UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, DC 20555 - 0001

March 27, 2019

MEMORANDUM TO: ACRS Members

FROM: Quynh Nguyen, Senior Staff Engineer ***/RA/***
Technical Support Branch, ACRS

SUBJECT: CERTIFIED MINUTES OF THE ACRS REGULATORY POLICIES AND PRACTICES SUBCOMMITTEE MEETING ON OCTOBER 17, 2018

The minutes of the subject meeting were certified on February 27, 2019, as the official record of the proceedings of that meeting. Copies of the certification letter and minutes are attached.

Attachments: As stated

cc w/ att. A. Veil
L. Burkhart

UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, DC 20555 - 0001

MEMORANDUM TO: Quynh Nguyen, Senior Staff Engineer
Technical Support Branch, ACRS

FROM: Walter Kirchner, Chairman
Regulatory Policies and Practices Subcommittee

SUBJECT**:** CERTIFICATION OF THE MINUTES OF THE REGULATORY POLICIES AND PRACTICES SUBCOMMITTEE MEETING ON OCTOBER 17, 2018

I hereby certify, to the best of my knowledge and belief, that the minutes of the subject meeting are an accurate record of the proceedings for that meeting.

**/RA/** **February 27, 2019**

Walter Kirchner, Chairman
Regulatory Policies and
Practices Subcommittee

Dated

Certified on:  February 27, 2019
Certified by:  Walter Kirchner

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
MINUTES OF THE REGULATORY POLICIES & PRACTICES SUBCOMMITTEE MEETING
October 17, 2018

The ACRS Regulatory Policies & Practices Subcommittee held a meeting on October 17, 2018 in 3WFN 1C3 & 1C5, 111601 Landsdown Street, North Bethesda, Maryland.  The meeting convened at 1:00 PM and adjourned at 3:51 PM.

The entire meeting was open to the public.

No written comments or requests for time to make oral statements were received from members of the public related to this meeting.

ATTENDEES

ACRS Members/Consultants/Staff

WALTER L. KIRCHNER, Chairman
DENNIS C. BLEY*, Member
RONALD G. BALLINGER, Member
MICHAEL L. CORRADINI, Member
MATTHEW W. SUNSERI, Member
QUYNH NGUYEN, Designated Federal Official
CHARLES H. BROWN, JR., Member
MARGARET CHU, Member
PETER RICCARDELLA, Member
HAROLD B. RAY, Member

*via telephone

Other Participants:

ALLEN FETTER, NRO
DAVID HEESZEL, NRO
GERRY STIREWALT, NRO
LUISSETTE CANDELARIO, NRO
KEVIN CASEY, TVA
REBECCA CARR, Bechtel
JANET SOWERS, Fugro
KEVIN CLAHAN, LCI
KIMBERLY HUMMER, Bechtel
WEIJUN WANG, NRO
ANDY CAMPBELL, NRO
JENISE THOMPSON, NRO

RAYMOND SCHIELE, TVA
DANIEL STOUT, TVA
MALLECIA SUTTON, NRO
SCOTT WEBBER, NuScale
WALTER JUSTICE, TVA
ZUHAN XI, NRO
TIM BEVILLE, DOE
MELISSA BATES, DOE
CLIFF MUNSON, NRO

SUMMARY

The purpose of this meeting is the review of the following sections: Geologic Characterization & Surface Deformation (2.5.1 & 2.5.3); Vibratory Ground Motion (2.5.2); and Stability of Subsurface Materials and Foundations & Stability of Slopes (2.5.4 & 2.5.5) of Tennessee Valley Authority's (TVA) Clinch River Early Site Permit (ESP) application. The meeting transcripts are attached and contain an accurate description of each matter discussed during the meeting. The presentation slides and handouts used during the meeting are attached to these transcripts.

| SIGNIFICANT ISSUES | |
|---|---|
| Issue | Reference Pages in Transcript |
| Mr. Justice stated that the only geological hazards are karst formations. Member Corradini asked if the age of a fracture can be determined (24). Ms. Sowers spoke specifically about karsts (27). She stated that karst formations would be essentially static for the lifetime of the plant (31) and shared her conclusions (32). Mr. Wong talks about the 1D and 2D ground site response analysis models (48). Tectonic deformation is negligible (54, 97). | 11 |
| Member Sunseri asked if the individual karst formations can be "united" by seismic activity to cause problems. | 51 |
| Member Brown questioned the relationship between deformation and observed seismicity which was addressed during the vibratory ground motion discussion. | 87, 102 |
| In response to Member Corradini's question, site remedies would occur during the COL (combined operating license) stage. | 94 |

Documents provided to the Subcommittee

REFERENCES:

1. Safety Evaluation, Geologic Characterization & Surface Deformation (2.5.1 & 2.5.3) (**ML17289B252, ML17289B254**)
2. Safety Evaluation, Vibratory Ground Motion (2.5.2) (**ML17289B253**)
3. Safety Evaluation, Stability of Subsurface Materials and Foundations & Stability of Slopes (2.5.4 & 2.5.5) (**ML17289B255**)

# Official Transcript of Proceedings

# NUCLEAR REGULATORY COMMISSION

| | |
|---|---|
| Title: | Advisory Committee on Reactor Safeguards<br>Regulatory Policies and Practices |
| Docket Number: | (n/a) |
| Location: | Rockville, Maryland |
| Date: | Wednesday, October 17, 2018 |
| Work Order No.: | NRC-3931 Pages 1-130 |

**NEAL R. GROSS AND CO., INC.**
**Court Reporters and Transcribers**
**1323 Rhode Island Avenue, N.W.**
**Washington, D.C. 20005**
**(202) 234-4433**

UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

+ + + + +

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

+ + + + +

REGULATORY POLICIES AND PRACTICES SUBCOMMITTEE

+ + + + +

WEDNESDAY

OCTOBER 17, 2018

+ + + + +

ROCKVILLE, MARYLAND

+ + + + +

The Subcommittee met at the Nuclear Regulatory Commission, Three White Flint North, Room 1C3 & 1C5, 11601 Landsdown Street, at 1:00 p.m., Walter Kirchner, Chairman, presiding.

COMMITTEE MEMBERS:

WALTER KIRCHNER, Chairman
MICHAEL L. CORRADINI, Member
RONALD G. BALLINGER, Member
DENNIS C. BLEY, Member*
CHARLES H. BROWN, JR., Member
MARGARET SZE-TAI Y. CHU, Member
PETER RICCARDELLA, Member
HAROLD B. RAY , Member
MATTHEW SUNSERI, Member

DESIGNATED FEDERAL OFFICIAL:

QUYNH NGUYEN

*Present via telephone

C-O-N-T-E-N-T-S

P R O C E E D I N G S

12:59 p.m.

CHAIRMAN KIRCHNER: Good afternoon. You need a click to go. Okay, the meeting will now come to order. This is a meeting of the Regulatory Policies and Practices Subcommittee of the Advisory Committee on Reactor Safeguards. I am Walt Kirchner, Chairman of this Subcommittee meeting.

ACRS members in the room are, I have to take my glasses off, Charles Brown, Ron Ballinger, Harold Ray, Matt Sunseri, Pete Riccardella, Mike Corradini, and Margaret Chu. And I believe we're expecting Vesna Dimitrijevic. And also I think we have Dennis Bley on the line.

Quynh Nguyen of the ACRS staff is the Designated Federal Official for this meeting. This turns out to be the fourth meeting of this subcommittee on the topic. Today, the Subcommittee will hear from representatives of TDA and the staff regarding the following sections of the Clinch River early site permit application and the corresponding safety evaluation: geological characterization and surface deformation, 2.5.1 and 2.5.3; a vibratory ground motion, 2.5.2; and stability of subsurface materials and foundations and stabilities of slopes, that's 2.54 and 2.5.5.

The Subcommittee will gather information, analyze relevant issues and facts, and formulate proposed positions and actions as appropriate for deliberation by the full Committee.

The ACRS was established by statute and is governed by the Federal Advisory Committee Act, FACA. This means that the Committee can only speak through its published letter reports. We hold meetings to gather information to support our deliberations. Interested parties who wish to provide comments can contact our offices requesting time after the meeting announcement is published in the Federal Register.

That said, we also set aside some time for spur of the moment comments from members of the public attending or listening to our meetings. Written comments are also welcome. In regard to early site permits, 10 CFR 52.23 provides that the Commission shall refer a copy of the application to the ACRS, and the Committee shall report on those portions which concern safety.

The ACRS section of the US NRC public website provides our charter, bylaws, letter reports, and full transcripts of all full and Subcommittee meetings, including slides presented at the meetings.

The rules for participation in today's meeting were previously announced in the Federal Register. We have received no written comments or requests for time to make oral statements from members of the public regarding today's meeting.

We have a bridge line established for interested members of the public to listen in. To preclude interruption of the meeting, the phone bridge will be placed in a listen-in mode during the presentations and Committee discussions. We will unmute the bridge line at a designated time to afford the public an opportunity to make a statement or provide comments.

At this time, I request that meeting attendees and participants silence their cellphones and any other electronic devices that are audible. A transcript of the meeting is being kept and will be made available as stated in the Federal Register notice. Therefore, we request that participants in this meeting use the microphones located throughout the meeting room when addressing the Subcommittee.

The participants should first identify themselves and speak with sufficient clarity and volume so that they may be readily heard. Make sure that the green light of the microphone is on before speaking, and off when not in use.

We will now proceed with the meeting, and I call upon Andy Campbell of NRO to begin. Andy.

MR. CAMPBELL: Good afternoon, my name is Andy Campbell, I'm the Deputy Director for the Division of Licensing, Siting, and Environmental Analysis in the Office of New Reactors. With me today are a number of staff from DLSC involved in this project, Alan Fetter, Mallecia Sutton, Garry Stirewalt, Jenise Thompson, David Heeszel, Luissette Candelario, Weijun Wang.

And I will let the TVA folks introduce themselves.

So this is the third of four Subcommittee meetings for the staff evaluation, the safety evaluation, with no open items. Let me repeat that, we have no open items.

First, ESP from an SMR plant design, the review has been proceeding as scheduled, and you'll hear today about the geology and ground information aspects of that safety evaluation. We look forward to continued fruitful dialog with the Advisory Committee on Reactor Safeguards as this ESP review continues moving forward.

And the last and final Subcommittee will be November 14, I believe. And so with the full Committee of the Advisory Committee on Reactor Safeguards scheduled for December 5.

And so with that full Committee meeting and any letter the Committee wishes to write, we would be closing out Phase C of our review. So with that, I'll turn it back to you. I want to thank everyone and thank the staff and thank TVA for coming in and supporting this review.

CHAIRMAN KIRCHNER: Thank you, Andy. So we'll turn to TVA. Ray, are you going to make the introductions, or is Wally? Go ahead, Ray.

MR. SCHIELE: Good afternoon, my name is Ray Schiele and I'm the Licensing Manager for the Clinch River early site permit application. I have over 44 years in the nuclear industry, including United States Navy, plant operations, and licensing.

TVA would like to thank Chairman Kirchner and the rest of the Subcommittee for their support in the review of this early site permit application.

This slide is an acknowledgment of the relationship between DOE and TVA and the associated responsibilities of that relationship.

Overview of TVA's mission. TVA's mission includes partnering with over 154 local power companies serving more than nine million people in a service area that covers seven states. TVA directly serves over 54 large industries and federal installations.

This slide is a review of our schedule thus far. The first section here we're going to talk about is the safety review. Today's meeting is the fourth of five planned Subcommittee meetings. Previous meetings included an overview of the project, sections on geography, tomography, aircraft hazards, radiological consequences of design-based accidents, emergency planning, and EPZ sizing.

Today, TVA will be presenting Section 2.5, geology, seismology, and geotechnical engineering. The final Subcommittee meeting, scheduled for November 14, will cover Sections 2-3, meteorology; 2-4, hydrology; 11-2 and 11-3, radiological effluent releases; and 17, which is quality assurance.

So as you can see, we're well ahead of the proposed FSER issuance of August of '17. The Environmental Review was issued, the DEIS was issued five weeks early. The NRC is on or ahead of the published schedule for the review and disposition of DEIS comments. TVA is looking forward to an early issuance of the FEIS. And this is the basic Gantt chart for the Environmental Review.

The hearing. In July of 2018, the ASLB dismissed the last remained admitted contention, rejecting two new proposed contentions, and terminated the contested hearing. And this is a, just a Gantt timeline of the hearing schedule.

This slide illustrates the NRC and reactions related to the ESPA SSAR Section 2.5. The first pre-application audit was held in July of 2015 with eight NRC staff and resulted in the identification of 68 issues that require resolution prior to application submittal. In January of 2016, there was a public meeting to discuss the disposition of those issues identified in the readiness assessment.

The second audit was held in May of 2017 to review geology, seismology, geotechnical information in the application. The audits focused specifically on geological information, vibratory ground motion, and geotechnical engineering information. It included a site, a vicinity tour of geologic features and a review of core samples.

This audit identified six specific areas where supplemental information was requested. Additionally, an NRC management and geology visit was conducted in January of 2018.

I'd like now to introduce the presenters for today's discussion. Wally Justice, who'll be assisted by both Kevin Clahan and Janet Sowers. Wally.

MR. JUSTICE: Thank you, Ray. Turn to Slide 8, please. My name is Wally Justice, and I'm a mechanical engineer with 36 years of experience in the United States nuclear industry. In the commercial side, including design, construction, and operation of nuclear power plants. The last several years I had been involved in the small modular reactor technology sector, in addition to working on COLAs and ESPAs.

Today I'm going to give you a high level overview of the geological investigations and results provided in early site permit application for the Clinch River site. From the investigations and analysis, you will learn that the only identified geological hazard for the site is karst formations. We will have detailed discussion on the subject later in the presentation.

The site directly adjoins the Oak Ridge Reservation, and if you look to the right on the slide, you will see the Clinch River site, bounded by the Clinch River itself as it goes around. It looks like a small foot.

For Section 2.5.1, TVA followed the requirements of 10 CFR 100.23(c). The information was developed in accordance with the NRC guidance documents per Reg Guide 1.206, and NUREG-0800 standard review plans for the review of safety analysis reports for nuclear power plants was followed to produce Section 2.5.1. Next slide, please.

The overall geological profile for the Clinch River site area is best explained by understanding of the regional geology and relationship to the eastern United States. A total of six physiographic provinces lie within the 320 kilometer, or 200 mile, radius of the site location. The site is located in the Valley and Ridge Province, with the Appalachian Plateau Province to the west and the Blue Ridge Province to the east. Next slide.

Drilling down from the regional view of 200 miles to the five-mile site radius from the center, the local ridges and valleys are presented in the figure. The 0.6 mile site location, also known as the one kilometer mile location, is located in the center of the figure.

As shown on the 200-mile radius map, the site lies within the regional stratigraphy associated with the Valley and Ridge Province of folded and faulted carbonate rocks. This consists predominantly of a sequence of Paleozoic sedimentary rocks ranging in age from Lower Cambrian to Pennsylvania, approximately 541 to 323 million years ago.

And this slide will reappear in today's presentation in two more instances because it contains useful information related to many of today's topics. This slide represents a one-mile cross-section of the Clinch River site. At the top of the slide, and it may be easier to see on your handouts, but you have Site A, also noted here as, excuse me, Site B, also noted as Location B, and Site, or Location A.

We'll be talking today about two faults, the Chestnut Ridge fault and the Copper Creek fault. You will also notice that these are the various rock formations that lie underneath the Clinch River site area. We're on a 33 degree dipping stratigraphy to the southeast, and the borings that are associated with this cross-section are located in their location of drilling, and the depths are presented.

CHAIRMAN KIRCHNER: Wally, would you just point out where the CRBR site was relative to A and B.

MR. JUSTICE: So I have a slide in a couple slides that will help you understand this a little better, but the old Clinch River Breeder Reactor excavation is actually located in the same rock formation as the Site B. And it would be out from the face of the slide you're looking at. That'll make a little more sense here in just a minute.

Now that we have a general idea about the location and the characteristics of the site in region, I would like to discuss some of the methods utilized to investigate and characterize the site, such as field reconnaissance activities.

Again, the previous Clinch River Breeder Reactor data and investigations that were done in the late 70s and early 80s, core borings that were performed, reports done for the Oak Ridge National Laboratory, karst mapping, river terrace mapping, just to name a few.

The picture to the right is actually a picture of the field investigation for the Copper Creek Cave, which is located approximately five miles from the site center to the northeast. Go to the next slide, please.

This slide's a little busy, but it depicts an example of the dates and locations for the field reconnaissance trips to investigate the relevant geological features in the site area. Much of the information I gathered was utilized in subsequent analyses and reports in determining the suitability of the site.

MEMBER CORADINI: Are these new, or is this from the original CRBR?

MR. JUSTICE: These were performed new. These were performed recently, and if you can see on the slide the dates are actually listed. They're just a little hard to see on the actual chart on the screen. That's okay.

We're on Slide 15 now. LiDAR data was taken for the area to ensure complete coverage of the file-mile site area. An example of the results of this effort are located on the right of the slide. The identification of karst depressions, a sink hole, and ground depressions are identified.

For example, Figure D, which is at the bottom right corner, shows close depressions that were identified from the LiDAR investigations.

MEMBER CORADINI: So remind me, these are surface depressions?

MR. JUSTICE: Yes, these would be surface depressions that were identified during the LiDAR investigation.

Okay, this is the core borings for the

Clinch River Breeder Reactor Project. Again, that was in the late 70s and early 80s. And I wanted to present this. It's very busy and hard to read, but you can see this area of a lot of borings. That's the actual excavation area for the Clinch River Breeder Reactor.

If we go to the next slide, this shows right here is the old Clinch River Breeder Reactor footprint. So it is outlined in blue on your slide. Then there's a series of new cores that were performed associated with the current Small Modular Reactor Project. Site B is generally located in the red circle, as is Site A.

And just to help understand the number of borings, 76 rock core borings were performed for the Small Modular Reactor Project in present day. And there were 104 borings that were performed for the original Clinch River Breeder Reactor Project. All of this information was utilized to help us characterize the site for this early site permit application.

MEMBER RAY: Was there any difference in the information provided by the two eras and types of boring used and so on?

MR. JUSTICE: In general, they were very close in agreement with, from one era to the next.

MEMBER RAY: So you didn't have some new technology that enabled you to get more information now than in the past?

MEMBER CORADINI: I think he was talking about old versus new, not A versus B.

MEMBER RAY: No, that's right, yeah.

MR. JUSTICE: That's correct. I understand the question you're asking is the old borings that were performed in the late 70s to support the Breeder, and then the borings that were performed in modern day, today, was there anything, any different or significant from those. And the answer to that is no.

MEMBER RAY: Thank you.

MR. JUSTICE: I would now like to turn --

CHAIRMAN KIRCHNER: Wally, before you go on, just --

MR. JUSTICE: Yes, sir.

CHAIRMAN KIRCHNER: I can't read it here. What's the distance between the center of B and A?

MR. JUSTICE: The center, the distance between B and A is approximately 600 feet.

CHAIRMAN KIRCHNER: Six hundred feet, okay. Two football fields. Is there a preferred site between A or B, or you were just covering all bets?

MR. JUSTICE: For the application, we evaluated two specific locations on the site, specifically because you'll learn that these are in different rock members from a geologic perspective. Based on the technology that TVA may decide to select, you may need more than one location to build one or more plants. So it was decided to do two locations, and at this time there's really not a preferred location associated ---

(Simultaneous Speaking.)

CHAIRMAN KIRCHNER: So there isn't at this point.

MR. JUSTICE: That's correct.

CHAIRMAN KIRCHNER: Thank you.

MR. JUSTICE: So I would now like to turn, or excuse me, to introduce Kevin Clahan from Lettis Consultants International to discuss faults and sheer fracture zones for the next few slides. Kevin.

MR. CLAHAN: All right, thank you, Wally. It's nice to be here. My name is Kevin Clahan and I'm a professional geologist and certified engineering geologist with over 25 years of experience conducting geologic and seismic hazard studies around the world. I've worked for over 12 years now in the nuclear industry evaluating conditions at 11 different proposed or existing nuclear sites, and I've been working on the Clinch River site since 2011.

This slide here, can I borrow a pen? Thank you. So faults are one of the more important aspects of any site evaluation, and the assessment of that faulting. The first step in this evaluation is understanding the bedrock and Quaternary geology.

And so what you see here at the latitude of the Clinch River site, we have a repeated section of interbedded carbonate and shale units that are part of the Rome. You can maybe see better on, oops. The Rome, Conasauga, Knox, and Chickamauga group.

And so you'll see those same patterns here. We have a light tan, green, brown, pink that are repeating. At the boundary of these repeating sections are large scale thrust faults that were active during the late Paleozoic Alleghanian orogeny, which occurred some 320 to 280 million years ago.

And you're going to be hearing the term Alleghanian orogeny, so I just want you to understand that that was the orogeny where the plates Gondwana and Laurentia collided to form Pangaea and close the proto-Atlantic Ocean before it reopened again. So that happened about 300 million years ago.

MEMBER CORADINI: No test, right?

MR. CLAHAN: There's no test after this. So we know that these faults have not become active or have been active in the last 276 million years, and that's due to fault gouge dating by argon-argon on the Copper Creek fault, just to the north, several miles to the north of the site here.

As well as a well-studied dyke system that was emplaced within the Valley and Ridge formation, which offsets these faults. And that dyke system was dated at about 200 million years, so that gives you a minimum age at least for the activity of that faulting.

In addition, what we did is we've mapped Quaternary river terraces upstream and downstream of the site along the Clinch River within the five-mile site radius. So we mapped from approximately here all along up to here, and mapped Quaternary fluvial terraces, plotted those terraces. And then where they projected across these particular faults, looked for any sort of deformation.

Some of these river terraces are on the order of several hundred thousand years old, and we saw no deformation associated with those terraces due to those faults. All right, next slide, please.

So while we're on the topic of faulting, a potentially related feature was described during the excavation of the Breeder Reactor. They referred to this particular feature as a shear zone, and we identified this same feature in our bore hole investigation. The two images here are a cross-section similar to what Wally showed early, our dipping stratigraphic units.

The shear zone, or shear fracture zone as we're referring to it, is in yellow here. And we found it in two locations, and it projects parallel to bedding and with the same dip as well.

The shear fracture zone itself, again, is a bedding parallel feature that's characterized by an abundance of calcite veins, stylolites, which are a result of pressure solution. These are oriented both parallel and perpendicular to bedding, as well as some slick insided fractures.

And what this image on the bottom right is trying to do, and it's difficult to see, but on your handouts, we give examples of those particular features. These black serrated lines here are parallel to bedding stylolites, the white blebs are veins, and then we have some normal, or perpendicular to bedding stylolites as well here. And we'll see some more of that on the next slide as well.

Before we go to the next slide, let's see, I want to mention that these features sometimes truncate each other in ways which support a diagenetic or syndepositional origin, meaning they occurred during deposition and lithification of the rock. And this rock, again, is the Chickamauga group, it's on the order of 500 million years old.

