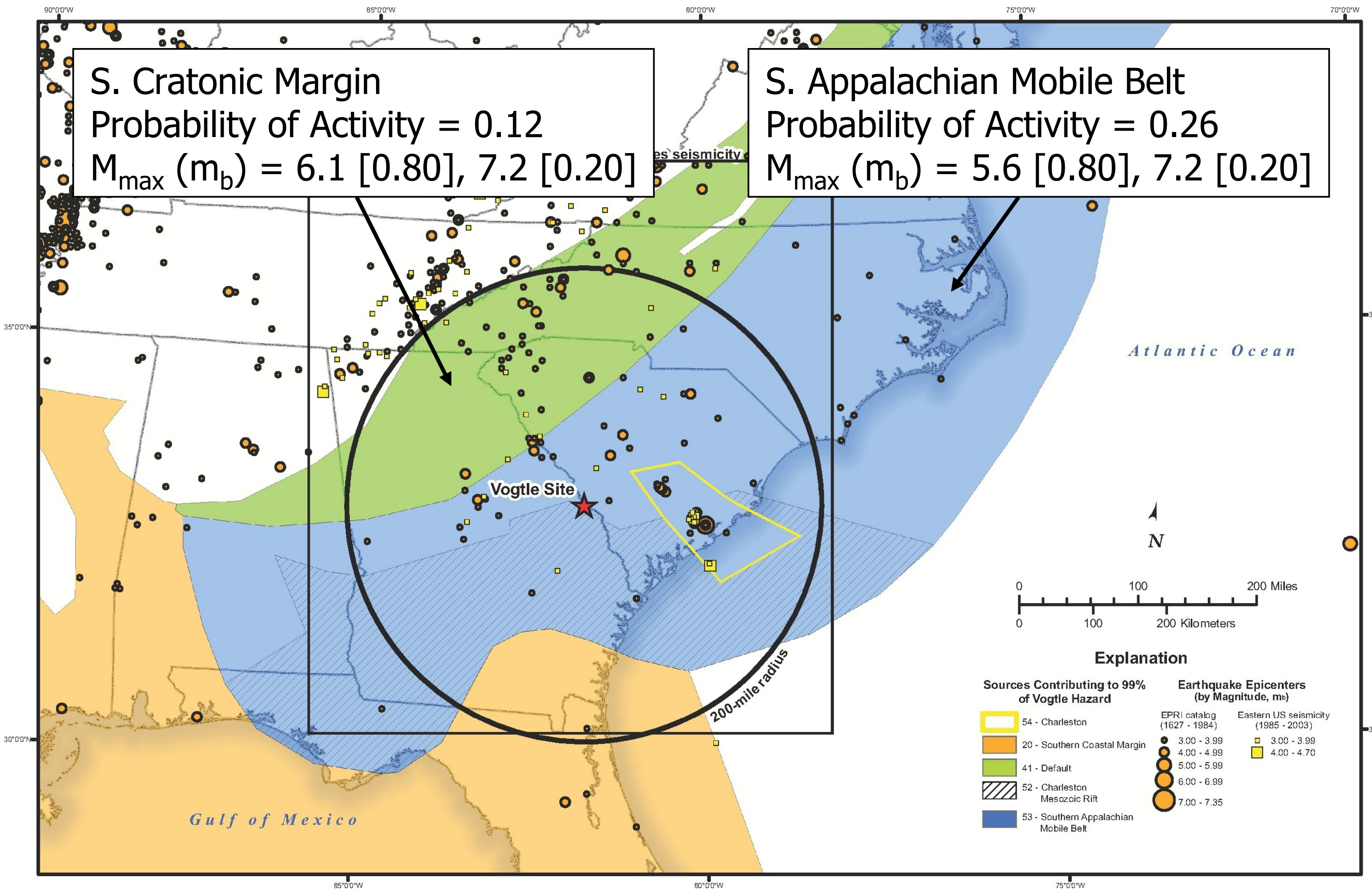
- **Charleston Seismic Source Update (OI 2.5-4)**
  - Applicant used a Senior Seismic Hazard Analysis Committee (SSHAC) Level 2 process to perform the update
    - Designated Technical Integrator (TI) responsible for conducting literature review and contacting appropriate experts
    - TI also responsible for integrating current literature and expert's views into final model
  - Staff requested additional details regarding expert elicitation process (RAI 2.5.2-4)
    - Questions asked of the expert's and their responses
    - Process used to combine the expert's responses
  - Staff has not yet completed its review of this information (OI 2.5-4)

2.5.2 Vibratory Ground Motion

- **The applicant did not update the following EPRI seismic source zones**
  - Regional seismic source zones that encompass the ESP site (OI 2.5-1)
  - Eastern Tennessee seismic zone (ETSZ) (OI 2.5-3)

- **Regional Seismic Source Zone M_{max} and Probability of Activity (OI 2.5-1)**
  - EPRI seismic source zones were determined by six Earth Science Teams during the 1980s
    - Dames and Moore team assigned low weights for larger M_{max} values (and low probabilities of activity) to two of their regional source zones
  - Resulting Dames and Moore hazard curves for the ESP site do not adequately characterize the regional hazard

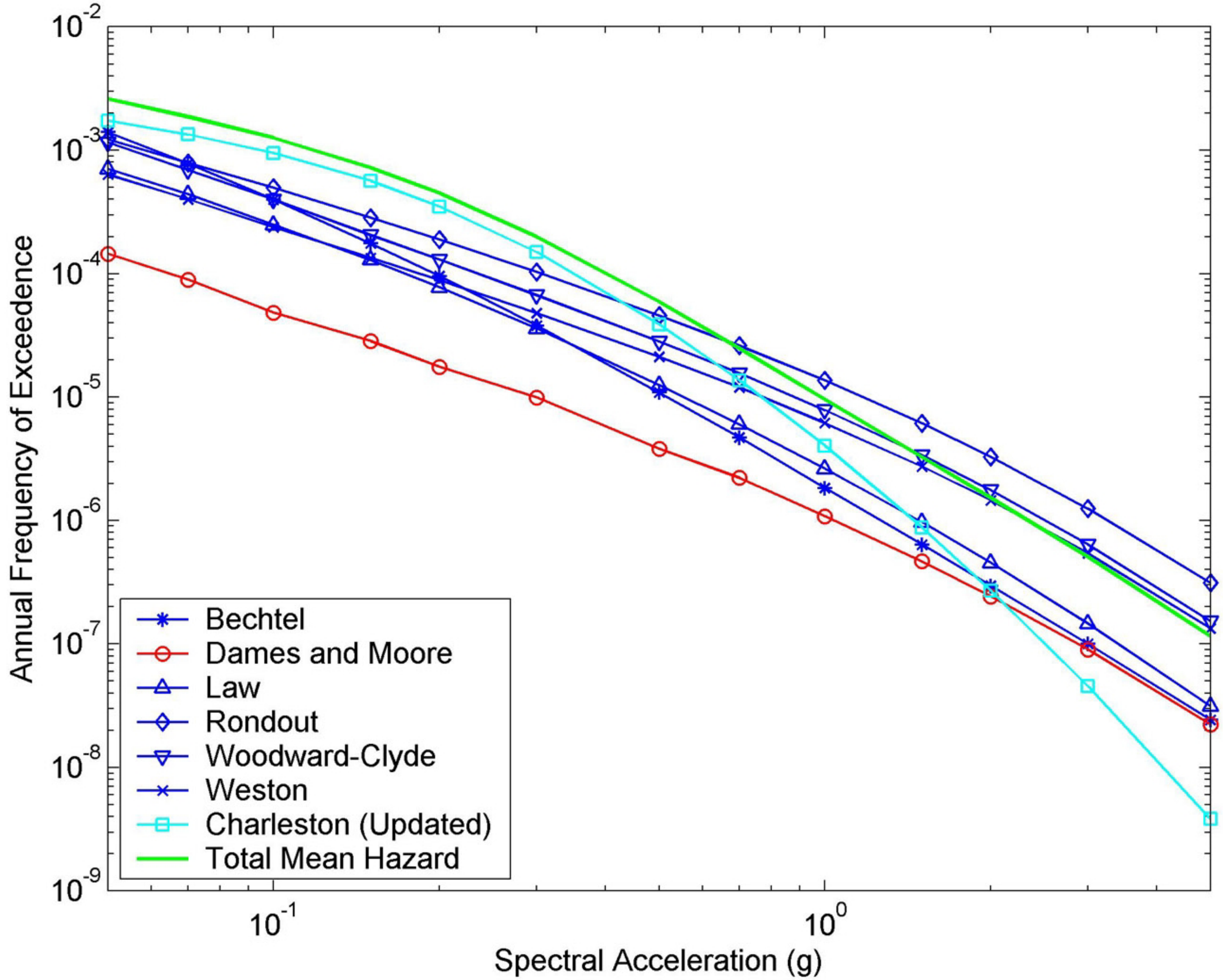
2.5.2 Vibratory Ground Motion



Dames and Moore EPRI Zones

2.5.2 Vibratory Ground Motion

10-Hz Total Mean Hazard Curve



- **Additional Information Related to the Low Probabilities of Activity Assigned to Regional Seismic Source Zones by the Dames and Moore EPRI team**
  - (DOE-STD-1024-92) "*Risk Engineering, Inc. has also found that the EPRI team of Dames and Moore does not fully account for historic seismicity near the Savannah River Site (SRS). One reason for this is the fact that the SRS host source zone was given a low probability of activity. Risk Engineering, Inc. recommended that the Dames and Moore seismic source input not be used to calculate the seismic hazard at SRS*"