When we see stylolites that are oriented perpendicular to bedding, we associate that with the tectonic overprinting, which I'll show you in the next slide. Again, there's no measurable displacement along this zone, and it is not visible in the ground surface. Okay, next -- oh, and I want to conclude that by saying the breeder reactor PSAR concluded that this feature is a zone of interbed slippage that occurred during the Alleghanian orogeny.

MEMBER CORADINI: So may we have a minute for digression?

MR. CLAHAN: Yeah.

MEMBER CORADINI: You said there's no displacement, so how are you measuring displacement? Because you're looking a long time ago.

MR. CLAHAN: Yes.

MEMBER CORADINI: So displacement means that I'm looking for a difference in the qualitative features of the rock? I'm --

MR. CLAHAN: That's right. No, that's right. If there was a fault, you would see a discernable displacement of like units on either side of that particular feature. Here, we don't see any discernable offset. There's minor microfracturing of things, there's vein, there's pressure dissolution, which sort of skews the margins of contacts, but there's no through going deformation or displacement.

MEMBER CORADINI: But more generally since you're going, I'm going to, you're going to lose me, is it more of a qualitative judgement on your part to look for something?

MR. CLAHAN: No --

MEMBER CORADINI: In other words, if I see a fracture or if I see an opening, the measurement of the opening is not important as much as there's physically an opening that you see of like rock.

MR. CLAHAN: Not necessarily. When you're looking at whether or not there's active faulting or there's faulting in a general area, you're looking for that displacement. So the fracturing and the separation of rock could be completely, something completely different.

MEMBER CORADINI: Okay, but then let me

push the point. So now I see a fracture, so how do I know how old it is? It could be a fracture from 100 million years ago, 200 million years ago.

MR. CLAHAN: Sure.

MEMBER CORADINI: Twenty years ago.

MR. CLAHAN: It's a good question, yeah, good question. And what that ties into are these stylolites, and these are a result in carbonate rock of dissolution during deposition. And we also see a imprint of a tectonic. And so what we're doing is correlating the two different phases of stylolite formation with the deposition of the rock 500 million years ago, and then the Alleghanian orogeny 280 million years ago.

And so all that deformation occurred within that window. Does that answer?

MEMBER CORADINI: Yeah.

MR. CLAHAN: So we can tell that age.

MEMBER CORADINI: The age of the fracture.

MR. CLAHAN: That's right.

MEMBER CORADINI: Okay.

MR. CLAHAN: Yeah, that's right.

CHAIRMAN KIRCHNER: Also, Kevin, so the picture on the left is the depth of the bore holes and the picture on the right has a scale of about two or three feet.

MR. CLAHAN: That's right.

CHAIRMAN KIRCHNER: All right, so what we'll see on the right is coming up on the next slide.

MR. CLAHAN: It is, that's right.

CHAIRMAN KIRCHNER: That's fine, okay.

MR. CLAHAN: Yes, and this is a schematic --

CHAIRMAN KIRCHNER: Connective pieces.

MR. CLAHAN: This is part of one of the RAIs that we helped, sort of explained the shear fracture zone. So next slide, please. So these images show photographs of natural and modified logs that are detailing the shear fracture zone features. And one thing to notice again is the abundant veining compared to the adjacent rock. You see that in certain areas here.

The serrated stylolites produced by pressure solution, both parallel to bedding and perpendicular to bedding. Down here, the stylolites are listed as in purple, bedding is in yellow on this figure. So bedding again here, you can see this is a 33 degree southwest dipping bedding, represented in the core. And then these are those bedding parallel stylolites that formed during syndeposition of that rock and lithification of that rock.

We also see stylolites that are perpendicular to the bedding here. And those give us an idea that those subvertical stylolites indicate pressure solution occurred during subhorizontal compression, which coincides with the shortening and emplacement of the Valley and Ridge thrust faults during the Alleghanian orogeny.

There's a lack of brittle cataclasis or fault brecchi or gouge that we see associated with the Copper Creek fault, which we know to have accommodated at least 50 kilometers or so of shortening. All the faults within the Valley and Ridge have accommodated together approximately 250 kilometers of shortening during the Alleghanian orogeny. That's going to be on the test.

So again, these parallel stylolites occurred during bedrock formation, and they're also located throughout all the cores. All right, and so these features, again, are not fault-related, but they accommodate internal deformation of the rock and they show no discernable displacement.

And that's all I have. I'd like to turn it back to Walt.

MR. JUSTICE: Thank you, Kevin. Next

slide, please.

Local geological hazards. NUREG-0800 requires the identification of geological hazards which may affect the suitability of a site for the construction of a nuclear power plant. As I stated earlier, through our investigations, karst dissolution is the primary geologic hazard of concern for this application.

Janet Sowers, who is also to my right and pictured in the picture on the slide, will now take up the discussion of the topic. Janet, would you please introduce yourself.

MS. SOWERS: Thank you, Wally. My name is Janet Sowers and I'm a licensed professional geologist with Fugro. I received an undergraduate degree from University of Virginia and a PhD from University of California. During my 30-year career, I've worked on site characterization and geologic hazard projects for many large infrastructure projects, including six proposed or existing nuclear power projects.

One of my specialties and my focus for the Clinch River Project is the karst characterization and evaluation of karst hazards. Next slide.

So karst is a landscape with distinctive features that are formed by the slow dissolution of limestone by groundwater. The water flows through the fractures and joints, enlarging them and eventually forming an underground drainage system, and karst landscape features such as sinkholes and caves and springs and an irregular bedrock contact underneath the soil.

This is an example of a karst model drawn for an area, the Copper Ridge area of Oak Ridge, where the, it's underlined by thick dolomite. The rock under the hillside has a number of dissolution passages shown by yellow, in yellow. Many were formed when the rock was under the groundwater table in the phreatic zone.

After the erosion cut down and drained these passages, vadose zone dissolution, or dissolution above the water table, took place by descending rainwater forming vertical slots and steep passages, which may intersect the older phreatic passages.

Sinkholes form at the ground surface, typically where the soil over the bedrock filters down into the underground slots and passages, and then undermines the surface soil. And the surface soil then sinks or collapses to form the sinkhole. It's called a cover collapse sinkhole, and that's the most common type of sinkhole in the Valley and Ridge.

Springs occur where conduits discharge at the surface. In a later slide we'll show you a karst model that we've developed for the Clinch River site. This particular karst model was developed by the Tennessee Geologic Survey for the Copper Ridge area. Next slide.

MEMBER CORADINI: So just a cartoon, since we have the cartoon in front, so this is mainly by rainfall moving its way through the earth to the river, versus river intrusion subsurface? Or some combination of that?

MS. SOWERS: Let's back up for just a second, because many of the passages are phreatic, which means they were formed below the water table. Right now, they're high and dry in this model. So imagine, undo the downcutting of the Clinch River and put a lot more rock back up on top.

And then you're under the groundwater table, and rainwater then descends down through, and then there's groundwater circulation underneath the water table that is dissolving out these phreatic passages.

MEMBER CORADINI: And so this all natural. Is there any mining operations in the area that uses

--

MS. SOWERS: No, no mining operations. And this is a very slow process.

MEMBER CORADINI: Okay.

MS. SOWERS: All right, so next one. We based our karst analysis on information from previous --

CHAIRMAN KIRCHNER: You said that, Janet, it was slow. Just for the record, how slow?

MS. SOWERS: How slow? It's slow enough that you would not notice dissolution in your lifetime or in the lifetime of the planet. We would not notice it. It's like in the order of centimeters per hundred or thousand years.

CHAIRMAN KIRCHNER: So if we do a good mapping of the potential site, then for the lifetime of the power plant, we would not expect one of the sinkholes to form.

MS. SOWERS: We would not expect additional rock dissolution that we could notice. Sinkholes are more of a surface phenomenon that involves the soil.

CHAIRMAN KIRCHNER: Yeah I know --

MS. SOWERS: So you could get, you can get sinkholes from, in the soil, during the lifetime of the plant.

MEMBER CORADINI: But to get to Walt's point, you've got to, once you know the shape of the geometrically.

MS. SOWERS: In the rock.

MEMBER CORADINI: You're going to be around essentially static during the life of this --

MS. SOWERS: Yes, the rock passages will be --

MEMBER CORADINI: Project.

MS. SOWERS: For the lifetime of the plant will be, we would consider static. Thank you for the question.

So we're basing our analysis on existing and new information that we develop for the project. There were many karst studies that were done at Oak Ridge on the Reservation, including an inventory of karst features and a number of groundwater studies that tracked flow of groundwater through karst passages.

We also looked at the Clinch River Breeder Reactor data from the 1970s and 1980s. This provided good topographic mapping of the site before development, so we could see locations of sinkholes and what the original ridges and valleys looked like.

We also were able to use the detailed logging that they did of the cavities encountered in bore holes and incorporate that in with our bore hole data.

For this SMR project, we conducted a LiDAR mapping of karst features from the five-mile radius, which Wally showed you some examples from. And then we compiled all the core boring information from the breeder reactor and the SMR project for analysis and modeling. Next slide.

Here are the conclusions. I'm sorry that's such a small font, we had intended to cut out some of this. The first bullet really says that the flow in our site is strike parallel, meaning the orientation of passages goes along strike, so perpendicular to the direction of the dip.

And the reason that we have that at our site is that the Chickamauga Group is a interbedded sequence of limestones and silt stones and silty limestones. And dissolution is more well developed in the pure limestones, so that the orientation of karst development is parallel to strike along those more pure limestone beds and units.

Second bullet says that there are some low carbonate units, and they are generally silt stones. We have the Fleanor formation, on which the Breeder

Reactor was built, and that would be for Site B. We also have the Blackford formation and the Bowen formation. Those are also more carbonate pure, and those units have no mapped sinkholes. And they have smaller and fewer bore hole cavities than the other units.

The third bullet says that based on the bore hole data, the frequency and size of cavities, generally these decreases with depth as you go down. It doesn't, we don't completely run out of cavities. There still are some in our deepest bore holes, but they're smaller. But they're there, so there are cavities beneath the water table. But in generally it's more of a surface-intensive process where we have the greater sizes and frequency of cavities closer to the ground surface.

The third bullet makes a point about hypogene dissolution, which we haven't introduced yet, but just to let you know. Epigenetic dissolution means that the water, rainwater comes down, it dissolves from the vadose zone, it forms the groundwater and dissolves in the phreatic zone.

Hypogene dissolution would be water welling up from depths below, where it may be warm, it may be super-charged with minerals. And that can often be a more aggressive dissolution and is documented in other parts of the Valley and Ridge, such as in Virginia, but not at our Clinch River site.

MEMBER CORADINI: Is that, you can tell that by the chemical content of the water?

MS. SOWERS: You can tell it by the chemistry of the water, by deposition of exotic minerals in around springs, and by the temperature of the water.

MEMBER CORADINI: Okay. So no possibility --

MS. SOWERS: No, we don't, no. Everything seems to have a meteoric signature, all the rainwater. I mean, all the spring water.

CHAIRMAN KIRCHNER: So Janet, since it's up there, would you just explain one more time for the quiz, phreatic versus --

MS. SOWERS: Vadose?

CHAIRMAN KIRCHNER: Where is the other?

MS. SOWERS: Phreatic is at and below the water table, the groundwater table. Vadose is in the unsaturated zone above. So in the vadose zone, water is generally descending along fractures, joints, bedding plains. In the phreatic zone, it's moving along whatever paths it can find.

MEMBER CHU: Can I ask you a question? You, I think you said the karst located below groundwater level, am I correct or not?

MS. SOWERS: Karst is, happens both above and below.

MEMBER CHU: Above, okay. What is the most, what do you see that's closest to the surface, the location of the karst from your mapping?

MS. SOWERS: The sinkholes are the most, are the surficial expression of karst processes happening at depth. Sinkholes is the number one thing that we see at the surface. Springs, cave entrances, those are also things that you see at the ground surface. And those are things that we were mapping with the LiDAR.

MEMBER CHU: Okay.

MS. SOWERS: Okay, next slide. All right, as promised, here is our karst model for our site.

MEMBER CORADINI: Let me just ask another question. So if you know have mapped where the holes are, and you now have Site A and B and you're going to dig through it to put down a foundation for a installation, do you fill the holes, or just monitor that they're small enough that you ignore structurally, or is that not your problem?

MS. SOWERS: We'll be discussing that --

MEMBER CORADINI: Later?

MS. SOWERS: In the, near the end when we talk about geotechnical engineering. But good question.

So here's our model, and it's a cross-section of the site, similar to what you saw before. It's a little bit more artistic, we tried to show what the bedrock, the rock types actually are. So going from the west to the east, the, here's the dolomite. And this is the Knox Group. We are not going to be building on this, this is at the northern part of the property, however.

And the Knox Group, like the Copper Ridge dolomite, is more intensely karstified than these other units. So we're representing the cavities with the black. Of course, it's a schematic, so nothing is implied here as far as actual locations. This is a schematic of how we think it might look.

There's the Knox Group, there's an unconformity between them. There was a period of erosion of the Knox before the Chickamauga was laid down. So here's the Chickamauga from here over to the Copper Creek fault over there, and our sequence of beds.

This is the siltstone, the Fleanor formation, on which the Breeder Reactor was excavated, and this is the location for our Location B. Our Location A will be over here, and one of the limestone units, it's one of the siltier ones, but it is a limestone unit, Location A, right here.

So we tried to show that there are cavities generally follow bedding plains and joints, and large bedding planes and joints, and that there are more near the surface and there are still some down at depth as well. On the other side of the fault, in the Rome formation, that's a sandstone. So that is not a karst unit.

And with that, I will turn it back over to Wally.

MR. JUSTICE: Thank you, Janet. Next slide, please.

We have discussed the Clinch River Breeder Reactor Project in this presentation, and this photograph is the completed excavation in 1983. The documented geological mapping of the excavation has been very helpful in our current site characterization efforts. This excavation is also located, as Janet said, in the same rock member, the Fleanor, as Site B that we are discussing today and in the application.

Karst features identified during the excavation of the Clinch River Breeder Reactor were considered small and manageable, particularly supporting the conclusion that karst cavities are reduced in size and frequency as depth is increased. Just for your information, this excavation was approximately 483 feet long by 360 feet wide, about 100 feet deep.

And if you look at the picture, this rock unit here is the Rockdell unit. This unit here is the Fleanor unit, and the basement of the excavation lied within the Fleanor unit. So this mapping that was performed, it was documented in some regulatory documents and some supporting reports. And again, during that excavation, they did not identify any large karst cavities as part of their mapping efforts. Next slide, please.

So in conclusion, for SSAR 2.5.1, active faulting is not a geological hazard for site area or the region. All identified faults are considered greater than 290 million years old. Shear fractures are not a geological hazard for the site area, as they are also greater than 290 million years old.

Karst conditions are identified as the potential geological hazard for the area, and the information to discuss how we will identify and mitigate in the future will be discussed in the following presentation. And we believe we've met the regulatory requirements of 10 CFR 52.17 and the guidance from Regulatory Guide 1.2.08.

I'll now take us to the second portion of the presentation, which is discussion on SSAR Section 2.5.2, seismology. I have Ivan Wong from Lettis Consultants International on the bridge line in the event that I have a question that needs a technical answer from him, but I will start the presentation.

2.5.2 is there to determine the site-specific ground motion response vector, the GMRS. The GMRS is identified as a free filled horizontal and vertical ground motion response spectrum at the site, and it must satisfy the requirements of 10 CFR 100.23.

We developed the GMRS in accordance with NUREG-0800, we also developed the ground motions in the SSAR with implementation of the provisions in Reg Guide 1.208, the performance-based approach to define the site-specific earthquake. Next slide, please.

This is a plot of the Central Eastern United States Earthquake Catalog, showing the location and magnitudes of seismic activity in the central and eastern United States. This information is contained in NUREG-2115, the central eastern United States seismic source characterization for nuclear facilities. Next slide, please.

Within that zone, the East Tennessee Seismic Zone is defined as an area of more frequent seismic activity, although this activity is relatively small in magnitude. The source is specifically detailed in NUREG-2115 and captures the current understanding of the seismic hazard.

It should be noted that TVA has two plants operating within the current East Tennessee Seismic Zone, the Watts Bar Nuclear Plant, located approximately there, and the Sequoyah Nuclear Plant, which is located approximately in that location. Next slide, please.

I'm sorry, the Clinch River is that red arrow or red star. Just slightly outside of the Eastern Tennessee Seismic Zone.

MEMBER RICCARDELLA: Okay, thank you.

MR. JUSTICE: Next slide, please. For the ground motion response development approach, this is a very high level description of how information is utilized to develop the GMRS for the Clinch River site.

The rock hazard is a result of the site-specific probabilistic seismic hazard analysis, which used an updated Department of Energy, EPRI, NRC, CUS seismic source characterization models in the EPRI ground motion models. This is now the standard practice for seismic analysis post-Fukushima. Next slide, please.

I would like to just a brief overview of the method we used out of Reg Guide 1.208, which is known as Approach 3. It is fully probabilistic, it preserves hazard levels. The hazard at the surface is computed by integration of the hard rock hazard with the probability distribution and frequency, and this results in a complete hazard curve at the ground surface.

It is endorsed by NUREG-6728. And the basic steps in Approach 3 are the randomization of site-dynamic material properties, the computation of amplification factors using random vibration theory, and the full integration of mean and fractal hazard curves. Next slide, please.

This slide I had a presented a couple of times earlier today, but I just wanted to point out again Site A, excuse me, Site B and Site A locations. We've talked about the faults on both ends, we talked about the dipping angle. This is a one-mile representation. I would like to go to the next slide.

And this is a four-mile representation, which includes the Clinch River site, which is the purple box. It has the Site B profile, which is this purple location, and the Site A profile. So this a much larger map, and it is also to basement depth of approximately 12,000 feet below sea level. So this shows all of the rock units that are associated with it, and it shows their relative velocities.

And I believe, if you'll pardon me, I just cannot see that number. So we see that the limestone is approximately 10,500 feet per second. And the shale, the Conasauga shale, is approximately 6,000 feet per second. The limestone, the Chickamauga, is also approximately 10,000 feet per second. Next slide, please.

Profiles were developed for both Sites A and B separately, based on the velocity shown on the cross-section you just saw, based on the particular rock members and depth. And if you compare these two, even though they're in different rock members, you notice that there's a lot of consistency in the profiles. Next slide, please.

The mean rock hazard curves were then developed based on that analysis. And this is the hazard at ground surface for the Clinch River site, an example. Next slide.

We then, from that information, developed the ground motion response specter for Site A and Site B. And then if you go the next slide. We then brought those two curves together and combined them into one overall, enveloping ground motion response specter for the Clinch River site. This is for both the horizontal and vertical ground motion response specter. Next slide.

The 2D sensitivity analysis was performed to determine if the dipping stratigraphy of approximately 33 degrees was fully recognized by the 1D analysis or the GMRS analysis. The 2D analysis is considered a multi-dimensional approach for validation for Reg Guide 1.208.

The 2D-1D comparison described in the SSAR and documented in the GMRS study involved calculating the amplification for the full, two-dimensional profile compared to amplification of single, one-dimensional profiles as best estimate slices through the midpoint of Sites A and B.

In the site response analysis performed to develop the GMRS, the best estimate 1D profiles at Sites A and B were used along with upper and lower wrench profiles at each location for a total of six profiles and associated amplification factors.

The hazard was then calculated for each of the six profiles, and the hazard at Sites A and B each reflecting a wave average over best estimate and upper and lower wrench profiles. Next slide.

MEMBER CORADINI: Can you go back to the angle?

MR. JUSTICE: Back one more?

MEMBER CORADINI: I'm just trying to understand what was done, so maybe Slide 36? That one. So the 1D basically layers them horizontally? Not vertically, I assume. So when you say it's a 1D model, I basically take all these various rock formations with different sound speeds and just layer them one on top of the other.

MR. JUSTICE: That is correct.

MEMBER CORADINI: Okay. And the two dimensional actually captures in two dimensions the angle or feature, the angle.

MR. JUSTICE: Correct. And then you perform a comparison to see if the assumptions that were performed in the 1D were fully captured, based on the 2D analysis.

MEMBER CORADINI: Okay then, so can you go back to 40?

MR. JUSTICE: Slide 40?

MEMBER CORADINI: Yeah. So the dark blue at the bottom is 2D, everything else is 1D above it.

MR. JUSTICE: That's correct.

MEMBER CORADINI: And on the Y axis is what?

MR. JUSTICE: The side amplification.

MEMBER CORADINI: What does that mean? Can you help me there? So it's the G force times that number?

MR. JUSTICE: So at this frequency, this is the amplification factor associated with each frequency from the analysis.

MEMBER RICCARDELLA: A single degree of freedom oscillator at the --

MEMBER CORADINI: You need to turn something on. Higher.

MEMBER RICCARDELLA: A single degree of freedom oscillator at the frequency, right? And so when the two dimensional you do, you look at the vertical as well as the horizontal, is that the two dimensions?

MR. JUSTICE: That's correct. And you have, and we had a slight accedence at approximately two, frequency of two hertz in both cases. But that was the only place that there was any accedence associated with 2D sensitivity.

MEMBER RAY: I think Mike's asking amplification of what.

CHAIRMAN KIRCHNER: Ground motion.

MEMBER CORADINI: And so I've got at some depth a wiggle, and I'm wiggling it at some frequency. And then I'm looking at the surface, what that wiggle corresponds to after it's passed through all these layers of stuff.

MR. JUSTICE: That is correct.

MEMBER CORADINI: Okay, so is this, it's got to be horizontal wiggle, it can't be side to side wiggling, because one dimensionally, it doesn't --

MR. CLAHAN: It's vertically propagating shear waves.

MEMBER CORADINI: But the shear wave is a vertical propagating shear wave, so it's not, it's horizontal motion. It's vertical motion, vertical motion. It can't be horizontal motion, not with a 1D modeling.

MEMBER RAY: Mike, there's two dimensions in the horizontal plane.

MEMBER CORADINI: I know, but they have a

1D model where they're levering rock this way, so I can't do anything here and model that. I'm only modeling wiggling that way.

MEMBER RAY: How much shear in the one direction? You're talking about -- yeah, yeah.

MEMBER CORADINI: So there's some sort of shear component perpendicular to the oscillation that's modeled in the 1D model.

MR. JUSTICE: So perhaps it would be best if we brought Ivan Wong from Lettis on the bridge line.

MEMBER CORADINI: I just want to understand all the curves. At least, so I understand it vertically, how you did the layering. I just was trying to understand the side-to-side horizontal motion.

MR. JUSTICE: We'll see if we can get you a little better explanation than I'm going to be able to give you on this subject. Is the bridge open where Ivan can hear me?

MR. WONG: Wally, I'm on the line.

MR. JUSTICE: Hello, Ivan. If you would be so kind as to give your background and experience and your full name, and we'll answer the question.

MR. WONG: Okay. My name is Ivan Wong,

I'm a seismologist with Lettis Consultants International. I have 44 years of experience in seismic hazard, and I guess my most conspicuous project was I was the Project Manager for the seismic hazard evaluation of the Yucca Mountain Project for about 15 years.

So Wally, are we looking at the slide that's a comparison of 1D and 2D amplification factors?

MR. JUSTICE: That is correct, we're on Slide 40.

MR. WONG: Okay, so what we're showing here is the results of basically a 1D and 2D site response analysis. So we're basically showing what we call amplification factors, which compare the ground motions at the input of a soil column, versus anywhere at the top of the column.

So in the 1D analysis, as one of the members of the Committee mentioned, in a 1D analysis it's a, basically a layer cake profile. We're modeling vertically incident seismic shear waves, so they're vertically propagating, they go up through the column in a vertical fashion.

But because they are shear waves, the particle motion is horizontal. So we're looking at the horizontal motion from a vertically propagating shear wave velocity.

So in the 2D, we're actually modeling the dipping stratigraphy and just calculation the amplification factors of the vertically propagating through the dipping layers. And in that figure, we're just comparing the amplification factors between the 1D and the 2D.

And as Wally has stated, the 1D amplification factors are conservative. But to the 2D, and that's simply because when we did the 1D, we had multiple profiles and we included all the uncertainties. And so that compensates for any 2D effects.

And the other observation is because the velocities of the rock are so hard, the 2D effects are very, very small. So it's easily captured in the 1D analysis.

MEMBER CORADINI: So just one last question, just so I think I get it. So there's a frictional, there's an assumption of frictional between the layer cakes? In other words, if I start wiggling it horizontally, which you call a shear wave, one made up of layer X then provides a force to layer Y.

But there must be a shear component at the interface between the two layers, which is the same assumed in both analyses?

MR. WONG: There is that particle motion, or friction as you call it. But again the velocities, because the rock is so hard, even though you're going from one rock type to another, let's say from 6,000 meters per second to 10,000 meters per second, that transfer of motion is relatively small.

If you were in lower velocity materials, like a soil, where the velocities are on the more, on the order of a few hundred meters per second, that effect that you're talking about would be more pronounced. But there it's not.

MEMBER CORADINI: Okay, so really what we're seeing between the blue line, which is lower in all the other colored lines, is the effect of the angle or structure.

MR. WONG: Yes.

MEMBER CORADINI: Got it, thank you.

MR. WONG: Absolutely, thank you.

MEMBER RICCARDELLA: So, yes, another question. So in the 2D model, are you still putting in a single, one dimensional horizontal movement that just, and you're just considering the stiffness in the two different directions, that they? Or are you looking at two different, distinct directions of vibratory motion, vertical and horizontal?

MR. WONG: No, we're still putting in, we're still putting in, you know, vertically propagating waves. But they, we're looking at the 2D, yeah.

MEMBER RICCARDELLA: Yeah.

MR. WONG: So we're looking at them in the two dimensional sense. And we're propagating them through that 2D structure.

MEMBER CORADINI: But the source term is the same. I thought what was Pete was asking, the source is the same. It's still --

MEMBER RICCARDELLA: The driving vibration, you're just putting in horizontal motion, at various frequencies, right?

MR. WONG: Yes, absolutely.

MEMBER RICCARDELLA: Okay, thank you.

MR. JUSTICE: Thank you, Ivan.

MEMBER SUNSERI: So I have a question. Maybe you're leading us to this answering my question, and if so I can be patient and wait. But if I think about the previous presentation with the karst, and I would characterize that as blemishes near the surface, such as streams, caves, sinkholes, etc., and then I think about the proximity of the site to this Eastern Tennessee Seismic Zone, is it possible that the seismic activity could connect perforations, like peeling the postage stamp off the perforated sheet and cause problems that way?

I'm just trying to think of where this presentation's going to end up, what the conclusion's going to be. You understand what I'm saying?

So you have the karst, which at least what I'm hearing described is blemishes near the surface, or it could be anywhere, but I'm talking about the ones near the surface, the caves, the streams, the sinkholes, whatever. They're randomly distributed, I presume. And you have the site, and then the site is adjacent to this Eastern Tennessee seismic area.

So now you have something seismically happen. Can you connect the blemishes and cause problems that way with the surface?

MR. JUSTICE: So I think to try to address that question, the earthquake activity would occur deep within the, near the Precambrian basin and up. The blemishes we're talking about, the karst depressions, sinkholes, naturally forming areas such as that, are very close to the surface.

From my foundation of a nuclear plant, and we will discuss some of that in the next part of the presentation, but from the depth of the foundation of the site and the anchorage of that site, you will have removed any of those considered blemishes in the area for the safety-related feature that you're putting in at the plant.

And perhaps, maybe we can table that a little through the next part of the presentation, and then maybe revisit your question and see if we've hopefully enlightened it or can answer it further.

MEMBER SUNSERI: Yeah, that's fine. I'm just trying to, you know, it's not my field, so I'm not even going to try to attempt to understand all these intermediate graphs, I just want to get from the beginning to the end kind of conclusion, right.

MR. JUSTICE: Understand, thank you for that. Let's go ahead and move to Slide 42, if we can. Just to conclude the seismology portion, the PSHA performed for the Clinch River site, specifically for Sites A and B, we followed 10 CFR 100.23, and we used the guidance of Reg Guide 1.208.

It represents the regional and local hazards and includes the local subsurface properties. And it evaluated the potential for 2D effects due to the dipping angle of 33 degrees.

Now I'd move to Slide 44 and discuss the remaining sections of SSAR 2.5. These would be 2.53, 2.54, and 2.55. Specifically, these subsections address the following issues: potential surface deformation associated with active tectonism, including any significant neotectonic features and faults; potential surface deformation associated with non-tectonic processes, such as collapse of structures, karst collapse for instance; slope failures; and any human activity, such as mining we talked about earlier.

The geological, geophysical, and geotechnical information is used as a basis to evaluate the stability of subsurface materials and foundations at the Clinch River site. And the information presented in this subsection is based on the results of the site-specific subsurface evaluations that were performed at the Clinch River site. Next slide, 45.

For surface deformation, TVA has performed geological, seismological, and geophysical investigations and analysis for the region and site. We concluded in the application that the potential for tectonic deformation at the site is negligible.

Non-tectonic karst deformation is possible with karst conditions. Detailed mapping of excavation walls and foundations will be performed during construction for a confirmation of the conclusions reached in this application. Next slide.

I would like to reiterate some of the investigations and activities that were performed to address the stability of subsurface materials and foundations. We've talked about the previous Clinch River Breeder Reactor Project subsurface investigations and analyses. We also did some additional work, a lot of additional work, for the current project.

There were 82 actual geotechnical core borings that were performed at the site. Earlier I told you there were 76 core borings. Those were rock borings, and there were six additional soil borings at the site.

We had test pits dug, we had groundwater observation wells. We did down hole geophysical testing in multiple borings. We did groundwater level monitoring in the observation wells, and we did laboratory testing of the boring soil and rock samples that were pulled up from the cores. These programs followed Reg Guide 1.1.32, site investigations for foundations for nuclear power plants. Next slide.

Engineering properties were developed to determine if the site was suitable for support of a nuclear power plant, in conjunction with Reg Guide 1.132. These are just a few examples of some of those properties that were investigated. Ultimate bearing capacity, allowable bearing capacity, settlement heat analysis, and additional properties such as rock strength and others.

Properties were evaluated against a surrogate plant for the Clinch River site using the plant parameter envelope approach. And I believe that plant parameter envelope approach was discussed previously in an ACRS meeting, but if there are any questions on what that is, I can go back through an explanation of that effort. Okay, moving to the next slide.

Due to the identified geological hazard of karst dissolution, additional geotechnical studies were performed to understand the effect on nuclear safety-related foundations. We performed a PLAXIS two dimensional analysis to determine foundation acceptability. We used a large reactor foundation that we selected that a current design because enough detailed information about the four conceptual SMRs was not available the time we performed the analysis.

Finite element models were developed for both Site A and B. These models were done at three different embedment depths, a 40-foot embedment, a 90-foot embedment, and a 140-foot embedment.

MEMBER CORADINI: Where did you come up with 40, 90, 140?

MR. JUSTICE: They will correspond to --

MEMBER CORADINI: Potential.

MR. JUSTICE: Potential foundation levels for SMRs being considered.

MEMBER CORADINI: Okay. I was guessing that, I just wanted to make sure. Undefined, thank you.

MR. JUSTICE: You're welcome. The 40-foot embedment was actually done because the embedment depth of the design we used to, as the surrogate model for this site. The 90 and 140 more closely represent embedment depths for the current SMR designs.

So for each Site A and B, we did the three different embedment depths. And then, at each of those embedment depths, we then evaluated the placement of the cavity at five foot below the embedment depth and at 30 feet below the embedment depth.

And then for each of those models, we then selected three different locations for the placement of the cavity at those depths. It was either at the edge of the nuclear island, at the center of the nuclear island, or at the appropriate bedding plane for the Site A or B. So multiple models were performed.

MEMBER CORADINI: Remind me what the cavity is in relation to the bottom of the embedment.

MR. JUSTICE: Five feet --

MEMBER CORADINI: Yeah, I understand that but --

MR. JUSTICE: Or 30 feet.

MEMBER CORADINI: But what do you mean by, I don't understand what you mean by cavities.

MR. JUSTICE: Karst cavity.

MEMBER CORADINI: Oh, cavity, I'm sorry.

MR. JUSTICE: An assumed --

MEMBER CORADINI: I got it.

MR. JUSTICE: Unfound, couldn't find it, never knew it was there cavity. Hypothetical cavity. And if we turn to the next slide --

MEMBER BROWN: Before you do that.

MR. JUSTICE: Yes?

MEMBER BROWN: What's the basis for a

large PWR being satisfactory as opposed to an SMR?

MR. JUSTICE: We looked at --

MEMBER BROWN: They are different.

MR. JUSTICE: They are different. You have similar building sizes in a lot of cases, even though an SMR is small. In some cases, their footprint can be almost as large as a current, modern PWR. We knew the information from the design, and we knew that that information had been previously reviewed and approved in a DCA or other method by the NRC. So the information was known and available.

If you'll allow me, in a couple slides, we get to do this analysis again for the technology --

(Simultaneous Speaking.)

MEMBER BROWN: I'll be happy to allow you.

MR. JUSTICE: Thank you.

MEMBER BROWN: This is not my area, just seemed to stick out, that's all. Thank you.

MR. JUSTICE: Our attempt at this was to do as many different scenarios as we could to fully explain the effect that an unknown cavity may have on our geology, with the best information possible at the time from the application.

If we go to the next slide, which should be 49, this is an example of a Site B. This is a finite element model for cavity placement for Site B, with a cavity diameter assumed of 15 feet. So the unknown cavity's 15 feet. At the center of the nuclear island, so we can see it's, if you can see my little red dot. And the foundation is at a 90-foot embedment depth.

So this is just an example of a sheet pulled out from the finite element analysis.

CHAIRMAN KIRCHNER: And the basis for 15-foot diameter is that you would probably detect anything larger than that when you do your site, final site where, before you start laying the concrete in?

MR. JUSTICE: That is one point, and it also corresponds to what we have found, either through the Breeder Reactor or through the investigations we did for the SMR.

MEMBER RICCARDELLA: Would you point to the cavity again, please?

MR. JUSTICE: I'm sorry, did you say the cavity?

MEMBER RICCARDELLA: Yeah.

MR. JUSTICE: Yes, it is, yeah. Sorry, this doesn't show it for some reason on that blue.

MEMBER RICCARDELLA: Got it.

MR. JUSTICE: So this again was at the

center of the island. It was a 15-foot cavity placed five feet below at a 90-foot embedment depth for the rock units associated with Site B. And if we go to the next slide.

Just to reiterate the foundation model results, the development in the site areas is generally limited to the most markedly weather zone, okay. We've discussed that before in how karst is formed and where you find it and at what depths.

Typically, these are to depths less than 100 feet. Seventy-five percent of reported cavities in the Site A and B borings occurred at depths less than 55 feet. And of course this material, if those sites are chosen, that material would be excavated and removed.

Cavity-related failure has a higher potential to occur at relatively shallow depth, less than about 30 feet. But the technologies that we are considering under this application have embedment depths between 80 and 140 feet. Precisely, they are at 86 feet and 138 feet as we move forward with the designs of these different facilities.

And we chose the 15-foot cavity as the terminal cavity for this analysis because it bounded the size cavities that we had found in the investigation for both the Clinch River Breeder Reactor and from the current SMR evaluations. Next slide, please.

Now to help with last question. So at COLA, if TVA moves forward with a COLA, the foundation performance will have to be re-evaluated based on that technology. And that technology would then have a DCA or a DCV that provides the requisite information you would need to do this type of analysis.

It would take into account the specific plant design, the loads, any potential ground improvement or grouting plans that may be necessary if you find --

MEMBER CORADINI: So grouting is what you'd stick in the hole.

MR. JUSTICE: So once you dig an excavation, you then do mapping and you do additional investigations to determine if in that area where our safety-related foundations are going, are there karst cavities. If you do find karst cavities, per regulatory requirements, then you come up with a grouting plan and a mitigation plan to deal with the karst cavities.

It is not an unusual practice, it happens in a lot of the areas where karst is normally found in the eastern United States. And there's plenty of regulatory guidance to tell you how to do that. But we won't do any of that until we have an actual technology pick for the site.

MEMBER RICCARDELLA: So is PLAXIS, is that a finite element computer code?

MR. JUSTICE: Yes. The PLAXIS analysis that was used for this is a finite element analysis model.

MEMBER RICCARDELLA: And what is the loading that you use, is it just the dead weight of the structure, or do you put in seismic loads as well?

MR. JUSTICE: It is the information, it would be the loading of the plant. It would be the footprint of the plant for a nuclear island. And it's a --

MEMBER RICCARDELLA: But it's just the dead weight, basically.

MR. JUSTICE: And footprint.

MEMBER RICCARDELLA: The footprint.

MR. JUSTICE: And footprint weight.

MEMBER RICCARDELLA: Oh, spread over that footprint, I assume.

MR. JUSTICE: Half of the building out --

MEMBER RICCARDELLA: But you're not

looking at the effects of, for example, cavities on a seismic loading.

MR. JUSTICE: No, we're just, you're looking at it from the effect of, as prescribed by 1.132, the effects of potential unrecognized cavities under a safety-related foundation. Can you find them, if you'd missed one, would it be okay. And if you do find them, can you mitigate them through grouting methods to shore that up.

MEMBER RICCARDELLA: Thank you.

MEMBER CORRADINI: So if one of these technologies wants to do seismic isolation, would any of this procedure change? Or that's more within the plant and the plant response to these, to this seismic source and the associated required foundation improvement.

MR. JUSTICE: So that would be considered in the infrastructure and seismic evaluation for the actual plant. But the characterization efforts would still be the same.

MEMBER CORRADINI: Okay.

MR. JUSTICE: As we have done for this application.

MEMBER CORRADINI: Thank you.

MR. JUSTICE: All right, I would like to

now move to Slide 52, discuss a little bit of stability of slopes. Giving the existing topography, the natural topography, and the planned finish grade as described in the application. So basically it would be a flat site with no safety-related slope planned in the vicinity of safety-related structures.

However, the stability of slopes as identified in the application will be re-evaluated during the COLA phase based on the actual technology selected.

And just to note, the previous Breeder Reactor excavation experience, the reports from that are very helpful also in determining this as it goes forward in future. Last slide, please.

In summary, the early permit application seeks approval for the Clinch River site for potential future use of a small modular reactor technology. The Clinch River site is capable from a geologic and seismic perspective for the construction of a small modular reactor.

As we discussed, the potential hazard, karst, is identifiable and can be mitigated through approved regulatory processes.

We'd like to also state that the efforts associated with the pre-application ratings review process and the site audit and visit were very helpful in ensuring that the right level of detail and supporting information was available in the application. And I would like to thank you for your time in listening and preparing in this presentation. Thank you.

CHAIRMAN KIRCHNER: Let's go around the table, then. Any of the members have questions, further questions of the applicant?

I have one question. In the unlikely event you didn't detect a cavity, highly unlikely I would guess, but would it appreciably change, my intuition says no to this question, but would it appreciably change the seismic loading in any way? You've got pretty hard rock that you're --

MR. JUSTICE: No.

CHAIRMAN KIRCHNER: Building this plant on. So I wouldn't expect that, but that would be my question.

MR. JUSTICE: That, and your assumption is correct. That would not, the identification of cavities in the safety-related excavation, additional borings will be performed, additional methods of detection of cavities.

Let's just assume that it's a 100-foot

excavation. You've now removed a 100 foot of material. You've most likely removed the vast majority of your karsistic material. But you're still going to attempt to identify everything you can in that excavation.

If you find a karsistic area, then you will then follow regulatory prescribed mitigation plans to fill those voids. The PLAXIS analysis is a pretty conservative view of you just somehow missed it and now you are determining what is the largest cavity that you could have that still, with the weight of the plant and the design of the plant, would not affect that safety-related foundation.

And again, that gets redone for this project if the project moves to a COLA phase for the specific technology that would then be picked and aligned with the COLA.

CHAIRMAN KIRCHNER: Thank you. Okay, with that, let's go to the staff. Andy. Or you want to break? Don't you want to go right through? Okay, let's take a break. And Qyunh will explain where the facilities are located. So we're, are we recessed or adjourned? We're recessing? Okay.

MR. CAMPBELL: And I'm going to let the staff sit up here for the presentation or wherever.

You have a table for them, okay, great. Thank you.

MR. JUSTICE: We're vacating.

MR. NGUYEN: Okay. Dr. Kirchner, when do you want people back? Twenty-five of three? Okay, so if you need to use the facilities, go out of this room, turn a left, and keep hugging that corridor and you'll find the restrooms.

There is a convenience store right before the security turnstiles. I don't know what's in there, but feel free to check it out. And for the members, there's some coffee and Munchkins.

(Whereupon, the above-entitled matter went off the record at 2:22 p.m. and resumed at 2:35 p.m.)

CHAIRMAN KIRCHNER: Okay. Let's reconvene and we're going to turn to the staff.

Andy, are you going to make any introductions or are they going to introduce themselves?

MR. CAMPBELL: I will happily let them introduce themselves, but I did want to introduce Dr. Cliff Munson, who's our senior-level advisor for siting, who's joined me at the table --

CHAIRMAN KIRCHNER: Uh-huh.

MR. CAMPBELL: -- and I'll let Allen take it from there.

CHAIRMAN KIRCHNER: Okay.

MR. CAMPBELL: And I don't have anything else to add, but this has been the culmination of a lot of outstanding effort on the part of the staff in their reviews through this whole project, and I'm going to let Allen take it from there. Thank you.

MR. FETTER: Yes.

CHAIRMAN KIRCHNER: Okay.

MR. FETTER: Good afternoon.

Everyone hear me okay?

Yes, I'm Allen Fetter, one of the two safety project managers on the Clinch River review. Mallecia Sutton, who is the other safety project manager, had to duck out to finish the SEs for the next ACRS meeting on the 14th.

So, Ms. Sutton and I will be at the table for the next ACRS meeting on SE Sections 2.3, 2.4.11 and 17 on November 14th, 2018.

So, I've been at the NRC since 2004, and in 2009 I started working as a project manager in the Office of New Reactors.

Prior to taking over as safety project manager on the Clinch River ESP review in July 2015, I was an environmental project manager for the Bellefonte COL and the PSEG early site permit reviews.

Today's ACRS meeting is the fourth meeting that TVA and NRC and the ACRS have had together. This is the third of four subcommittee meetings on the SEs that have been prepared for the project.

Today, the NRO Geoscience, Geotechnical and Engineering Branch technical reviewers, listed on this slide with their credentials, will give presentations on their safety evaluations under Section 2.5, Geology, Seismology and Geotechnical Engineering.

Of course you will have the opportunity to ask questions throughout the presentations and for the sections discussed today.

In addition to staff's review of TVA's application, staff conducted two audits, one site visit and issued three RAIs comprising ten questions to the Applicant in order to obtain additional information to support NRC's findings.

I will now turn it over to Dr. Gerry Stirewalt and Ms. Jenise Thompson for the first part of the presentation.

DR. STIREWALT: Thank you, Allen.

Good afternoon. I am indeed Gerry Stirewalt. What we would like to do, we'd like to discuss the pure geology pieces, 2.5.1 and 2.5.3

first.

So, I'll start with 2.5.1, which is titled "Geologic Characterization Information." And if we could take a look at Slide 4 just as a reminder of what the SSAR includes that the Applicant prepared, 2.5.1 -- again, Geologic Characterization Information is divided into two subsections.

2.5.1.1 relates to original geology. Let me remind you that that region is a 200-mile radius around the site.

The Applicant presented information on physiography, geomorphic processes, geologic history, tectonic evolutions, stratigraphy, tectonic setting, including distribution of seismicity and stress in the eastern U.S., and certainly nontectonic hazards including karst.

2.5.1.2 gets -- it sort of narrows down the scope of where the data was collected and evaluated. Local geology relates to site vicinity that's 25 miles, site area that's five miles, and site location, which is a 6/10th of a mile radius of the site.

And, again, similar things were reviewed at this scale as well; physiography, geomorphic processes, geologic history, stratigraphy, lithology, structural geology, including faults and shear-fracture zones in particular, geologic hazards, including karst, and certainly the site engineering geology piece that included potential effects of human activity.

Let me, in the next slide, just sort of remind you of the physiographic scene. The site is located in the valley and ridge physiographic province, and the parallel ridges in that province really developed as a result of differential weathering and erosion of the folded and faulted sedimentary rock strata that characterized that province.

Okay. Let's think about what the -- so, what are the key geologic features of interest here? Well, there are two. One, is the regional thrust faults; and the other is the localized shear-fracture zones.

Now, neither of those two features is really well-exposed at the surface in the site area. Staff are able to examine them in rock core samples that the Applicant provided during site audits and site visits and both of those features, as you have heard mentioned before, are generally parallel to bedding.

Okay. So, the thrust faults are, in fact, tectonic in origin and they are regional features. The shear-fracture zones are more localized and they contain features of both a nontectonic and probable tectonic overprint origin.

Okay. So, the important thing that the staff really needed to focus on was determining and documenting that the thrust faults and the shear-fracture zones are, in fact, older than Quaternary -- that's greater than 2.6 million years in age -- and consequently pose a negligible hazard for the site.

So, it was really important to confirm the ages of these features just to make certain that they didn't pose a problem.

Okay. Let's do a quick look at a cross-section that you've seen just to sort of show you, again, the subsurface stratigraphy, faults and shear-fracture zones.

This profile essentially crosses the entire site location and extends beyond. What I would like to point out to you, on this particular slide, are the Copper Creek fault that is revealed in borehole CCB2.

And I mention that because I'm going to take you into the field and show you what it looks like in core.

The other fault that actually occurs that was also mentioned, is the Chestnut Ridge fault. That's really a local fault. Has the same orientation as the regional structures, but it's really localized, but the Copper Creek certainly is very characteristic of what the regional thrust faults look like.

We're also going to take a look in the field -- I'm a geologist. I have to take you into the field, after all.