- **Eastern Tennessee Seismic Zone M_{max} (OI 2.5-3)**
  - Applicant concluded no new information has been developed since 1986 that would require significant revision to the EPRI seismic source model.
  - Staff concludes more recent studies suggest significant revisions to the EPRI seismic source model are warranted.
    - Analyses of earthquake focal mechanisms and hypocenter locations (Chapman et al., 1997; Dunn and Chapman, 2005) indicate a series of northeast-trending basement faults, intersected by several east-trending faults
      - Inferred fault lengths (~20-50 km) large enough to produce significant earthquakes (~M_w 7+)

- **Eastern Tennessee Seismic Zone M_{max} (OI 2.5-3) (Cont'd)**
  - Chapman (2000[1]; 2002[2]) concluded historical record too short to rule out possibility of larger (M>5) earthquakes
  - Mean M_{max} for the 1986 EPRI study (~M_w 6.2) is significantly lower than more recent mean M_{max} values, which range from M_w 6.3 to M_w 7.5
  - Staff concludes that the applicant has not:
    - Adequately justified decision to not update ETSZ
    - Performed sensitivity analysis to determine impact of updating ETSZ

[1]USGS CEUS hazard mapping workshop notes, June 13-14, 2000, Saint Louis University
[2]TIP report (NUREG/CR-6607)

- **Post EPRI PSHA Studies (OI 2.5-2)**
  - The applicant described three post EPRI PSHA studies, which involved the characterization of seismic sources within the ESP site region: USGS, 2002; SCDOT, 2002; NRC TIP Study (NUREG/CR-6607)
  - The applicant dismissed the TIP study because it focused on the implementation of the SSHAC PSHA methodology
  - The staff believes that much of the data and results contained in the report may be applicable to the ESP site.

2.5.3 Surface Faulting

- **Injected sand dikes (Open Item 2.5-10)**
  - Stratigraphic information suggests dikes may be as young as 1.8 my to 10,000 yrs (Pleistocene age)
  - Applicant did not clearly show dikes are spatially related to dissolution depressions
  - Fluid/plastic injection of sand could be associated with seismicity and liquefaction
  - Detailed description of dike characteristics and spatial associations is necessary

2.5.4 Stability of Subsurface Materials and Foundations

- **12 Open Items on the subsurface materials**
  - Static properties
  - Dynamic properties

2.5.4 Stability of Subsurface Materials and Foundations

- Applicant performed limited borings and tests to characterize static properties of the load-bearing layers (Open items 2.5-11-17)
  - 14 total borings were performed at the site
  - 3 of the 14 penetrated through the Blue Bluff Marl
  - Limited soil samples were obtained and lab tested
- Applicant relied on results from VEGP Unit 1 and 2 investigations (1970s) for soil properties such as internal friction angle, unit weight and undrained shear strength

2.5.4 Stability of Subsurface Materials and Foundations

- Applicant did not conduct laboratory tests on soil samples to determine soil dynamic properties (Open Items 2.5-19-20)

- These dynamic properties are needed to determine the site-specific Ground Motion Response Spectra (GMRS)

  - GMRS is equivalent to Safe Shutdown Earthquake (SSE)

  - GMRS is compared to DCD design spectrum at Col stage

2.5.4 Stability of Subsurface Materials and Foundations

- The applicant conducted more explorations and testing on the subsurface materials after submission of the ESP Application
- Additional geotechnical data has been submitted by the applicant as part of LWA-2 (not included here)

- **CONCLUSIONS**
  - **2.5.1**
    - The Pen Branch fault extends beneath the ESP site but is not considered a capable fault
  - **2.5.2**
    - Applicant updated the Charleston Seismic source based on paleoliquefaction data
    - Applicant chose not to update local seismic source zones or ETSZ

- CONCLUSIONS
  - **2.5.3**
    - Additional description of injected sand dikes is necessary to complete staff review
  - **2.5.4**
    - Additional static and dynamic testing, borings and field and laboratory tests are necessary to complete staff review

BACKUP SLIDES

BACKUP SLIDES

2.5.2 Vibratory Ground Motion

- **OI 2.5-1** Local seismic source zone M_{max} and probability of activity
- **OI 2.5-2** Consideration of the TIP Study
- **OI 2.5-3** Eastern Tennessee seismic zone M_{max} and probability of activity
- **OI 2.5-4** SSHAC Level 2 update of the Charleston source model
- **OI 2.5-5** Occurrence of large inland earthquakes