We're going to take a look at the shear-fracture zone in the Rockdell formation in borehole MP-101.

Now, one thing I'd like to mention, this cross-section is actually vertically exaggerated. So, the depth that you keep hearing mentioned of around 33 degrees are exaggerated.

So, let me take you into the field really quickly, show you an exposure of the Fleanor formation. This is within the site location and, in fact, this really shows the amount and direction of the dip of bedding that is commonly seen at the site. And the bed's around 33 degrees southeast dipping towards the geologic scale that you have.

Okay. Let's talk about thrust faults

then. Again, they are characteristic of the entire Valley and Ridge province in which the site is located. They do occur in the site area.

And, again, there is no surface expression of any thrust faults in the site area, so -- and although not exposed at the surface, I pointed out the Copper Creek and Chestnut Ridge faults that are located within the site location at 0.6 miles from the site.

During the site audits and the site visit, staff were able to examine the Copper Creek fault and core from borehole CCB2.

And I'm going to drag you into the field and let you take a look at that in a moment, but I just wanted to mention that the Copper Creek, although it's not exposed at the surface at the site, is very well-exposed in the site region and, again, it's typical of the orientation northeast-striking, southeast-dipping faults that characterize the entire valley and ridge.

Okay. Let's take a quick look again at the site area itself. That's the big red circle, and the smaller one is the site location.

You will note that the site is, in fact, located between two of these regional thrust faults.

One is the Copper Creek; the other is the Whiteoak Mountain fault.

So, geometrically, what that is, you have the Whiteoak dipping beneath the site about 33 degrees, again, parallel to bedding, and the fault that overlies that in that stack of units is the Copper Creek, and the site is located within that fault block in between those two structures.

Okay. Well, it's kind of an important thought to note we have an age date on the fault gouge. Okay. What is "fault gouge"?

Well, that's when you sort of are grinding the fault along the surface beneath it, you actually crush the rock and mill the rock and grind it. So, it's called cataclasis, but the point is that you develop a gouge, a pulverized rock that's sort of very characteristic and it's due to displacement, in this case, along the Copper Ridge fault.

That gouge has been dated at around 280 million. Now, it wasn't dated at the site; it was dated at a different location, but it's the same fault.

Reported displacement on this fault is ranging between 7 and 31 miles, depending on where you look at it. And with this age date, again, it is clearly older than Quaternary. No question about that.

Well, okay. I promised you a look at stuff in the field, so let's --

MEMBER SUNSERI: Just a quick question.

DR. STIREWALT: I'm sorry. Yeah, please.

MEMBER SUNSERI: Can you tell me, again, what "northeast-striking and southeast-dipping" means?

DR. STIREWALT: I certainly can.

If I talked about a bed, the strike would be in this direction for this. So, it would be striking towards you and it would be dipping towards my colleagues here.

So, that's literally a three-dimensional orientation of that fault surface and, in fact, the bedding, because they're parallel. Good question. Thank you. Sorry, I got carried away.

MEMBER RICCARDELLA: And would you clarify what the 7.4 to --

DR. STIREWALT: Is your mic on?

I'm sorry, could you repeat the question?

MEMBER RICCARDELLA: Yeah. Would you clarify what you mean by the 12 to 50 kilometers of displacement along the fault?

DR. STIREWALT: Yes. That's actually

measured -- a question earlier came up about how do you identify a fault? You can look at a marker that's displaced and they can determine, in the field, from field data, that that is the actual displacement -- amount of displacement along this fault.

And, again, the movement would be like this. So, there's evidence from what they see, in the field, that it has moved somewhere between 7 and 31 miles.

Of course, I mean, the fault doesn't go on forever. It does dies out. So, the amount of displacement will vary along it. So, a maximum of about 30 miles or so, yeah.

Okay. I promise to --

MEMBER RICCARDELLA: Sorry. So, I thought I got it, but I don't got it.

So, are you saying it's the length of the fault or the actual fact that it moved 31 miles?

I thought it was --

DR. STIREWALT: Yeah. The displacement is parallel to the fault surface, it's not the length.

MEMBER RICCARDELLA: Okay.

DR. STIREWALT: That is the actual displacement.

MEMBER RICCARDELLA: Okay.

DR. STIREWALT: The actual displacement. Am I clear on that?

MEMBER RICCARDELLA: And that took place over many years a long, long time ago, right?

DR. STIREWALT: Yes. Yes. Because we have this nice, little age date at around 280, so we know it's pretty old.

MEMBER RICCARDELLA: Yeah.

DR. STIREWALT: Okay. All right. I'm excited to show you what fault gouge looks like.

This is, again, along the Copper Creek fault. This is in borehole CCB2 that I located for you, and I hope that you can see a rather clear distinction between the gouge and between the rock that is not involved in faulting.

Well, what are some of the differences? Okay. Again, we know the gouge is dated at 280. And if you look at this, I mean, this is really pulverized rock.

In the part that's not faulted, you can see very, very well-developed bedding. You don't see anything like that here. It's totally structureless. All the original sedimentary structures that were there before the fault movement are erased, they're gone, they're pulverized.

So, this, again, is a -- I think a good illustration and why you would know in the core that, gosh, I'm not looking at a normal stratigraphic sequence. Something has happened to this rock.

And what happened to it, in this case, is 30 or so miles of displacement along the Copper Creek fault.

Any questions on that?

Okay. Well, then let's talk about the shear-fracture zones. They were of concern because we wanted to make certain that there wasn't anything related to those particular features that suggested Quaternary deformation.

Now, you've already heard that the shear-fracture zones at the site contain pressure solution features, namely stylolites, in two different orientations. So, two sets of these solution features. They are both parallel and perpendicular to bedding.

Now, those features tell us some really important stuff about the orientation of the stresses that must have influenced those shear-fracture zones. So, let me just sort of talk about that a bit.

The -- maybe I should qualify. The reason you can see a stylolite, and you saw them in the earlier slides -- I'm going to show you in another slide, but the reason you can actually see this little surface where the dissolution occurred, is because when you -- again, the stress itself operates perpendicular to the dissolution feature and you can actually see it because I'm dissolving a limestone.

You have parts, clays and things, that do not dissolve and, lo and behold, they concentrate right along that little surface so you can see -- you can see a little crinkly line that's marked by minerals that did not dissolve. And that's how -- that's why you can see the stylolite.

Okay. The nontectonic bedding-parallel stylolites that, again, are the earliest, these formed during deposition and lithification of the sedimentary units due to the vertical overburden pressure.

That is to say as you're stacking -- depositing this rock, stacking them one on top of the other, you develop a very thick overburden. And that overburden produces a stress that's perpendicular to bedding, just like those stylolites, and that's the source.

So, this is syndepositional sort of nontectonic strictly, but it occurred very, very early.

All right. Now, the bedding perpendicular stylolites, which are the latest, likely formed in response to the near-horizontal stresses related to transport of the flow sheets.

And we know that timing is around 280 million, so they're old, also, but the point is that it is a tectonic overprinting, but that tectonic overprinting is not Quaternary in age. It's also very, very old. Very, very old.

So, during the site audits and site visits, then, staff were able to examine the shear-fracture zone specifically on the Rockdell formation in borehole MP-101.

And, guess what. As you suspected, I'm going to show you that. You saw this same piece of core in something that the Applicant presented, but what I'd like to do, I just sort of blew up one part of it to sort of note that bedding is well-developed, you can see bedding surfaces; you can see these little squiggly, dark-colored lines marked by the clay that didn't dissolve that are parallel to bedding; and you can also see some that are perpendicular to bedding.

Now, again, since these features form essentially perpendicular to the causative stress, they must have developed at two different times. And we have the timing of the latest because of the dating on the fault motion. It's around 280 million.

So, again, that sort of sets the scene for the conclusions that we can make about any concerns related to tectonic features that are young Quaternary at the site.

If there are no questions on that picture, let's take the final slide and let's sort of address the conclusions.

Again, no tectonic features with the potential for adversely affecting suitability of the site occur in the site region, the site vicinity, the site area or at the site location. That is to say, no data suggests the presence of Quaternary tectonic features.

In fact, the primary event that's registered, which is development of the regional thrust faults, is dated around 280 million.

It's kind of geologically fun to think about that that actually happened when Africa was colliding with North America, growing the Appalachian Mountains to the east of this. So, it's a part of that major tectonic package, but that's exciting to a geologist anyway.

Okay. And, again, no field data --

CHAIRMAN KIRCHNER: An earlier slide had it 280.3 or something.

DR. STIREWALT: Yeah. 279 --

CHAIRMAN KIRCHNER: So, how do you get such precision in this dating? How did they derive significant figures?

DR. STIREWALT: Well, it's done with radiometric dating using --

CHAIRMAN KIRCHNER: Okay.

DR. STIREWALT: -- I believe it was argon-argon in this case. And you still have that era band (phonetic) on it, but, I mean, it --

CHAIRMAN KIRCHNER: It's not using argon in the laboratory.

Is argon the element --

DR. STIREWALT: Yes.

CHAIRMAN KIRCHNER: -- just for the public record?

DR. STIREWALT: Yes. Yes.

CHAIRMAN KIRCHNER: Okay.

MR. FETTER: Potassium-argon, argon-argon.

DR. STIREWALT: Yeah. That's a good question.

Okay. And, again, there's no field evidence that suggests the shear-fracture zones are younger than that thrusting event which, again, really pins it as being certainly older -- certainly preQuaternary age, which was our concern.

Well, there's no question that karst is a primary nontectonic feature that's recognized, and that does have a potential for adversely affecting site suitability.

Certainly the Applicant described the geologic characteristics of the site region, site vicinity, site area, site location in full compliance with the regulatory requirements and in accordance with guidance in 1.208.

Are there other questions or comments or anything on this?

Okay. Well, that being the case, I am pleased to pass the talking baton to my colleague, Ms. Jenise Thompson, who will speak to 2.5.3; and you may be certain she is going to mention karst.

MS. THOMPSON: And show lots of pictures.

My name is Jenise Thompson. I was the primary reviewer to Section 2.5.3, Surface Deformation.

So, in Section 2.5.3, we focused on the information related to the assessment of both tectonic and nontectonic surface deformation and the potential for that surface deformation.

So, at the Clinch River site, we looked specifically at geologic features observed in the East Tennessee seismic zone and at numerous karst-related features that were observed in the site area.

So, for tectonic surface deformation, we looked at potential for tectonic surface deformation in the site area and concluded that there were no Quaternary age tectonic structures near the site location.

So, this was based on available data that showed negligible potential for surface deformation due to tectonics.

We also looked at river terraces. I know that the Applicant mentioned a rather extensive river terrace study that they did.

We observed those terraces in the field and saw no evidence of surface deformation that could be attributed to tectonics.

So, the staff concludes that there's no evidence of Quaternary age tectonic surface deformation at the site.

The relationship of potential tectonic surface deformation to observe seismicity in the East Tennessee seismic zone is undetermined.

Due to carbonate rocks in the subsurface, direct observation of karst features in the field and ongoing dissolution processes in the site vicinity and interpreted cavities in the rock core, as indicated by missing segments, which I will show you, the staff concluded that karst has the potential to cause surface deformation at the Clinch River site.

So, you saw this picture earlier. This is the distribution of karst features in the Clinch River site area.

MEMBER BROWN: Could you go back a slide, please. 16. You said the relationship between the deformation and observed seismicity is undetermined.

That sounds not like a good conclusion. You don't know what's going on.

MS. THOMPSON: There are features within the site vicinity and the site region, so not within the five-mile site area, that are still under study. And there are numerous possibilities of what their origin could be, but none of them have been definitively determined to be related to seismicity in the East Tennessee seismic zone.

MEMBER BROWN: Does that have any meaning relative to the positioning of this plant in this location?

What's the conclusion?

Is it it doesn't bother siting this particular potential plant in this region?

Is that what that means?

MS. THOMPSON: My colleague David will address that more in his discussion of the vibratory ground motion in Section 2.5.2.

MEMBER BROWN: Okay. Well, I'm old enough I may not remember this by that time.

(Laughter.)

MS. THOMPSON: David will.

MEMBER BROWN: Thank you.

MS. THOMPSON: So, moving on to karst, each of the black dots shown here is a karst depression.

So, there were approximately just under 3,000 karst depressions or karst features mapped in the five-mile radius of the Clinch River site, which is that red star in the center.

So, these depressions can be any number of forms. They can be swales, which are kind of a small, wet depression at the surface; a swallet, which is slightly larger and usually has some percolation or water draining in it; or sinkholes, which the Applicant showed you some great examples of, which is that surface depression which is the result of subsurface dissolution and collapse. So, that's how we can kind of see what's going on in the subsurface without digging down into the ground.

Something to note here, Gerry was talking about the dip of the layers. And you can see the blue dip angle -- dip symbols here showing you what direction these layers are dipping, and you'll notice that most of these depressions, these karst features are in the Knox group, which is that tan color; there are a few in the Chickamauga group, which is what's underlying the Clinch River site; and then there are just a handful in the Conasauga group, but all three of those groups are present in the subsurface because of that dip angle.

So, we also observed cavities in the rock core at the site that was part of the boring program. So, one interpretation of these cavities is that they may be recording the cavities that we see for karst and dissolution features.

So, this particular cavity was mapped here in borehole MP-418, and the cavities were of varying thicknesses.

In total, there were 238 cavities encountered in the boreholes of numerous, varying sizes. Anything that was more than a tenth of a foot of no recovery was mapped as a cavity in the boring logs.

So, they were encountered -- these cavities were encountered in all of the subsurface units that the boreholes encountered, but the size differs.

So, when you have the more pure carbonates of the limestone units, you would have larger and more frequent cavities. Whereas when you have the more classic units, some of the siltstones, you would have smaller and less frequent cavities.

So, one possible interpretation of what these cavities could be representative of is pinnacle and cutter karst -- or buried pinnacle and cutter karst.

And so, these are two examples of pinnacle and cutter karst that the staff observed within the five-mile site area. And pinnacle and cutter karst is the result of dissolution along joints and bedding planes and it could result in these cavities.

And so, on the left picture, you see my colleague's hand here and this is the joint along which you have dissolution and you end up with this larger dissolution pit.

The depth of this, I can stick my arm all the way in to my shoulder, and I could keep going if I had larger arms.

And then for -- on the lower right, this is a typical exposure of the pinnacles that you see. So, we have these high points, and then you would have the joints at the low points here, which is where you have your dissolution occurring, and it kind of looks like a jawbone in this kind of classical exposure of pinnacle and cutter karst.

So, some of the things that you might see in borings that would lead you to think that it would be buried pinnacle and cutter karst would be different thicknesses of soil or overburden or filled-in cavities that have kind of soil or other material that is not consistent with the subsurface layers that you would expect to see.

So, additional karst features that we saw, we mentioned the swales, the swallets and the sinkholes, which are additionally the surficial karst depressions that we see.

And I use this picture because this is the best one that I have of a clear sinkhole. So, you can see that classic karst depression and what it looks like.

And this is 4 1/2 miles east of the Clinch River site near the Melton Hill Dam, and the rim of this depression is generally the tree line and where this nice little house is sitting.

So, you would have water flow down the slope into this sinkhole here where you have ponded water, but there is active percolation. So, the presence of ponded water is generally determined on a precipitation event.

So, if you were to come in the middle of a drought, there wouldn't necessarily be ponded water, but this is one of the examples of many of the sinkholes that the staff went and observed at the site.

Another karst feature that was observed in the site area was caves, which are kind of the classic karst feature.

So, the Copper Ridge cave was the largest cave that the staff visited in the Clinch River site area, and this occurs in the basal unit of the Knox group, which, again, because of that dip angle of the units below the Clinch River site, the Knox group is present in the subsurface.

And this is a cave that occurs inside a

closed basin in a hill slope. So, you have this closed depression -- that's the rim, the dotted line there -- you have a flow down into the joint, which continues here -- there's the entrance to the cave -- and that line in the roof, that joint, that small break in the roof, that's where dissolution is occurring.

You also have dissolution along bedding planes. As you can see down here at the yellow arrow, you kind of have that dissolution where you have some units that are more prominent than others.

And supporting this dissolution along joints and bedding planes is that this cave follows the orientation of the joint through a 90-degree turn just inside the entrance to the cave. So, you have dissolution along the joint, and when the joint turns 90 degrees, the cave follows.

So, given the presence of karst and the numerous karst features in the site area, the Applicant acknowledged the need to perform geologic mapping for documenting the presence or absence of karst features, faults or shear-fracture zones in plant foundation materials.

Accordingly, the staff identified Permit Condition 1, which is here, to allow the staff to confirm and the Applicant to verify the determinations made at the ESP stage with respect to surface deformation. And then, if necessary, to mitigate any potential hazard through the appropriate means.

MEMBER CORRADINI: So, they would map out where the holes are. And then if they are of a certain size, they would have to be filled or is that left to the Applicant? That's what I'm curious about.

MS. THOMPSON: This will be addressed at the COL stage. So, if there are -- so, they will perform the mapping and it will be made available for the staff to go into the field and examine.

And then if anything is identified, it will be up to the Applicant to determine an appropriate mitigation plan.

MEMBER CORRADINI: So, they can suggest a remedy which you can then --

MS. THOMPSON: Yes. And that goes to something -- the permit condition, the confirmatory activities, which would include the geologic mapping and, if necessary, the development and implementation of a mitigation plan were -- are all included as part of COL Action Item 2.5-3 in Section 2.5.4 of the ESP.

MEMBER CORRADINI: So, if they map out -- just for example. So, for example, if they plan to have an embedment that's a hundred feet deep and so wide and so deep -- or so wide and long based on a particular design, if they map out the cavities, is there -- and they find that they have -- I'll pick a number -- ten of them three feet or less, is there some smaller -- is the size of the cavity determined on how one would remedy it or is there a prescribed approach?

I'm still trying to understand what this condition means other than look, see what you find and report back.

DR. HEESZEL: Or mitigate as needed.

MEMBER CORRADINI: Or mitigate as needed, but what I -- then my next question is that once they repot back and they suggest a remedy, are there acceptable remedies that have been done in the past and they would just pick from those or is it quite customized to the region? That's what I'm trying to understand.

MEMBER RAY: Before you respond, isn't this just a carve-out from the normal scope of an ESP? In other words, it simply can't be addressed until --

MS. CANDELARIO: Yes.

MEMBER RAY: -- COL --

MS. CANDELARIO: It won't be addressed

until COL application --

MEMBER RAY: There's no prescribed solution --

MS. CANDELARIO: Right.

MEMBER RAY: -- no criteria that are preestablished or anything like that.

MS. CANDELARIO: Right. But if they find voids on the geologic mapping phase, then the COL applicant will address that as part of COL Action Item 2.5.3 which I can read.

And it says, an applicant for a COL or CP referencing this early site permit should design and conduct additional subsurface investigation during excavation and construction to detect cavities below the foundation elevation that could adversely affect condition performance. In addition, the Applicant should perform confirmatory drilling or borehole testing during excavation/construction to characterize the source of geophysical anomalies and to develop a grouting program with associated ITAACs when needed based on the information obtained by the geologic mapping, geophysical surveys and specific analysis to mitigate the effect of bores or cavities on foundation performance at and below the foundation level of the safety-related structure.

MEMBER RAY: Okay. Thank you.

MS. THOMPSON: Thank you, Luissette.

So the staff's conclusions on the next slide are as follows: "The staff concludes that a negligible potential exists for tectonic surface deformation that could adversely affect the suitability of the Clinch River site. Staff also concludes that karst is the primary potential hazard for nontectonic surface deformation at the Clinch River site. The staff further concludes that the Applicant described the information related to the assessment of the potential for tectonic and nontectonic surface deformation in full compliance with the regulatory requirements."

CHAIRMAN KIRCHNER: So, this addresses what Charlie raised earlier. It just struck me, as well as him, that your Slide 16, that first bullet, that's rather a sweeping conclusion because your summary slide says that there's not a problem.

In other words, in 16 you say "surface deformation in this area is largely undetermined," but then you go on and draw a conclusion that says, "for this site, negligible potential exists for tectonic surface deformation." That would be adverse.

MS. THOMPSON: So, the statement on Slide

16 is that the relationship between tectonic surface deformation and the observed seismicity in the East Tennessee seismic zone is undetermined, but that does not -- that's not in conflict with our conclusion that there's a negligible potential for tectonic surface deformation at the site.

And David will get a little more into the relationship in the seismicity of the East Tennessee seismic zone and how it may affect the site; but from the perspective of surface deformation and what evidence we have now and the conclusions that we have available to us, there is a negligible potential for tectonic surface deformation to affect the site.

CHAIRMAN KIRCHNER: Okay.

MEMBER BROWN: Would you say that again? There is -- did you say "negligible"?

MS. THOMPSON: Negligible potential --

MEMBER BROWN: Okay. I didn't hear you.

MS. THOMPSON: -- for tectonic surface deformation to affect the site.

The primary hazard for surface deformation, either tectonic or nontectonic, at the Clinch River site is karst.

MEMBER BROWN: You gave us a picture and a discussion about the cave and how it went in and it goes at right angles underground. That didn't look like a very good place to try to mount -- to put the site.

That's a nice example, but I'm trying to connect the dots between your example and what they reported in their writeups, in their presentation.

MS. THOMPSON: The cave is just under five miles east-northeast of the Clinch River site.

MEMBER BROWN: Okay.

MS. THOMPSON: And it's within the Knox group, which is in the deep subsurface at the Clinch River site.

So, this is the -- the cave -- the example that I used is the Copper Ridge cave and it occurs in the Copper Ridge dolomite, which is the absolute bottom layer of the Knox group.

Which, if you remember Gerry's slides of the borings, the deepest boring at the site, I think it just reached the top of the Knox group, which was the Newala formation, and we're talking about what's way at the bottom far below that.

But because of the way the faulting in the area has occurred and the exposure of the units, in some areas you have -- the Knox group has -- if you click once -- or, I'm sorry, back to the second slide,

Slide 17, I think.

So, the Knox group is this one here. So, we're talking about the bottom unit of that. So, something that's like down over here.

Do you want us to go back to the picture of the --

MEMBER BROWN: No, that's fine.

MS. THOMPSON: Yeah.

MEMBER BROWN: You could stop on that one you were talking about, gaps. I didn't ask the question at the time. Right there -- no, not that one. It's in your presentation.

MS. THOMPSON: Oh, cavities.

MEMBER BROWN: Cavities.

MS. THOMPSON: Yes.

MEMBER BROWN: Where are the cavities? What should we look at in that picture for the cavities?

MS. THOMPSON: So, this is the --

MEMBER BROWN: Right there?

MS. THOMPSON: -- recovered core.

MEMBER BROWN: Okay.

MS. THOMPSON: And this here -- and I'm sorry the picture is not lighter, but this is a -- basically a pool noodle that is marking no recovery.

So, it's a foam tube that's marking that there was no rock recovered between 59 feet and I think that's 63. So, you had about a four-foot period of no recovery.

CHAIRMAN KIRCHNER: So, meters down from the surface where that borehole was extracted --

MS. THOMPSON: Yes. So, this is the --

CHAIRMAN KIRCHNER: -- that sample was extracted.

MS. THOMPSON: Yes.

MEMBER BROWN: Okay.

MS. THOMPSON: So, this is depth. So, this is just an example of what we observe as a cavity in core, what a cavity looks like when you encounter it in a boring program.

And when you open up the core box, that's what it is. It's a piece of round foam that says, "no recovery" on it and a boring log that documents the --

MEMBER BROWN: Well, somebody put the foam in, I guess, when they open it up, right?

(Laughter.)

MEMBER BROWN: I'm sorry, you got to have humor in here somewhere. Okay. I understand what you meant. I couldn't see that when you were talking about it.

MS. THOMPSON: Okay.

MEMBER BROWN: Thank you.

MS. THOMPSON: If there are no other questions, I'll introduce my colleague --

CHAIRMAN KIRCHNER: Would you -- again, a slide like this is very informative, but is it directly relevant? So, yes, you find cavities, karst you identified as a major issue.

Would you agree with the Applicant that most of the cavity formation is probably closer to the surface than the depth of the foundation that they plan to use for the actual site?

MS. THOMPSON: In general, you will have larger and more frequent cavities closer to the surface.

CHAIRMAN KIRCHNER: Okay. Are you going to talk to their analysis with PLAXIS?

MS. THOMPSON: That will be addressed by our geotechnical engineer.

CHAIRMAN KIRCHNER: Okay. Good. I'll wait then. Thank you.

MS. THOMPSON: So, I will pass the pointer on to Dr. David Heeszel for vibratory ground motion.

DR. HEESZEL: Good afternoon. My name is David Heeszel. I was the lead reviewer for Section

2.5.2, Vibratory Ground Motion.

Next slide. So, some key topics of review for Section 2.5.2 was the Applicant's treatment of the Eastern Tennessee seismic zone, the Applicant's approach to developing its site response inputs, and its 2D site response sensitivity study.

So, the Eastern Tennessee seismic zone is a region outlined in green here of elevated seismicity rates relative to the background rate and rest of -- the majority of the rest of the eastern United States. The magnitudes are quite small, magnitudes 3, there's a couple 4s.

These earthquakes generally occur within the basement rocks, so within the granitic bedrock beneath the sedimentary section that we spent all of this time talking about. So, they're quite deep relative to what we've been discussing previously.

The Eastern Tennessee seismic zone is included within NUREG-2115, the CEUS SSC. It's included both within our seismic tectonic zones and within the Mmax source zones.

Sensitivity studies were done at the time of the NUREG-2115 to ensure that the Eastern Tennessee seismic zone was adequately captured by the models as they were developed; however, there's been a couple of recent geologic studies that have interpreted the potential based on some trenching work and some field mapping for potentially large earthquakes, magnitude greater than 6 1/2.

Next slide.

MEMBER RICCARDELLA: Is that subsequent to NUREG-2115, that recently?

DR. HEESZEL: It's subsequent, yes.

Next slide.

CHAIRMAN KIRCHNER: Let's go back to that slide.

When you put something down like that, that, for the public, would raise questions, I would think.

DR. HEESZEL: Exactly. I'm going to address them.

CHAIRMAN KIRCHNER: So, you're going to address the --

DR. HEESZEL: Yeah.

CHAIRMAN KIRCHNER: But in terms of notwithstanding potential, but based on measurements where you have a lot of data, it seems to me, not surprisingly, it's -- and I'm not a geologist, so I may not be using correct clinical terminology, it looks like this is active, that's not surprising given the geology, but the magnitudes that have been measured are, on the average, quite low.

DR. HEESZEL: That's correct.

So, if you look at this slide here, you can't quite see the --

CHAIRMAN KIRCHNER: Well, we can read it from your view of --

DR. HEESZEL: Yeah.

CHAIRMAN KIRCHNER: Yes.

DR. HEESZEL: So, you know, there's, what, two magnitude 5 -- between 5 and 6 over here; but within the Eastern Tennessee seismic zone you're looking at 3s and 4s.

CHAIRMAN KIRCHNER: So, you have not -- in the past, you've never seen something six or greater?

DR. HEESZEL: No, not within --

CHAIRMAN KIRCHNER: And we make large arguments about how this is geologically aged 280 million years.

What would -- what is the potential for newer seismic activity of such a magnitude?

DR. HEESZEL: Background tectonic stresses.

CHAIRMAN KIRCHNER: But that's true almost everywhere you have a fault and --

DR. HEESZEL: And that's why Mmaxes within the entire central and eastern United States account for the potential for large earthquakes.

CHAIRMAN KIRCHNER: Okay. And that frequency would be what?

DR. HEESZEL: On the order of which frequency?

CHAIRMAN KIRCHNER: 6.5 or greater.

DR. HEESZEL: It was suggested within 120,000 years, I believe.

CHAIRMAN KIRCHNER: 10 to the minus fifth. Okay.

MEMBER RAY: What did you say?

MEMBER RICCARDELLA: 10 to the minus 5th.

MEMBER RAY: Yeah. Well, I come from a different part of the country where the continued escalation of the potential doesn't seem to ever stop.

CHAIRMAN KIRCHNER: Yeah. That's my concern. It's kind of an open-ended item here, unless there is more explanatory information.

Is it speculative or is it --

DR. HEESZEL: The geologic studies are quite preliminary and the interpretations vary widely amongst different experts about what the source for the geologic features is.

CHAIRMAN KIRCHNER: Just caution, in general, that's a declarative statement there. That's not -- that's suggestive of a much higher seismic risk.

DR. HEESZEL: And that's what the recent geologic study has -- that's their assertion.

CHAIRMAN KIRCHNER: And that recent study has been reviewed and considered as a reasonable conclusion?

DR. HEESZEL: It is one possible interpretation for the field notes.

CHAIRMAN KIRCHNER: Okay. Well, I'm just, in a different way, voicing Harold's concern that when you put that on the table, then there's the danger of ever escalating the design-basis earthquake that you're designing the plant for.

Okay. I've made my point. Thank you.

DR. HEESZEL: Next slide, please.

So, in response to this recent geologic data, the Applicant performed two sensitivity studies following SSHAC guidance for a Level 2 study.

The first study, they evaluated the Mmaxes; and then the second study, they evaluated the magnitude-frequency relations.

The Mmax values in NUREG-2115 encompass

the proposed Mmax values developed by these -- or suggested by these recent geologic studies and, in fact, give a large amount of weight to magnitudes that are consistent or larger than what has been suggested.

MEMBER RICCARDELLA: But they were further away, right? As I understand, you know, the Mmaxes -- the big high ones are just -- they're not specifically within the zone, are they?

DR. HEESZEL: Within each zone there's a set of Mmax values that are established. So, within the PEZ, the Paleozoic Extended Zone, the zone that the Clinch River site and Eastern Tennessee sit within, there is a suite of Mmaxes, a range. And that range encompasses the range that has been recently suggested.

In addition, the recurrence of these large-magnitude events that's in NUREG-2115, if you look at the NUREG-2115, the recurrence rates for magnitude 6 1/2 and 7s is on the order of 13,000 to 88,000 here. So, again, within the same range of values as has been suggested recently.

And so, you know, based on the fact that the Mmax values are consistent and the frequency of recurrences is consistent, staff has concluded that NUREG-2115 adequately captures our current understanding of the seismic hazard in the Eastern Tennessee seismic zone.

Next slide. This slide simply shows staff's confirmatory PSHA calculations at three frequencies compared to the Applicant's. Applicant's are solid; staff's are dotted. You can see at 10 to the minus 4 and 10 to the minus 5 there's very good agreement.

Next slide.

MEMBER BALLINGER: I'd like to be a little bit more blunt.

DR. HEESZEL: Okay.

MEMBER BALLINGER: Back on Slide 26, that statement, recent geologic studies interpret --

MEMBER CORRADINI: Is your microphone on?

MEMBER BALLINGER: I did -- it's on. Okay. So, there's that statement. And then on two slides later -- no. No. Excuse me. One slide later, the bottom on, that implies to me that you folks have done a study because the recent geologic studies interpret potential for larger than 6.5. Now, you say that the staff concludes.

So, this study was done after 2115?

DR. HEESZEL: That's right.

MEMBER BALLINGER: So, but now you

conclude that 2115 does adequately capture the events that would be greater than 6.5?

DR. HEESZEL: The study proposes that there is the potential for large events. Our conclusion is that the NUREG adequately captures the potential for large events.

MEMBER BALLINGER: Oh, okay. Okay.

CHAIRMAN KIRCHNER: Another way to say it would be at brackets, that potential.

DR. HEESZEL: But it bounds.

CHAIRMAN KIRCHNER: Okay.

MEMBER RICCARDELLA: But still I'd like to get back to this distance.

As I recall -- I reviewed 2115 several years ago -- the big, large-magnitude earthquakes were pretty far away from this Tennessee --

DR. HEESZEL: You're talking about the RMLEs like in Charleston or in --

MEMBER RICCARDELLA: And near Detroit. I think there was one near Detroit, right, or --

DR. HEESZEL: New Bridge, Charleston, Charlevoix --

MEMBER RICCARDELLA: Is that where these recent geologic studies are talking about or --

DR. HEESZEL: No. No.

MEMBER RICCARDELLA: -- are they talking about right in that geologic --

DR. HEESZEL: Right in here. Sorry. Right in this -- I believe it is in the little box, this little black box that is barely visible.

MEMBER RICCARDELLA: Okay. Although, the data showed that the largest was about five, right?

DR. HEESZEL: Say again?

MEMBER RICCARDELLA: The data shows that the largest --

DR. HEESZEL: The seismicity data shows magnitude 5s, yeah.

MEMBER RICCARDELLA: Okay.

MEMBER RAY: Well, in all cases, we're talking about recurrence interval or probability.

MEMBER RICCARDELLA: Yeah.

MEMBER RAY: And so, there's no capping of the size that could conceivably occur. The issue is, do we have the recurrence interval of a large earthquake correct, and they're saying they think 2115 still does it.

Okay? I mean, is that -- do you agree?

DR. HEESZEL: Yes.

MEMBER RAY: All right.

DR. HEESZEL: All right. Site response.

So, the Clinch River site has a significant dip in the subsurface approximately 30 degrees. We've discussed it previously.

It has relatively high seismic velocities greater than 5,000 to greater than 10,000 feet per second.

Just for a reference frame, basement crystalline rock is considered about 9200 feet per second. So, you're talking about - you know, for sedimentary rock it's quite fast.

CHAIRMAN KIRCHNER: So, hard rocks.

DR. HEESZEL: Hard rocks. If you're not careful, you'll hit yourself in the head when you swing your rock hammer at it.

So, the Applicant developed site response inputs using three profiles in each of its two locations. And the base case profile was developed using log mean seismic velocity as a function of depth.

So, if you go down 50 feet, you take all of your data for 50 feet, calculate the log mean, and you calculate an upper and lower profile based on the standard deviation of that log with the statistical variation.

The effectiveness is obviously that if you have Unit A right next to Unit B, with the dip, you're going to smear those units together. So, you're going to discard some of your geologic information in favor of your geophysical information.

And so, the staff requested that the Applicant explain how the use of these multiple-phase cases accounts for the dip across the site.

The Applicant's response was that the smearing of the units, using their approach, is appropriate because you're maintaining both the mean and the range of values as a function of depth.

If you think about your plant that crosses boundaries, it's going to sense both units in accordance with how much of those units it's on top of. And so, the stratigraphic variations, the dip, is accounted for.

Staff performed its confirmatory site response by considering the dip explicit. So, if you think about, from left to right, you have an up section, a middle and a down section profile.

In addition, the staff truncated its profiles at the top of the Knox unit as it's over a kilometer thick and it has a velocity of greater than three kilometers per second. So, it's basically basement rock from a geologic -- or seismological perspective.

And as you'll see on the next slide, staff's overall results are consistent with the Applicant's.

And so, this shows staff's confirmatory GMRS in red, and the Applicant's in blue, and it's just shown for reference. And the dotted black is if you just consider the hard rock GMRS, you know, it's a hard rock site. Just make that assumption.

MEMBER CORRADINI: Maybe I don't understand what you mean by the staff's GMRS.

How did you come to that? By a separate calculation or just --

DR. HEESZEL: We did an independent confirmatory analysis using our base rock seismic hazard curves that I showed a few slides ago involved with site response that we developed in-house.

MEMBER CORRADINI: So, you used generic curves that you showed on Slide 28?

DR. HEESZEL: Yeah. The base rock hazard curves for the site that we developed for -- on Slide 28.

MEMBER CORRADINI: Thank you.

DR. HEESZEL: And as you can see --

DR. MUNSON: Just to clarify, they're not generic. They are specific to that latitude and longitude, those basement rock hazard curves.

And then on top of that, we do the site response and develop hazard at various elevations beneath the site.

MEMBER CORRADINI: Okay. Thank you.

MEMBER RICCARDELLA: For the record, I also compared those to the new GMRS for the Sequoyah site and these are very, very close to the new --

DR. HEESZEL: I mean, we did a similar analysis through the 2.1 process for the other sites.

MEMBER RICCARDELLA: Yeah.

DR. HEESZEL: And, as you can see, staff and applicant's GMRSes are very similar indicating that the differences in our approach to site response are -- don't change this overall answer.

Next slide.

DR. MUNSON: Just to add one thing -- David, could you go back?

CHAIRMAN KIRCHNER: Just state your name, please.

DR. MUNSON: Cliff Munson. I'm the senior-level advisor.

The dotted line shows that if you just treat this as a hard rock site and don't do site response at all, that's the GMRS you get.

So, of this wrangling about 1D versus 2D versus dipping layers, really, it doesn't have that big of an impact if you look at the dotted curve.

So, in the end, this is an extremely hard rock site that - the impedance contrasts are very small.

DR. HEESZEL: Okay. Next slide.

MR. CAMPBELL: And Dr. Munson is the senior-level advisor for siting for NRO.

MEMBER CORRADINI: Can you go back, because I wanted -- I agree with you that they don't look that different. But if I take the blue versus the dots or the red, the fact that at high frequency the Applicant's blue is a little bit lower comes from the very fact of the next slide which shows at high -- what am I trying to say -- at high frequency they are slightly below the 1D.

What I'm trying to understand is -- I understand what you're getting at is you're saying if you just take a monolithic, hard rock site, it's close enough for government work, right?

But I was just trying to -- when I was asking this of the Applicant, I was trying to understand 1D versus 2D calculations and it's all at high frequency.

MR. CAMPBELL: "Close enough for government work" isn't the right word.

(Laughter.)

MR. CAMPBELL: Close enough for the purposes of characterizing the site for the ESP.

DR. MUNSON: And I think that the slight dip you see in the high frequency might be due to the Applicant using a slightly higher damping.

DR. HEESZEL: Slightly higher damping and differences in interpolation algorithms, you know.

MEMBER RICCARDELLA: Because my understanding is the Applicant used 1D analysis.

DR. HEESZEL: Yes.

(Simultaneous speaking.)

MEMBER RICCARDELLA: He just did the 2D for comparison to show that the 1D was conservative.

DR. HEESZEL: Next slide. So, the Applicant, as we've discussed, has performed a 2D site response sensitivity study due to the relatively high dip in the subsurface.

Reg Guide 1.208 specifically called out this potentiality if there's a complicated subsurface structure, a multidimensional approach may be necessary.

In response to that, the Applicant developed this 2D analysis. Initially, the 2D analysis compared -- so, the blue line to a suite of lines that were developed using the same inputs that were developed for the 2D response, staff requested that they compare to the 1D response used for the licensing basis.

And the result is this graph here on the right, which satisfied staff's concern that the 2D results account for -- or the 1D results, excuse me, account for 2D structure using the site response inputs that are used in the GMRS development.

Next slide. So, staff's conclusions. The Applicant provided thorough characterization of the seismic sources surrounding the site as required by 10 CFR 100.23.

The Applicant adequately addressed the uncertainties inherent in that characterization through the use of a PSHA, and the PSHA follows guidance provided in Reg Guide 1.208.

Finally, the Applicant's GMRS adequately represents the regional and local seismic hazards and accurately includes the effects of the local site subsurface properties.

If there are no additional questions, I

will pass the baton to my colleague Luissette Candelario.

MEMBER RICCARDELLA: Is it the anticipation that in addition to designing this GMRS that at COL time there will also be a seismic PRA considering all frequencies?

I mean, at some point I would assume there'd be -- or a seismic margins analysis?

DR. HEESZEL: That is part of the Part 52 process.

MEMBER CORRADINI: But I want to make sure that I understood it could be either. It wouldn't have to be a probabilistic seismic analysis, it could be a --

MEMBER RICCARDELLA: SMA.

MEMBER CORRADINI: What is --

MEMBER RICCARDELLA: Seismic margins analysis.

MEMBER CORRADINI: Seismic margin analysis.

DR. MUNSON: Now, before fuel loading, they have to do a seismic PRA. A seismic margin is done for the design certification, but for the site-specific COL before fuel loading, once they receive license, they have to do a seismic PRA.

MEMBER RICCARDELLA: Okay. Thank you.

MEMBER CORRADINI: Thanks for the clarification.

MS. CANDELARIO: Thank you, Dr. Heeszel, and good afternoon.

My name is Luissette Candelario, and I was one of the technical reviewers for Section 2.5.4, Stability of Subsurface Materials and Foundations, and Section 2.5.5, which is Slope Stability Analysis.

My colleague, Dr. Weijun Wang in the audience, was also involved in the review of these sections.

This slide presents a summary of SAR Section 2.5.4 and the key areas reviewed by the staff. SAR Section 2.5.4 present the individual properties of subsurface materials and evaluation of stability of subsurface materials and foundation at the site.

SAR Section 2.5.4 includes the staff review of the Applicant field and laboratory investigations data and associated assumptions and calculations used to determine the geotechnical properties of materials at the site.

The staff also review the relationship of foundations and underlying materials, descriptions of your physical investigation performed at the site and the result of same.

The excavation and backfill, groundwater conditions, response of soil and -- dynamic loading, liquefaction potential and stability of foundations.

SAR Section 2.5.4 also includes 16 COL action items and one permit condition, which I will explain in detail in the upcoming slides.

In order to provide sufficient geotechnical information of the site without having a specific design, the Applicant provided a surrogate design in its application.

The surrogate plant approach covered a set of bounding parameters also known as the plant parameter envelope or PPE.

Under the PPE approach, the resulting ESP will be applicable for a range of reactor designs if the relevant design parameters falls into the PPE.

Section 2.5.4, PPE site characteristic, includes a minimum bedding capacity of 110 kips per square foot, a minimum shear-wave velocity of 4,650 feet per second, no liquefaction, and the deepest foundation embedment depth of 138 feet from the finished grade.

This slide present a site layout and a boring location plan at the Clinch River site. The figure provides the bounding power block area associated with the plant parameter envelope.

The Clinch River site subsurface investigation included 82 borings with depth of about 20 feet to 540 feet.

Seven of the borings were drilled at inclinations between 25 and 29 degrees from the vertical.

The Applicant performed three test pits, 44 observation wells, two surface geophysical tests, and rock pressuremeter tests in two borings. The Applicant performed downhole geophysical tests in 28 borings.

Next slide. This slide shows a cross-section of a bedrock structure and the stratigraphic unit of the site underneath the power block area.

The area bounded by the green lines shows the -- foundation level that the Applicant considered for the power block area.

The Applicant considered foundation embedment depth of 80 feet and 138 feet below plant grade. Bedrock is encountered approximately between 20 and 30 feet below the existing ground surface.

The average of the existing site elevation in the power block area is about 810 feet. The

Applicant use a finish plan rate elevation of 821 feet from the power block area -- for the power block area.

The groundwater generally occurs at depths ranging from near surface to approximately 25 feet. The average dip of the bedding plane is about 33 degrees southeast, and, as you can see, it doesn't change considerably between layers.

Because of this dipping bed at the site, various stratigraphic units may be exposed at the foundation level at different locations within the power block area.

The implications of this geologic feature for the evaluation of bedding capacity and sediment will be explained in the upcoming slides.

Next slide. One of the key review topics of interest is the assessment of the effect of underground voids on foundation stability.

As Jenise and Gerry point out, karst exists at the Clinch River site and the underground voids may adversely affect the foundation stability.

The Applicant site investigation provided preliminary information on void distribution and size. The Applicant data shows that cavities are present in all stratigraphic unit of the site, but are more predominant in the Rockdell Formation and Eidson

Member.

These cavities ranges from one feet to about 17 feet in height and includes open and clay-filled voids and are predominantly found within the first hundred feet from the ground surface.

The staff review the Applicant's PLAXIS 2D finite element analysis that assess the effect of postulated underground voids on foundation stability at the Clinch River site.

The staff review of the analysis focus on assessing the suitability of the site related to the critical size of a cavity that can affect foundation stability.

The 2D finite element model consider actual site conditions based on information obtained from the site investigation.

The diameter of the maximum void was assumed based on boring data, and the length of the void was conservatively assumed to be infinity.

Locations of the maximum voids were assumed at the most critical locations where the materials is the weakest and stress induced by structures is the highest.

Next slide. Another key review topic of interest is the foundation stability analysis with inclined strata.

The Clinch River site consists of multiple incline layers of various rock formation with possible weakened interfaces between the formations.

The staff review the Applicant's multiple traditional methods and finite element method used to assess foundation stability at the Clinch River site.

The Applicant used different traditional methods to obtain a range of calculated values and to identify which method is more suitable for the site.

The staff noted that traditional methods for the evaluation of foundation stability, such as bedding capacity and sediment, are based on assumptions of flat layers, either half-space (phonetic) uniform material, or layered uniform material. Therefore, the suitability of the traditional methods needed to be evaluated.

As such, the Applicant developed a two-dimensional finite element model to estimate the bedding capacity and sediment. The analysis modeled the actual site geologic conditions based on the site investigation data.

The staff concludes that the traditional method's results are in good agreement with those obtained from the finite element model and that the selected PPE values related to the site stability analysis are appropriate.

The staff identifies COL Action Item 2.5-12 through 2.5-14 for the COL or CP applicant to address the foundation stability of the site once a reactor technology and a specific location and extent of the seismic category I structure is identified.

Next slide. The Applicant used a PPE instead of a specific plant design. As such, seismic category I structures for the proposed site are not identified and the specific location and extent of the structure is not known at the ESP stage.

As such, the staff identify COL Action Item 2.5-1 through 2.5-16 that specifies that the reactor technology and site location-specific actions needed to be addressed by the COL or CP applicant when referencing this ESP.

Those COL action items are related to the following site characteristics: Site geologic features, properties of subsurface materials, excavation and backfill, groundwater conditions, static and dynamic stability, design criteria, and techniques to improve subsurface conditions.

The staff identified permit condition two, to ensure that the material above elevation 741 feet in areas where safety-related structure would be located are removed to minimize the adverse effect of discontinuities, weather and shear-fracture zones, and karst features on the stability of subsurface materials and foundations.

And that additional geotechnical investigations are performed at the excavation level to identify any potential geologic features that may adversely impact the stability of subsurface materials and foundations.