BACKUP SLIDES

2.5.2 Vibratory Ground Motion

- **OI 2.5-6** Clarification steps to determine soil UHRS from site response results
- **OI 2.5-7** Suitability of equivalent-linear approach for site response
- **OI 2.5-8** Verification of horizontal GMRS-seismic hazard curves
- **OI 2.5-9** Development of V/H ratios for vertical GMRS

2.5.3 Surface Faulting

- **OI 2.5-10** Deformation features- description of (non-tectonic) injected sand dikes

2.5.4 Stability of Subsurface Materials and Foundations

- **OI 2.5-11** Conduct sufficient field & laboratory tests to reliably determine subsurface soil static & dynamic properties at the ESP site

- **OI 2.5-12** Provide sufficient data to derive reliable site-specific engineering parameters for the load-bearing layer (Blue Bluff Marl)

- **OI 2.5-13** Provide sufficient sampling and testing results to reliably derive the undrained shear strength and other related engineering parameters

- **OI 2.5-14** Provide reliable effective angles of internal friction for the subsurface soils

2.5.4 Stability of Subsurface Materials and Foundations

- **OI 2.5-15** Provide information to demonstrate that the Blue Bluff Marl will behave as a hard clay or soft rock material
- **OI 2.5-16** Provide sufficient site-specific data to justify the determination of the design parameter elastic modulus “E” for the Upper and Lower Sand Strata
- **OI 2.5-17** Develop sufficient data (vs. values from previous investigations) to calculate the unit weight values for the ESP subsurface soils
- **OI 2.5-18** Provide sufficient shear wave velocity measurements to define the site-specific shear wave velocity profile

2.5.4 Stability of Subsurface Materials and Foundations

- **OI 2.5-19** Provide site-specific soil degradation and damping ratio curves for the site-specific soil amplification calculation

- **OI 2.5-20** Revise SSAR Sections 2.5.2.5.1.5, 2.5.4.7.2.1, and 2.5.4.7.2.2, along with associated tables and figures, to show the degradation curves only at a ≤1% cyclic shear strain

- **OI 2.5-21** Provide sufficient ESP soil property data to confirm that the Blue Bluff Marl is non-liquefiable

- **OI 2.5-22** Provide appropriate bearing capacity estimates

2.5.4 Stability of Subsurface Materials and Foundations

- **Permit Condition 2 2.5.4**
  - The NRC staff proposes to include a condition in any ESP that might be issued in connection with this application requiring the ESP holder or an applicant referencing such an ESP perform geologic mapping of future excavations for safety-related structures, evaluate any unforseen geologic features that are encountered, and notify NRC no later than 30 days before any excavations for safety-related structures are open for NRC staff's examination and evaluation.

2.5.4 Stability of Subsurface Materials and Foundations

- **COL Action items**
  - 2.5-1 A COL or CP applicant will need to confirm the absence of soft materials in the load bearing layers.
  - 2.5-2 A COL or CP applicant will need to confirm the locations of the soft zones and evaluate the potential impact of the soft zones on the foundation and structures.
  - 2.5-3 A COL or CP applicant will need to provide chemical test results on the backfill.

2.5.4 Stability of Subsurface Materials and Foundations

- **COL Action items**
  - 2.5-4 A COL or CP applicant will need to submit plot plans and profiles of all seismic Category I facilities for comparison with the subsurface profile and material properties.
  - 2.5-5 A COL or CP applicant will need to provide detailed excavation and backfill plans during the COL stage.
  - 2.5-6 A COL or CP applicant will need to provide sufficient information to show the backfills meet the minimum shear wave requirement.

2.5.4 Stability of Subsurface Materials and Foundations

- **COL Action items**

  - 2.5-7 A COL or CP applicant will need to submit ground water condition evaluations and a detailed dewatering plan during the COL stage.

  - 2.5-8 A COL or CP applicant will need to demonstrate quantitatively whether the observed large settlement that occurred at the existing VEGP units will occur at the ESP site and have no impact on the new units.

  - 2.5-9 A COL or CP applicant will need to provide more details regarding the bearing capacity during the COL stage.

2.5.4 Stability of Subsurface Materials and Foundations

- **COL Action items**
  - 2.5-10 A COL or CP applicant will need to describe the design criteria and design methods, including the factor of safety for slope stability at the COL stage.
  - 2.5-11 A COL or CP applicant will need to provide information regarding ground improvement after removal of Upper Sand Stratum for the ESP site.
  - 2.5-12 A COL or CP applicant will need to provide a detailed slope stability analysis for permanent slopes at the ESP site.