MEMBER CORRADINI: I want to make sure I understand this condition. So, this says that regardless of the design chosen, if it's chosen for this area, they have to excavate down to 741 feet, which is how much above the surface?

MS. CANDELARIO: 80 feet is the shallowest embedment considered by the Applicant.

MEMBER CORRADINI: Thank you. At least?

MS. CANDELARIO: At least.

The staff concludes that the Applicant adequately determined the site-specific engineering properties of subsurface materials underlying the Clinch River site and conducted sufficient evaluation of the stability of subsurface materials and foundations based on the result of field and laboratory tests and the state-of-the-art methodology and in accordance with Regulatory Guides 1.1-32, 1.1-38 and 1.1-98.

The staff concludes that the Applicant meets the requirements of 10 CFR Part 52.17(a)(1)(vi) and 10 CFR Part 100.23(c) for this ESP application regarding the stability of subsurface materials and foundations.

Any questions?

(No questions.)

MS. CANDELARIO: So, Sections 2.5.5 discuss the stability of slopes. Next slide. The NRC staff reviewed SSAR Section 2.5.5 which provide general descriptions of site related to slope stability analysis.

There are no existing slope on the site at this time, either natural or manmade, that could affect the stability of the site.

The Applicant deferred the actual slope stability analysis to the COL or CP application. In order to address the need for future slope stability analysis, the staff identified COL Action Item 2.5-15, which specifies that an applicant for a COL or CP application that references these early site permit should perform a slope stability analysis of any safety-related slopes, including dams and dikes, consistent with the selected reactor technology.

Next slide. The staff conclude that the Applicant provided unnecessary information on site topography and geologic characteristic and adequately described the slope's characteristic at the site.

The staff conclude that the SSAR Section 2.5.5 is adequate and acceptable because it meets applicable requirements of 10 CFR Part 50 Appendix S, 10 CFR Part 52.17(a)(1)(vi) and 10 CFR Part 100.23.

Any questions?

CHAIRMAN KIRCHNER: Questions? Members?

(No questions.)

CHAIRMAN KIRCHNER: Well, I think we should now turn to any members of the public who wish to make a comment.

Anyone present in the audience?

(No questions.)

CHAIRMAN KIRCHNER: Can we now turn to our phone connection, please.

OPERATOR: The conference is now in talk mode.

CHAIRMAN KIRCHNER: If there are any members listening in who wish to make a comment, please identify yourself and make your comment.

(No comments.)

CHAIRMAN KIRCHNER:  Hearing none --

MEMBER BLEY:  You said members?

CHAIRMAN KIRCHNER: Oh, excuse me, Dennis. That sounds like a familiar voice.  Please go ahead.

MEMBER BLEY: Okay. Well, I assume you're doing our round now and --

CHAIRMAN KIRCHNER:  Yes.

MEMBER BLEY: (Telephonic interference) presentation revises the questions, but I don't have anything to add.

CHAIRMAN KIRCHNER:  Thank you, Dennis.

Members?

(No questions.)

CHAIRMAN KIRCHNER: Let me then thank both the Applicant and the staff for very good presentations.  And with that, we are adjourned.

(Whereupon, the above-entitled matter went off the record at 3:51 p.m.)

# Clinch River
# Early Site Permit
# Part 2, SSAR Section 2.5

Advisory Committee on Reactor Safeguards
Committee Meeting
Presented by
Ray Schiele, Licensing
Wally Justice, Engineering
October 17, 2018

# Acknowledgement and Disclaimer

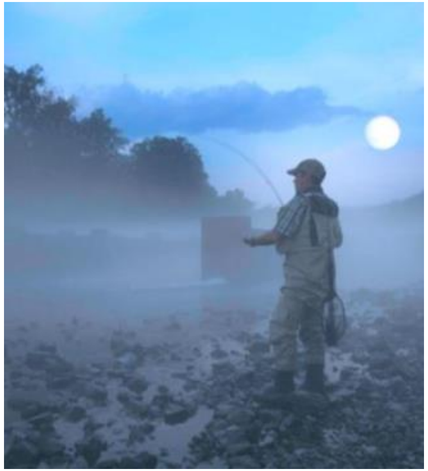
Acknowledgment: "This material is based upon work supported by the Department of Energy under Award Number DE-NE0008336."

Disclaimer: "This presentation was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof."

# TVA's Mission

## Serving the people of the Tennessee Valley to make life better.

Energy

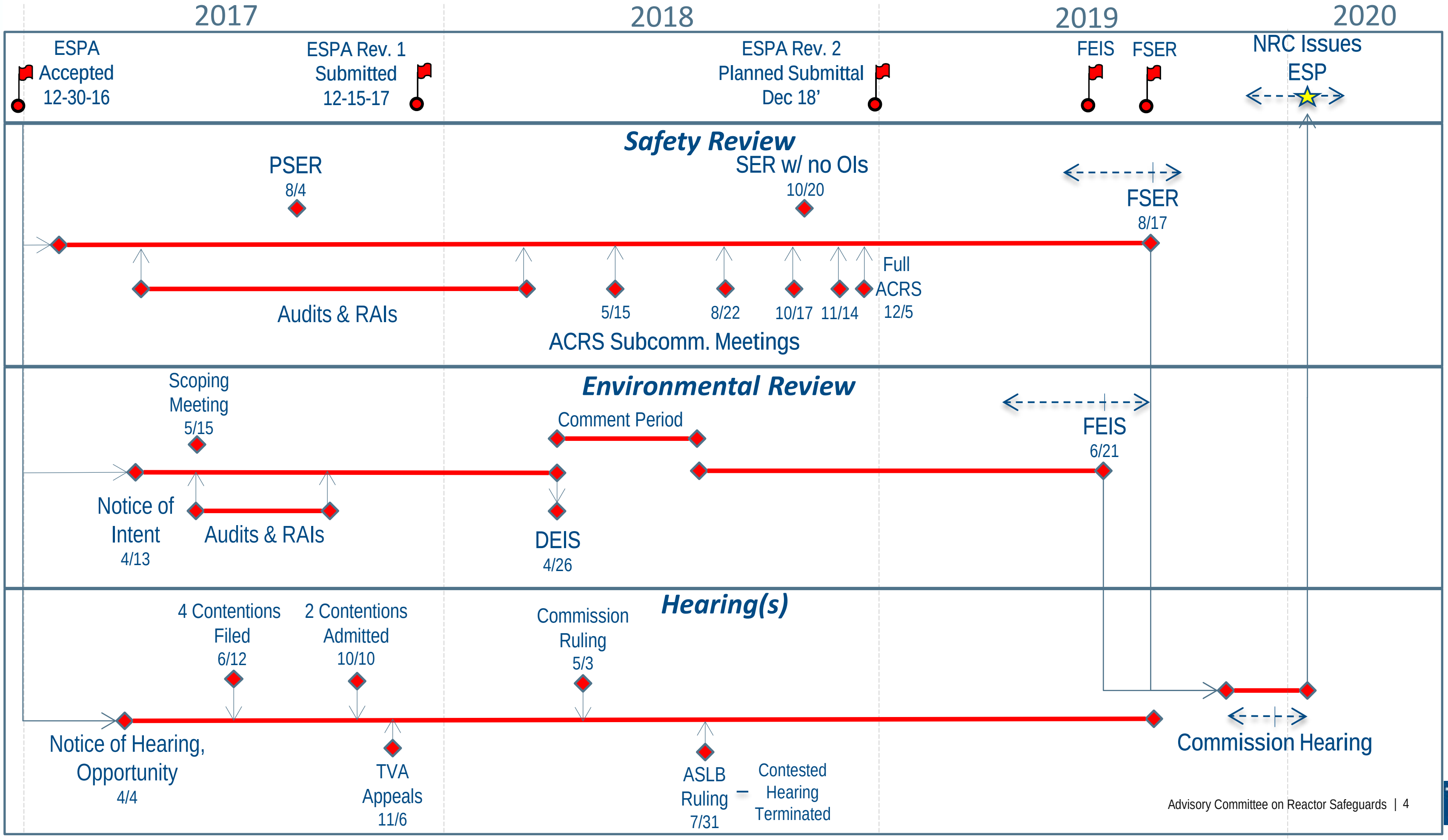


Environment

Economic Development

Partner with 154 local power companies, to serve more than 9 million customers in parts of seven states.  Directly serve 54 large industries and federal installations.

# NRC Review of ESPA



# Key NRC Interactions Related to ESPA SSAR Section 2.5

Two audits and one management/geologist visit were conducted to review the geology, seismology, and geotechnical information in the ESPA

- Pre-Application Readiness Assessment – September 15-17, 2015
  - 68 specific actions identified for resolution prior to application submittal
  - January 13, 2016 Public Meeting to discuss TVA's incorporation of issues in the application
- Audit – May 8-9, 2017
  - Office discussion
    - General presentation of the Clinch River site
    - Discussion and response to specific NRC Audit Information Needs regarding Geologic Information, Vibratory Ground Motion, and Geotechnical Engineering
  - Site Tour
    - Tour site and site vicinity geologic features
    - Review core samples
    - 6 specific areas where supplemental info was requested (part of RAIs)
- Management Visit – January 30-31, 2018
  - Office discussion
  - Site Tour

# Presentation Outline

Part 2, Site Safety Analysis Report (SSAR), Section 2.5, Geology, Seismology, and Geotechnical Engineering:

- Geology – Wally Justice, SMR Engineering ,Kevin Clahan, LCI, Janet Sowers, Fugro
- Seismology – Wally Justice
- Geotechnical Engineering – Wally Justice

# ESPA Part 2,
# SSAR Section 2.5
# Geology

# SSAR Section 2.5 - Geology

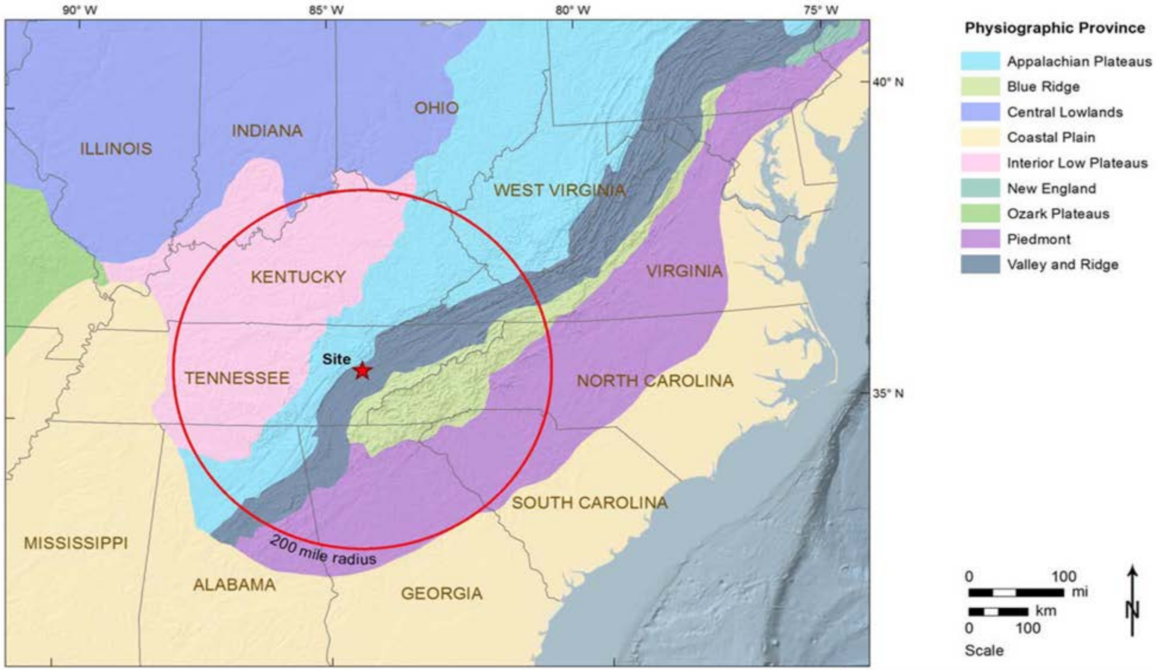
The geological and seismological information presented in this subsection 2.5.1 was developed from a review of previous reports for the proposed Clinch River Breeder Reactor, published geologic literature, and interpretations of data obtained as part of the surface and subsurface field investigations.

- Complies with the requirements of 10 CFR 100.23(c).
- The geological information was developed in accordance with NRC guidance documents Regulatory Guide (RG) 1.206
- NUREG-0800, Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition, Section 2.5.1, provides guidance for the development of Subsection 2.5.1.

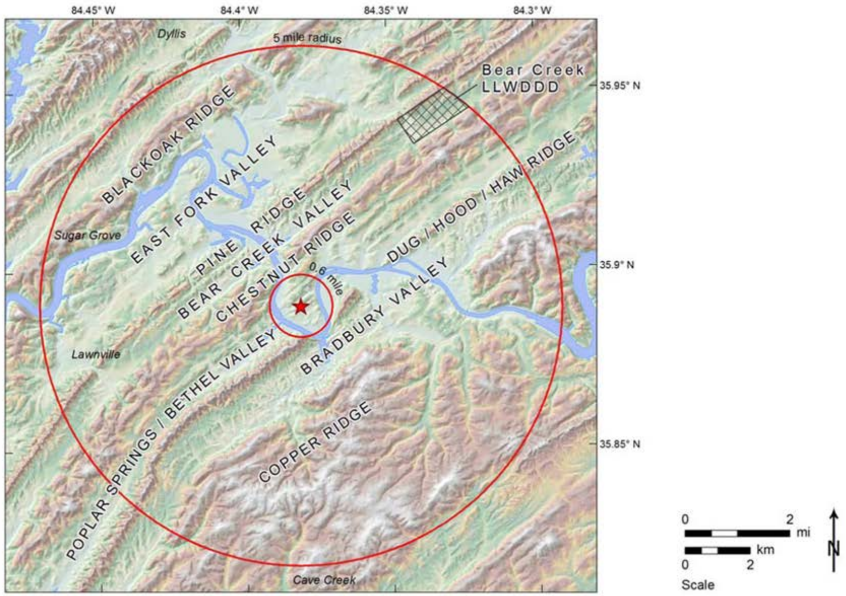
.

Clinch River Site

# Clinch River Site Regional Description

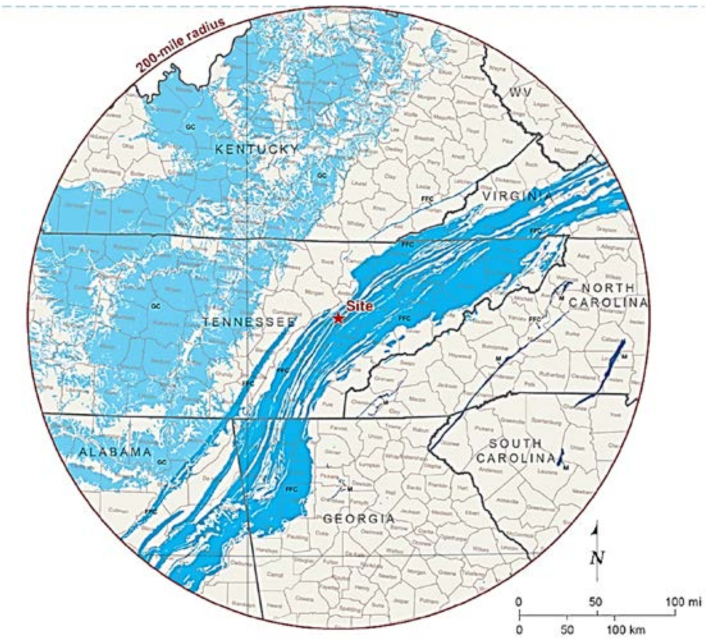


# Local Physiography




Bedrock physiography is characterized by a well-developed valley and ridge system.

# Regional Distribution of Carbonate Rocks



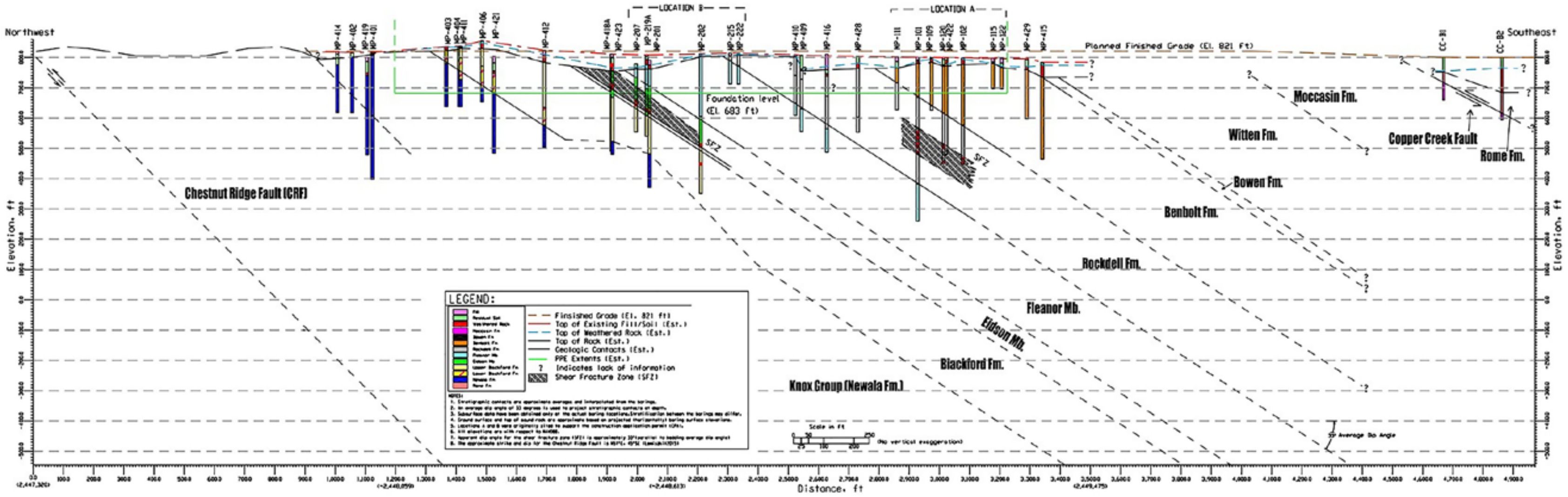

**Description of Map Units**

**GC** Gently folded and flat-lying carbonates rocks: indurated limestone and dolomite that has not been strongly deformed. Predominantly found in interior plateaus and lowlands. Dissolution may produce solution, collapse, and cover-collapse sinkholes. Where carbonates are thick and extensive, cave systems may be long and complex. Where thin and interbedded with non-carbonates, caves are small and short. Geometry of cave passage patterns often shows stratigraphic and bedding-plane control often resulting in branchwork caves. (Reference 2.5.1-35)

**FFC** Folded, faulted carbonate rocks: limestone and dolomite in areas flanking and in orogenic zones. May be intensely folded and faulted, commonly well jointed, commonly with cleavage. These rocks are located in the Valley and Ridge Province on this map and most are Paleozoic in age. Dissolution may produce solution, collapse, and cover-collapse sinkholes. Caves range from small and simple to long and complex systems. Geometry of cave passage patterns tend to show at least some structural control producing network caves. (Reference 2.5.1-35)

**M** Marbles and metalimestones: highly deformed carbonate rocks, usually found in long, thin, linear belts or pods. Mapped areas are often exaggerated as these rocks are usually mapped with associated, non-soluble metamorphic rocks. Dissolution may result in solution, collapse, and cover-collapse sinkholes and small, short caves.

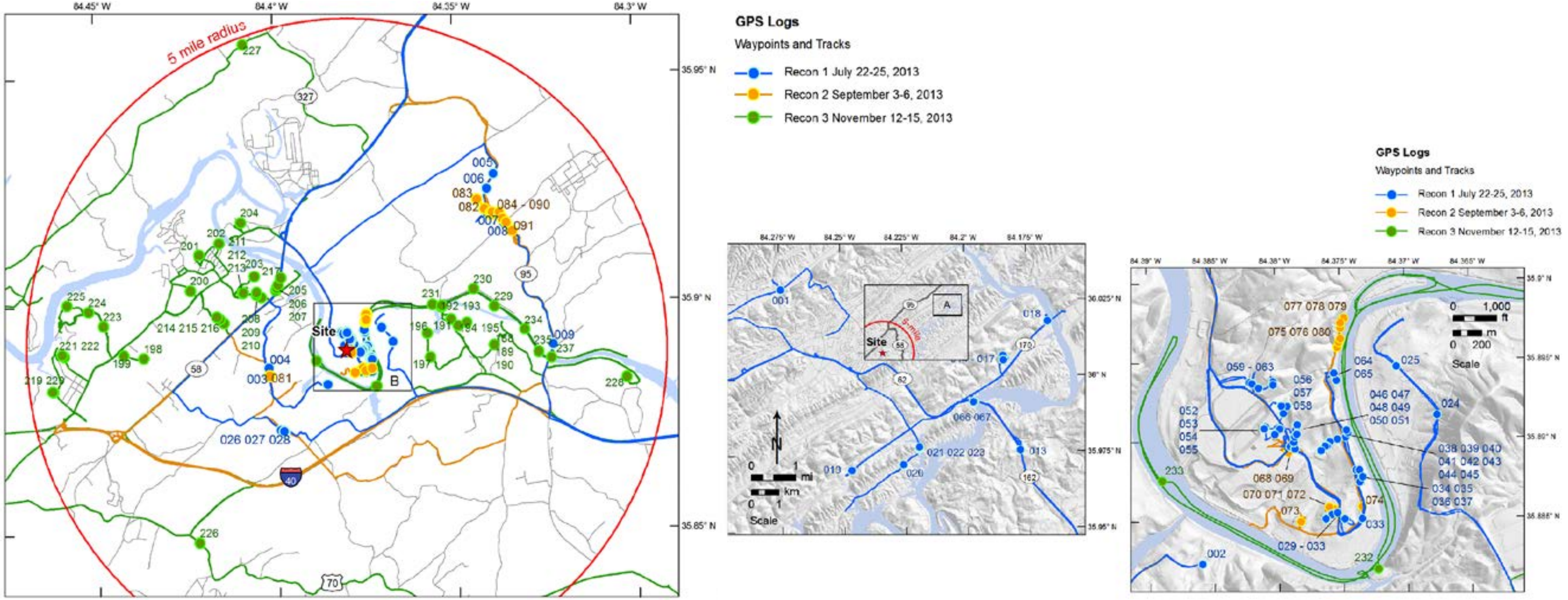
# Geological Cross Section of Clinch River Site



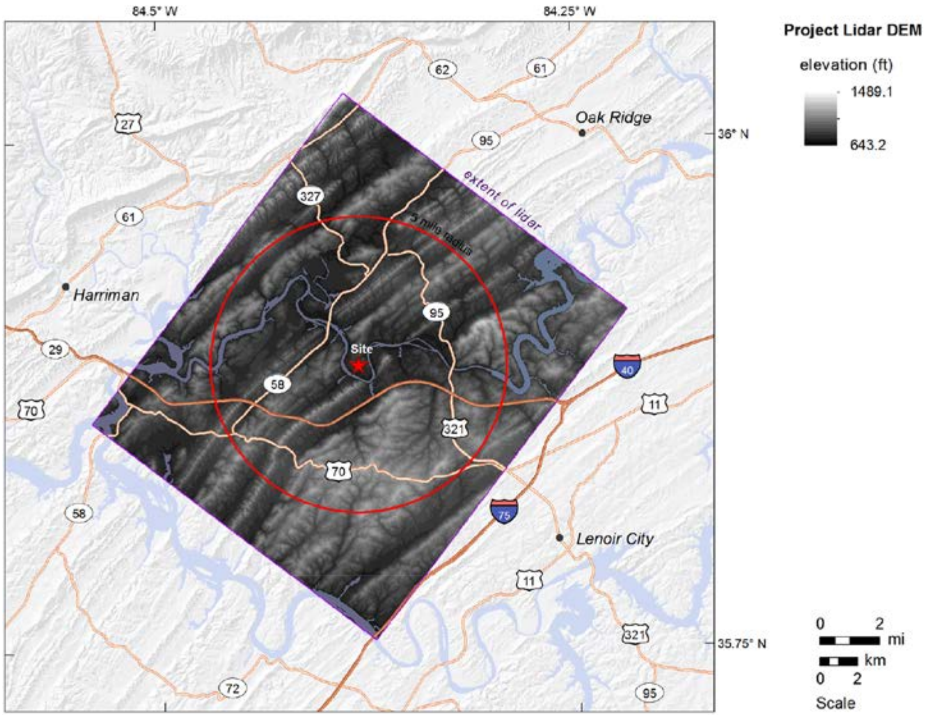
# Field and Data Investigations

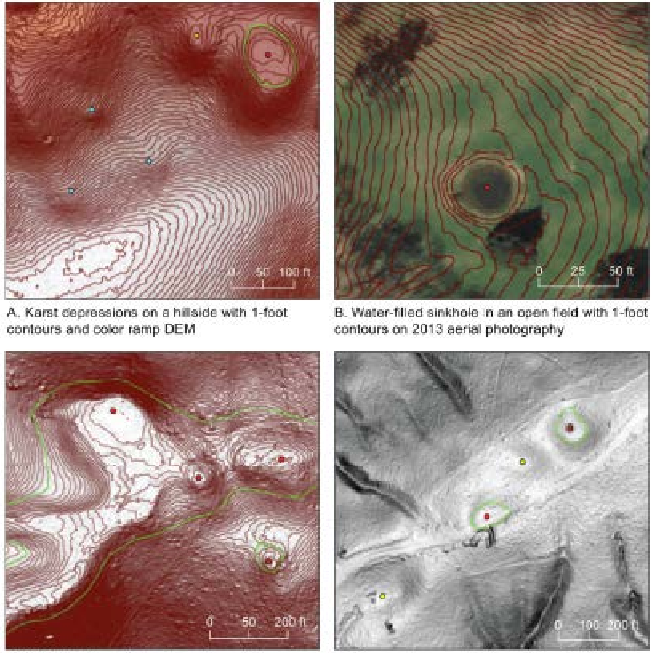
- Field Reconnaissance
- Geomorphic analyses/LiDar digital elevation data
- Previous Clinch River Breeder Reactor data and investigations (70's -80's)
- Core Borings
- Oak Ridge National Laboratory reports
- Geologic publications
- Karst mapping
- River-terrace mapping

# Field Reconnaissance Waypoints – Regional and Site Area



# LiDAR Digital Elevation Model Coverage




A. Karst depressions on a hillside with 1-foot contours and color ramp DEM

B. Water-filled sinkhole in an open field with 1-foot contours on 2013 aerial photography

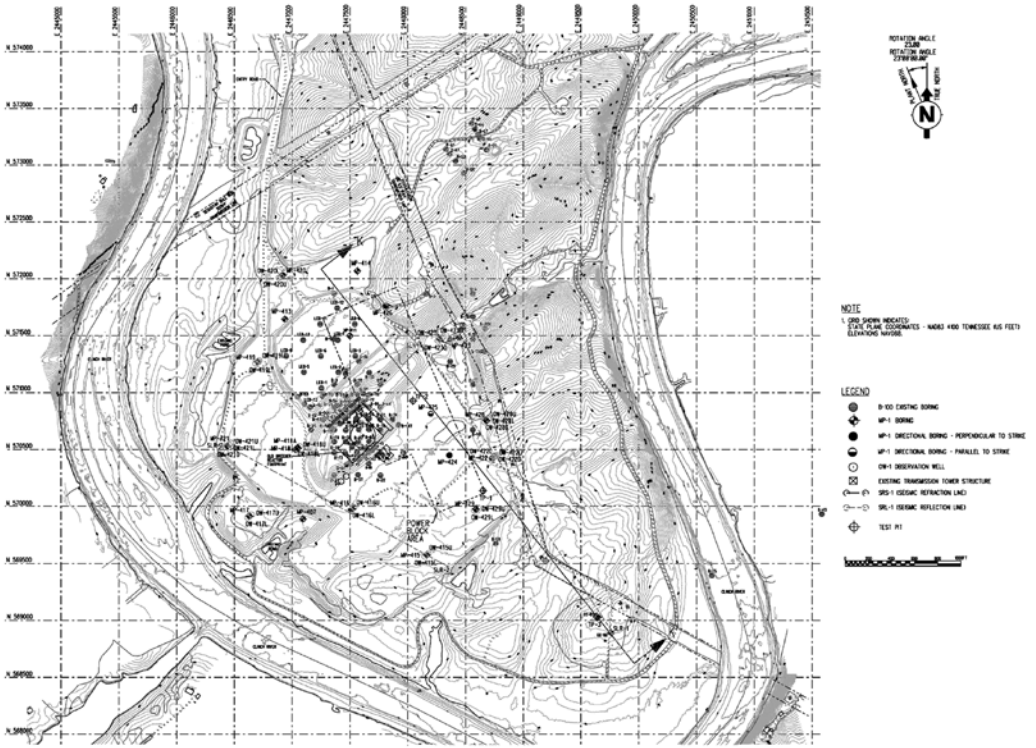
C. Multiple sinks within a larger closed depression with 1-foot contours

D. Depressions on ridge top, hillshade DEM

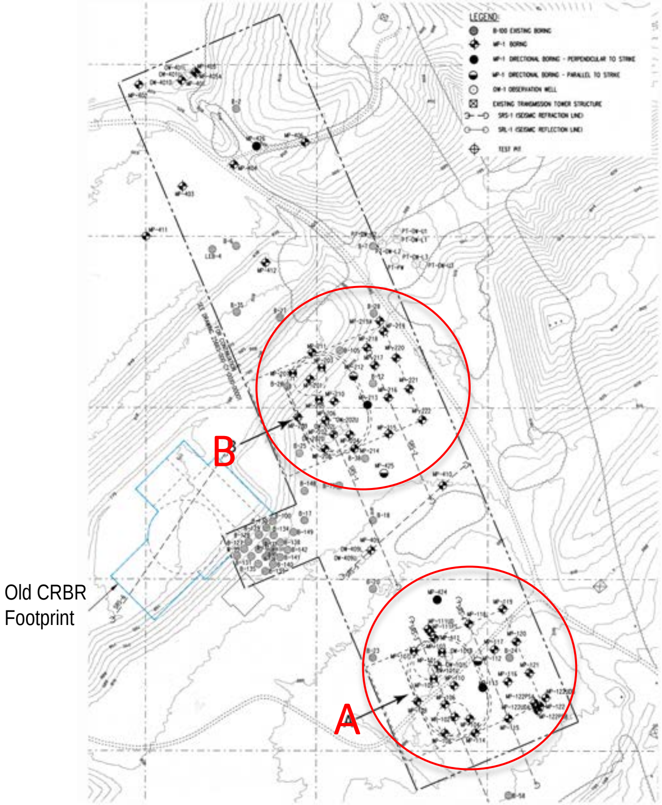
**Explanation**

- Center of closed depressions 2-foot depth and 100-square-foot area
- Extent of closed depression
- Two-sided depression
- Three-sided depression
- Shallow depression

# Core Borings of CRBR Project



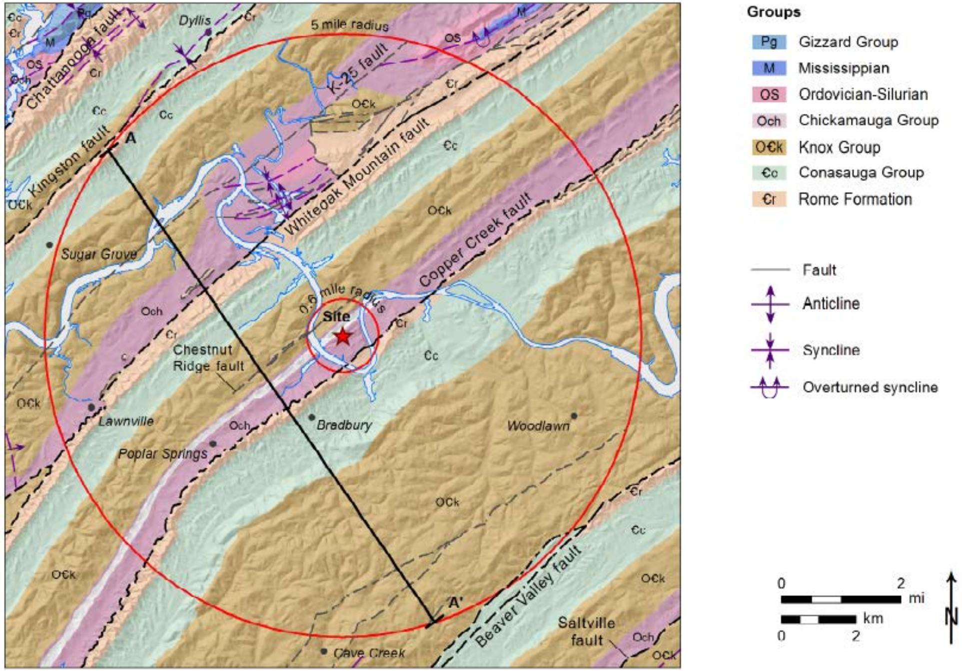
# Borehole Locations at Site A and B




Core Borings

- 76 rock borings performed for the SMR project
- 104 borings performed for the Clinch River Breeder Reactor Project

# Faults

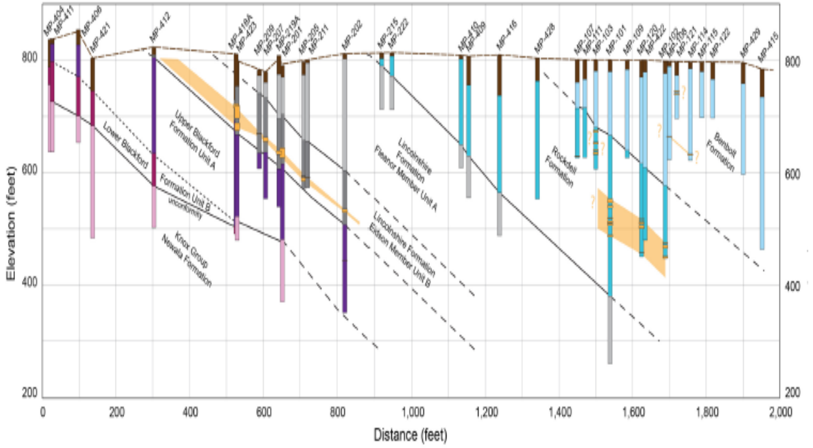



Two Faults traverse the Clinch River Site Location

- Copper Creek Fault
- Chestnut Ridge Fault

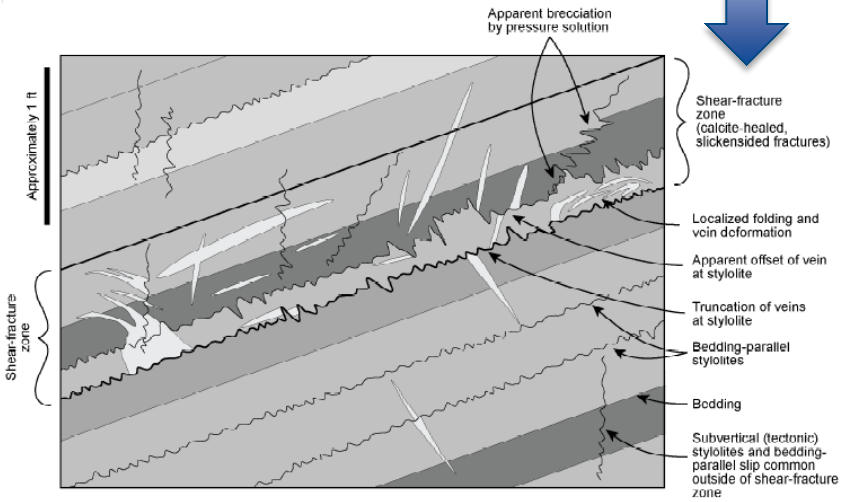
*No evidence of deformation within the Quaternary time period*

# Shear Fracture Zone

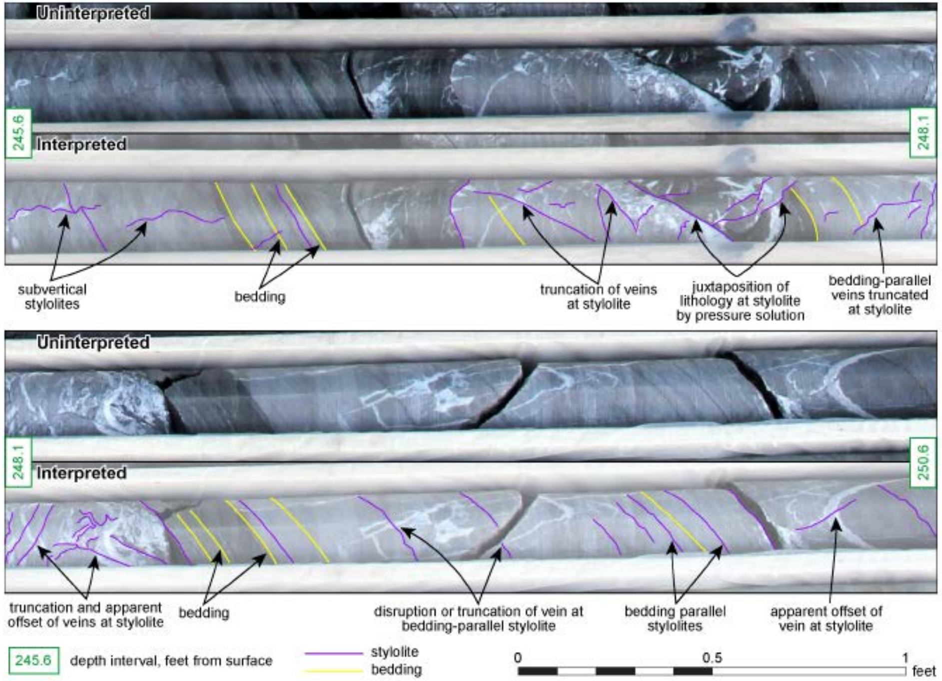



Cross-section through Shear-Fracture Zones

Schematic diagram of relationship between Bedding, Styolites, and Shear-Fracture Zones



# Shear Fracture Zone Core Boring Photograph




Photograph of Boring MP-101

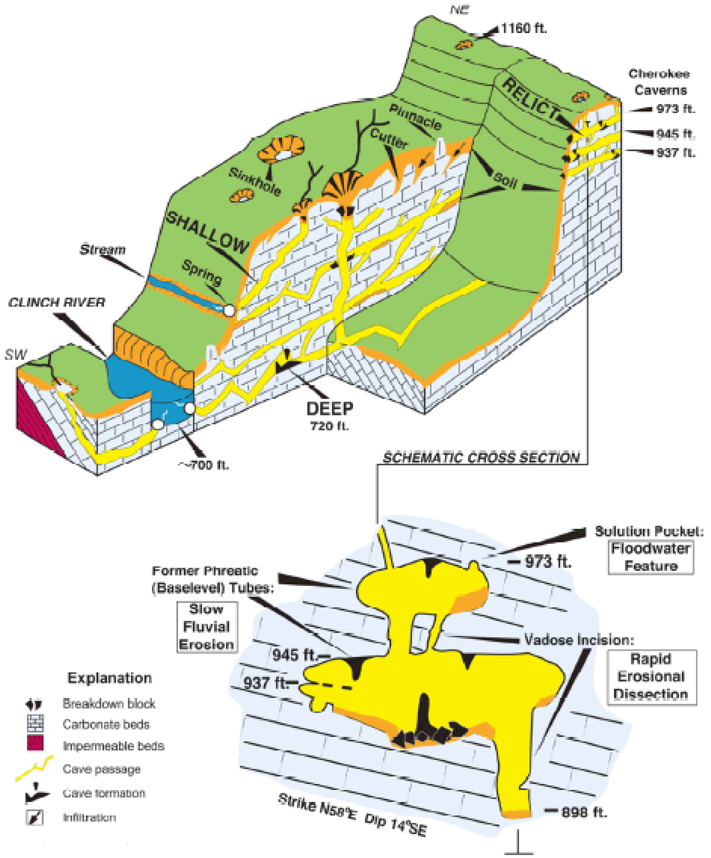
- Shear-Fracture Zone is very small
- Not a fault breccia
- Resulted from strain relief during the Alleghanian orogeny

# Local Geologic Hazards

- Karst features and active processes are common throughout the site
- Sinkholes, springs, underground drainage and irregular soil-bedrock contact
- Karst conditions are the primary geologic hazard of concern for this application

# Karst Model Example

- In summary, karst models show that dissolution occurs in a variety of hydrogeologic settings.
- Epigenetic dissolution, by descending and circulating meteoric water, can occur in the vadose zone, in the shallow phreatic zone, and in the deep phreatic zone.
- A karst model for the CRN Site, informed by the above discussions, is shown on a following slide.



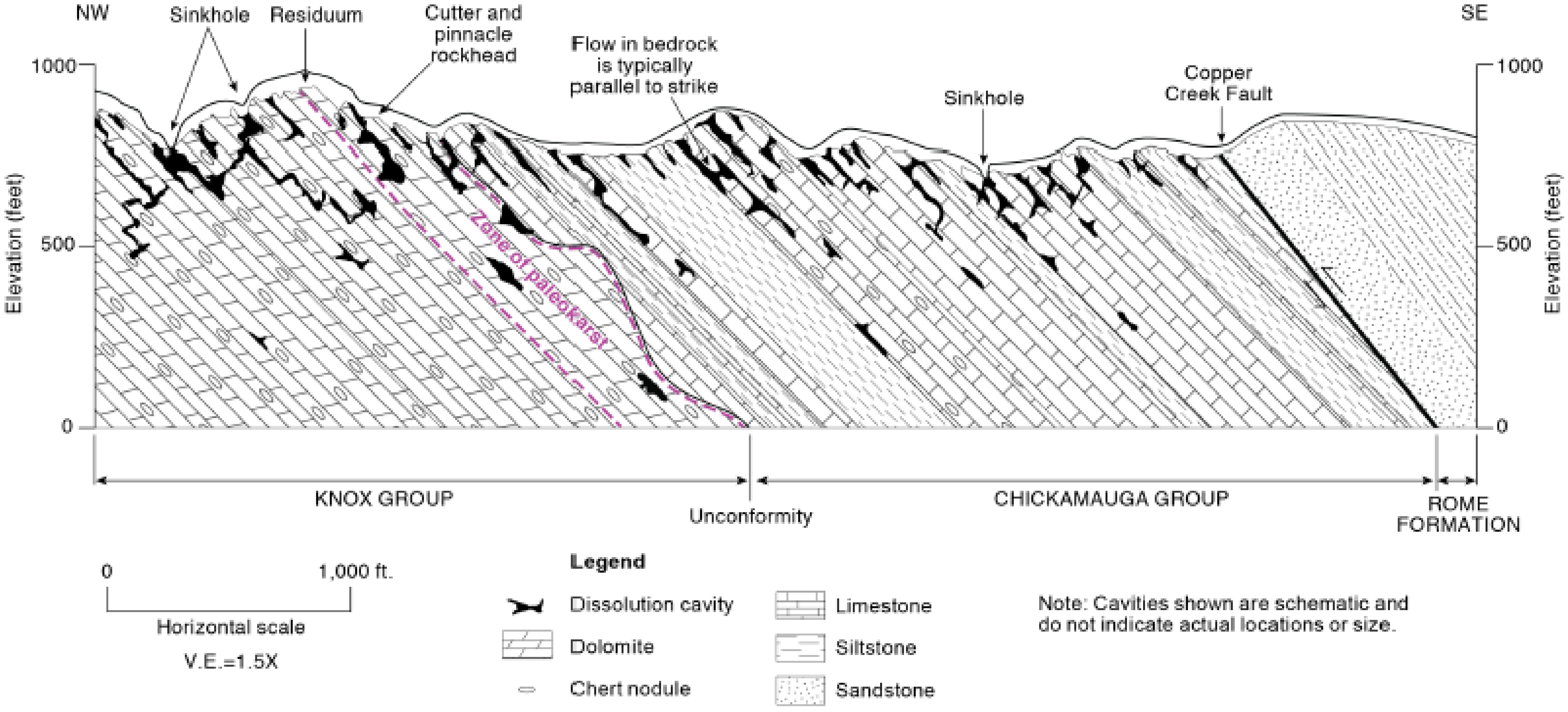
# Karst-related studies

- Multiple karst studies performed for the Oak Ridge Reservation were utilized, including karst inventories and ground water flow testing
- Karst studies performed for the Clinch River Breeder Reactor Project were utilized, including information from core borings
- Recent studies included LiDAR mapping of karst features, compilation of core boring information, analysis and modeling

# Karst Study Conclusions

- The dominant orientation of phreatic dissolution pathways is strike-parallel. Groundwater flow is constrained by low-carbonate units, resulting in strike-parallel drainage systems
- The Fleanor, Blackford, and Bowen formations, the most carbonate-poor units in the Chickamauga Group, have no mapped sinkholes and smaller and fewer borehole cavities than other units.
- Borehole data show that subsurface dissolution is most intense near the surface and decreases steadily with depth. Small numbers of cavities are observed below the water table indicating deep pheratic dissolution has occurred. This is consistent with observations of decreased fracturing frequency and groundwater flowrates with depth in the ORR studies
- Direct evidence of hypogene dissolution processes is not documented at the CR Site or within the ORR. Most evidence is consistent with dissolution by epigenetic processes in the vadose and phreatic zones. This evidence includes the decrease in frequency of fractures and dissolution cavities with depth in boreholes

# Karst Model of the Clinch River Site



# Clinch River Breeder Reactor Excavation Mapping circa 1983

- The excavation mapping report concluded that the site was suitable for development of the proposed facility or other industrial facilities based on the character of the rock exposed. NUREG -0968

- The planned foundation level of the CRBRP, 714 ft MSL, was below the zone of weathered siltstone observed in the excavation, and the limestone at that elevation was found to be hard and sound. No cavities were described on the floor of the excavation.

# Geologic Investigation Conclusion

- Active faulting is not a geological hazard for the site area
- Shear fractures are not a geological hazard for the site area
- Karst conditions are identified as the potential geologic hazard for the site area
- Met regulatory requirements of 10CFR52.17 and the guidance from Regulatory Guide 1.208

# ESPA Part 2,
# SSAR Section 2.5
# Seismology

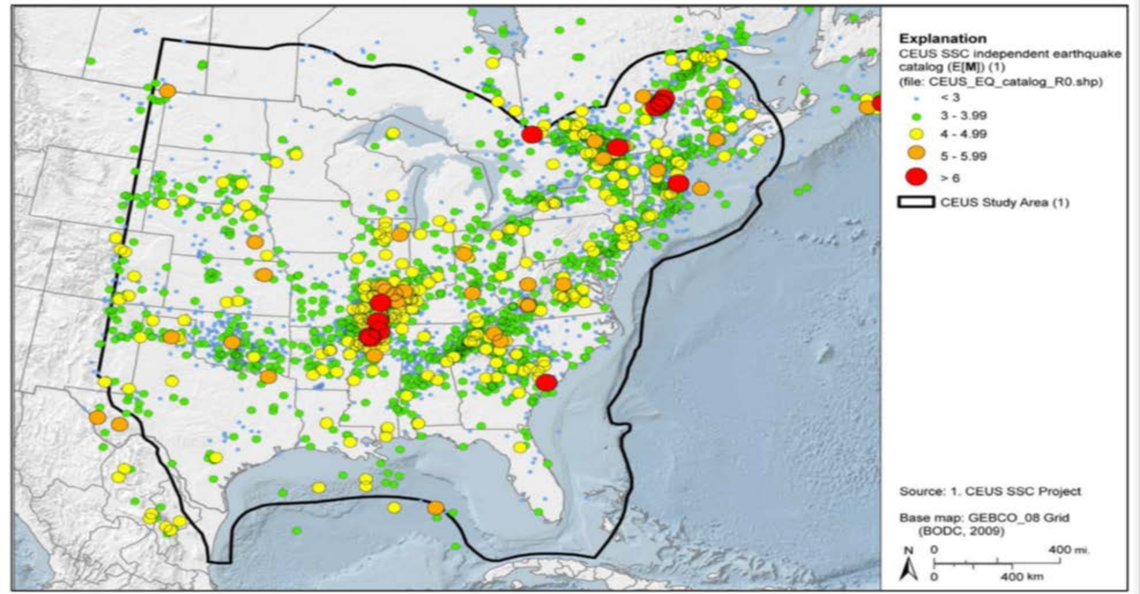
# SSAR Section 2.5 - Seismology

- The purpose of Subsection 2.5.2 is to determine the site-specific ground motion response spectrum (GMRS). The GMRS is defined as the free-field horizontal and vertical ground motion response spectra at the site and must satisfy the requirements of 10 CFR 100.23.

- The GMRS was developed with consideration of the guidance provided in NUREG-0800, Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants

- Development of the ground motions for the SSAR begins with implementation of the provisions of RG 1.208, A Performance-Based Approach to Define the Site-Specific Earthquake. This regulatory guide describes acceptable methods to conduct geological, seismological, and geophysical investigations of the CRN Site and region around the site, identify and characterize seismic sources, perform a probabilistic seismic hazards analysis (PSHA), perform site response analysis, and determine the Ground Motion Response Spectra (GMRS) using a performance-based approach.

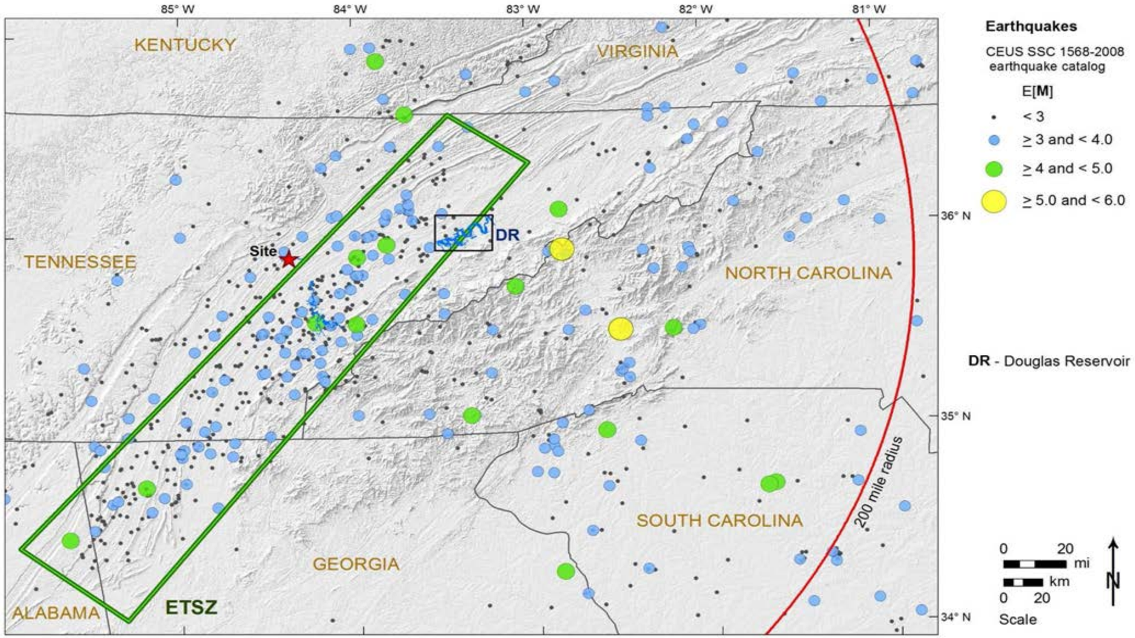
# Seismicity




Plot of Regional Seismicity from the Central Eastern United States (CEUS) SSC Earthquake Catalog (2009)

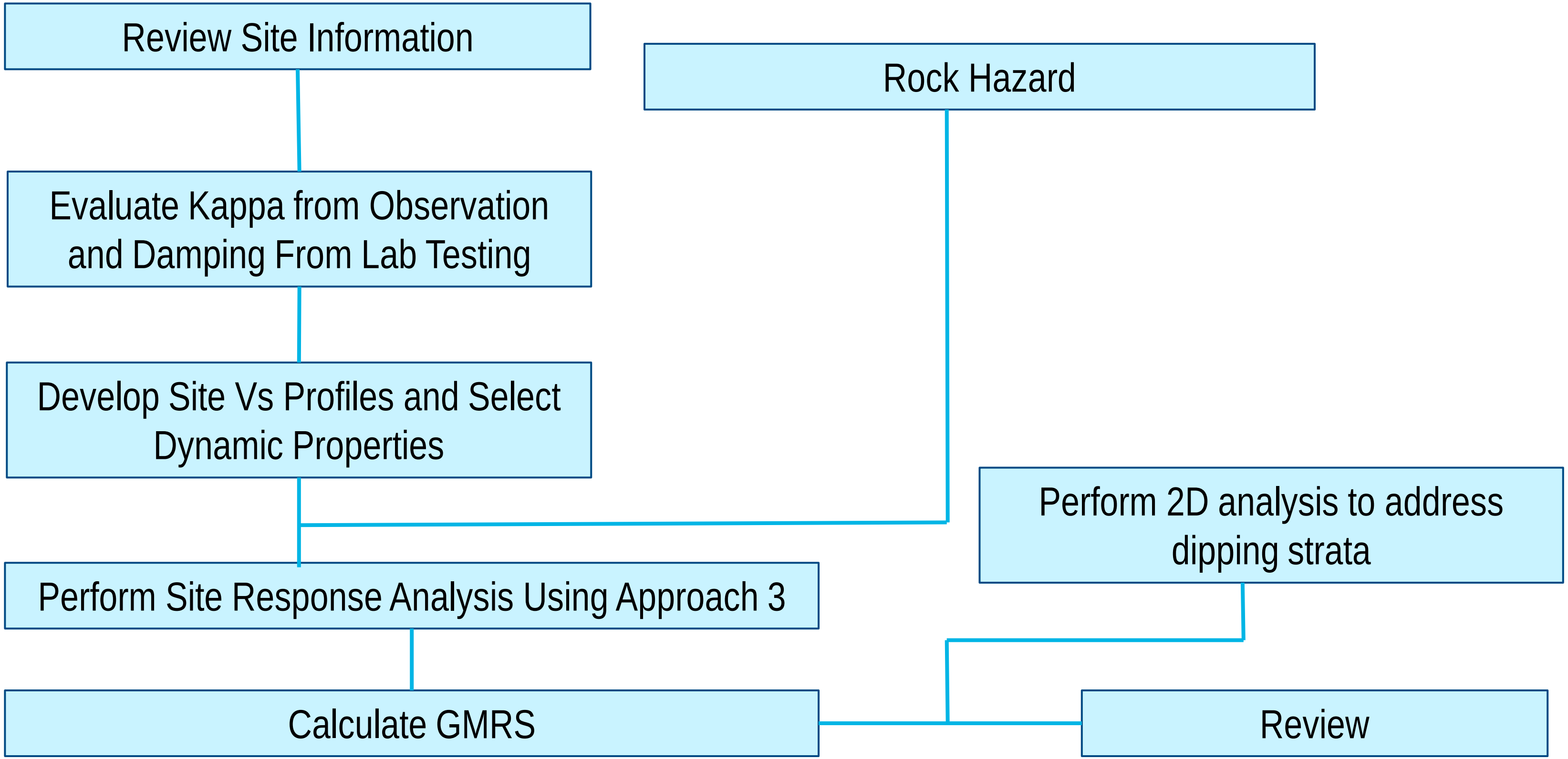
Application was based on 2012 data update

# Seismicity




East Tennessee Seismic Zone Geometry (As Defined by USGS)

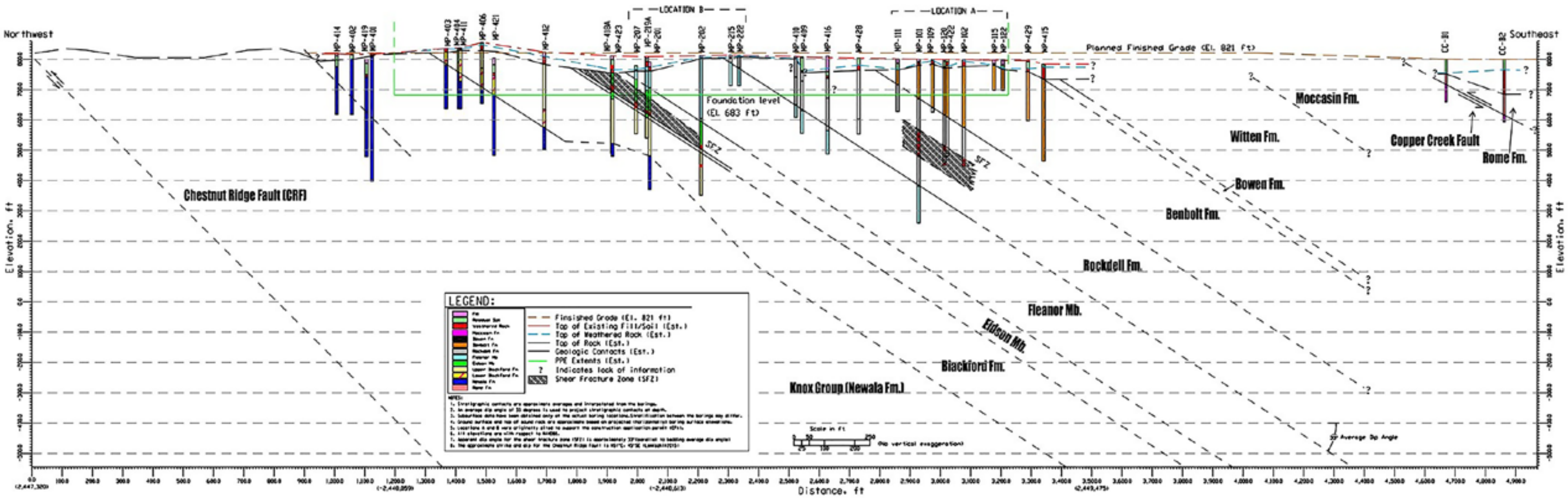
# GMRS Development - Approach



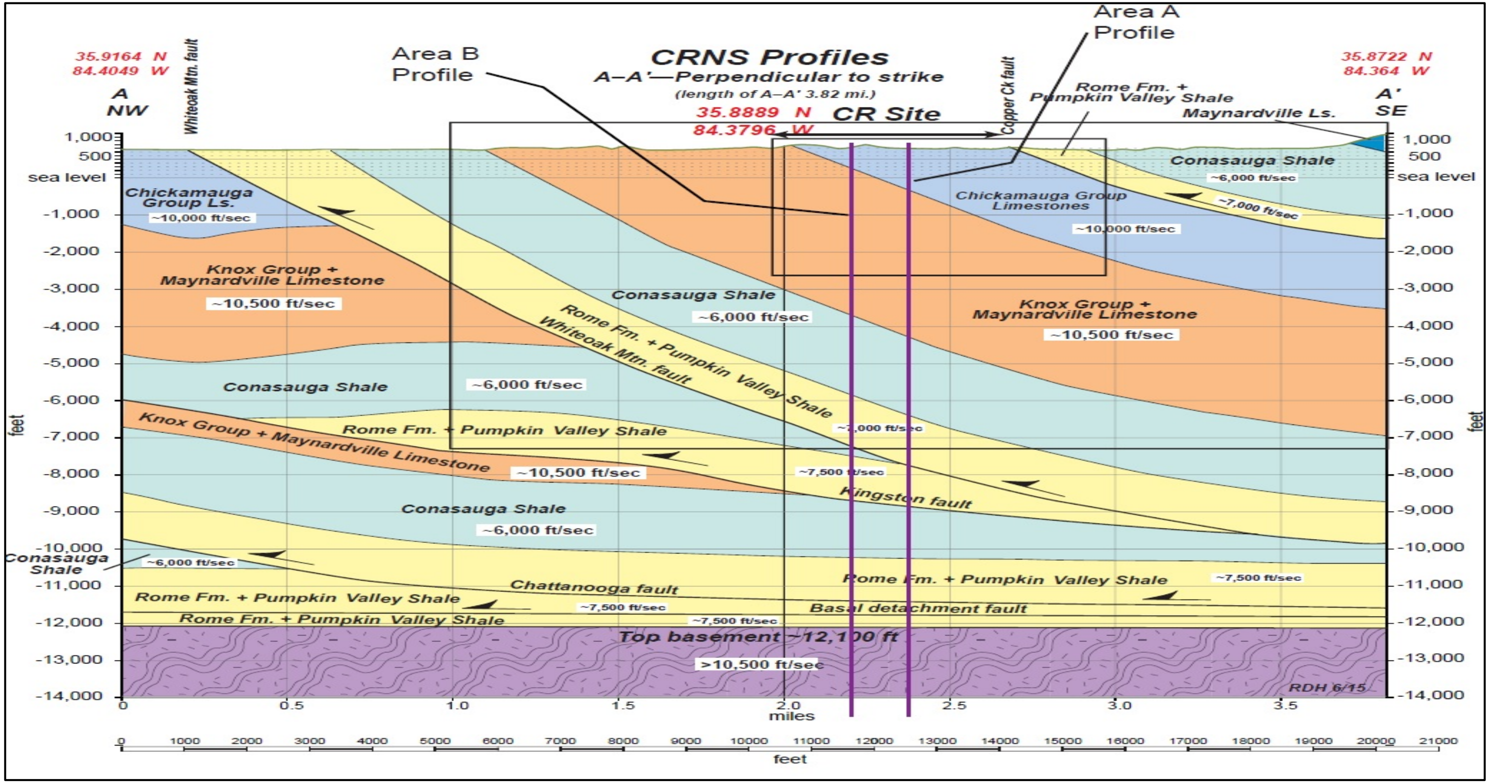
# RG 1.208 Approach 3 Description

- Approach 3
  - Fully Probabilistic
    - > Preserves Hazard Levels
    - > Hazard at Surface computed by integration of Hard Rock Hazard with probability distribution of frequency and strain dependent factors
    - > Results in complete hazard curve at ground surface.
  - Endorsed by NUREG CR/6728: Technical Basis for Revision of Regulatory Guidance on Design Ground Motions: Hazard- and Risk-Consistent Ground Motion Spectra Guidelines
  - Basic Steps in Approach 3
    - > Randomization of site dynamic material properties
    - > Computation of amplification factors using Random Vibration Theory
    - > Full Integration of mean and fractile hazard curves

# Geologic Cross-Section Showing Borehole Locations and VS Profiles

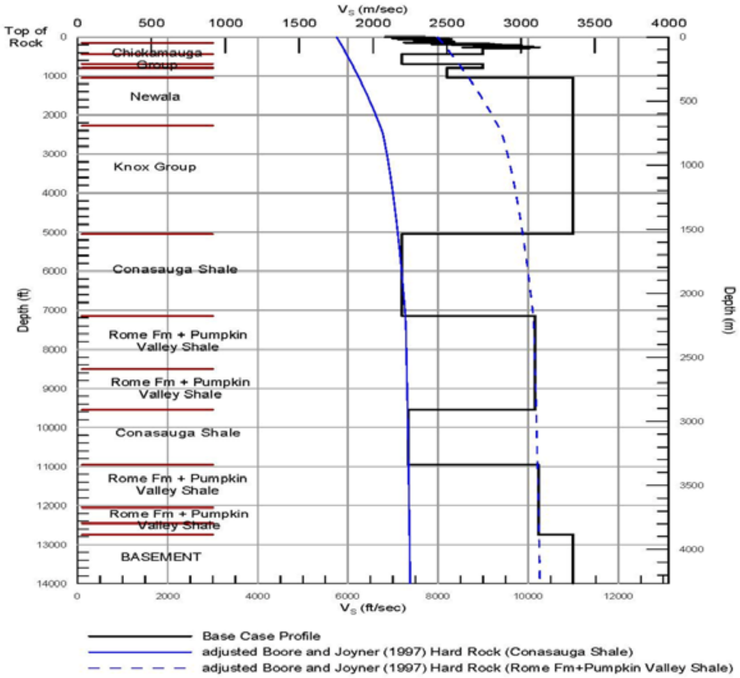


# Geological Cross-Section with $V_s$ Profiles

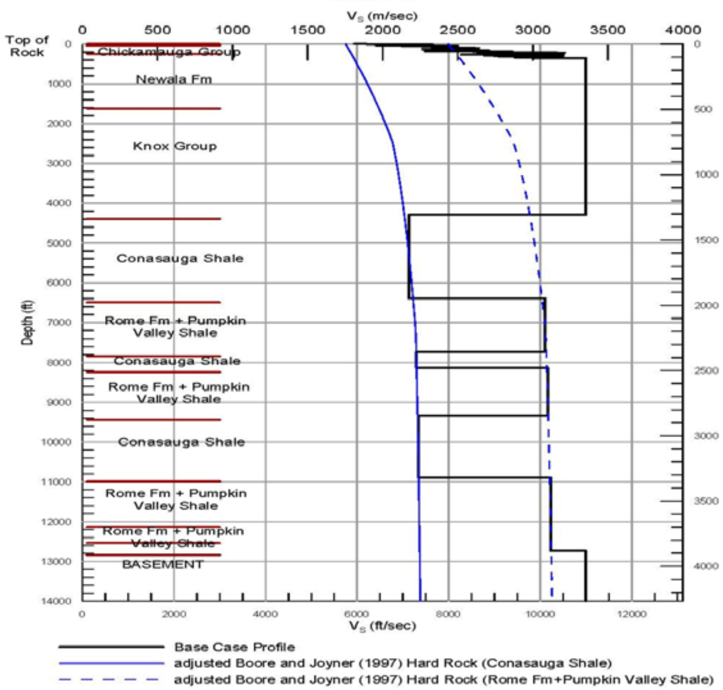


# $V_s$ Profiles for Site A and B

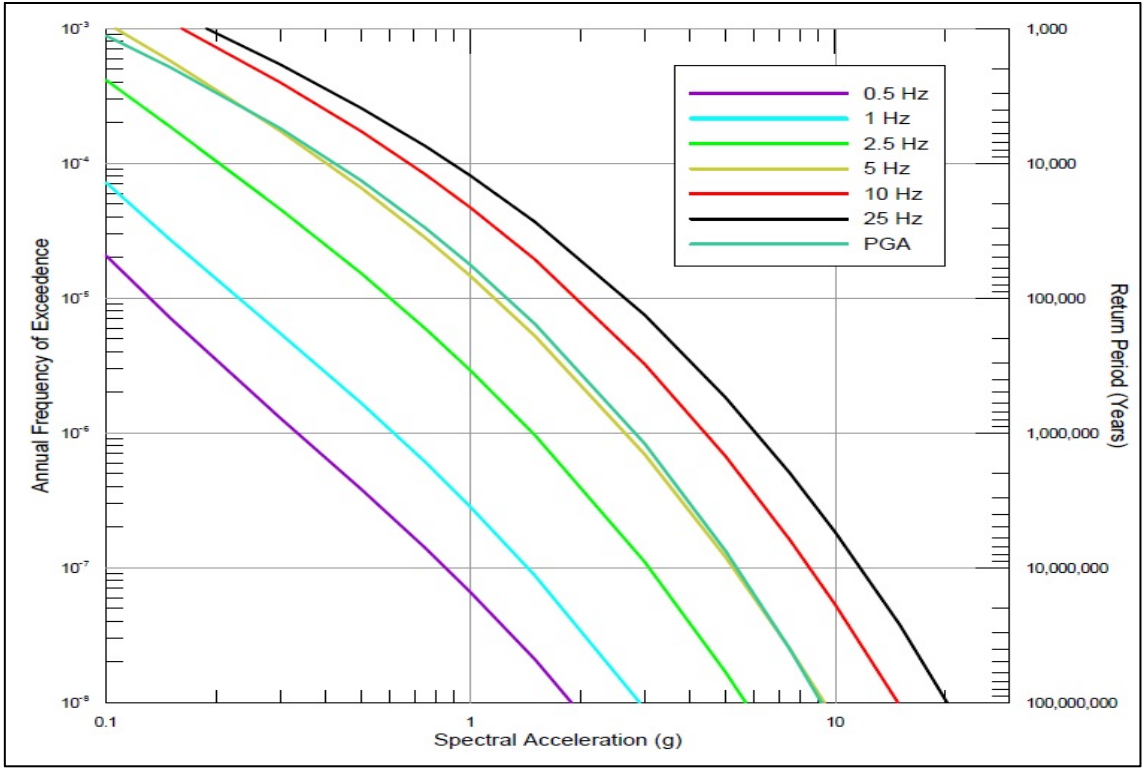
Geologic and Velocity Profiles for Site A




Geologic and Velocity Profiles for Site B

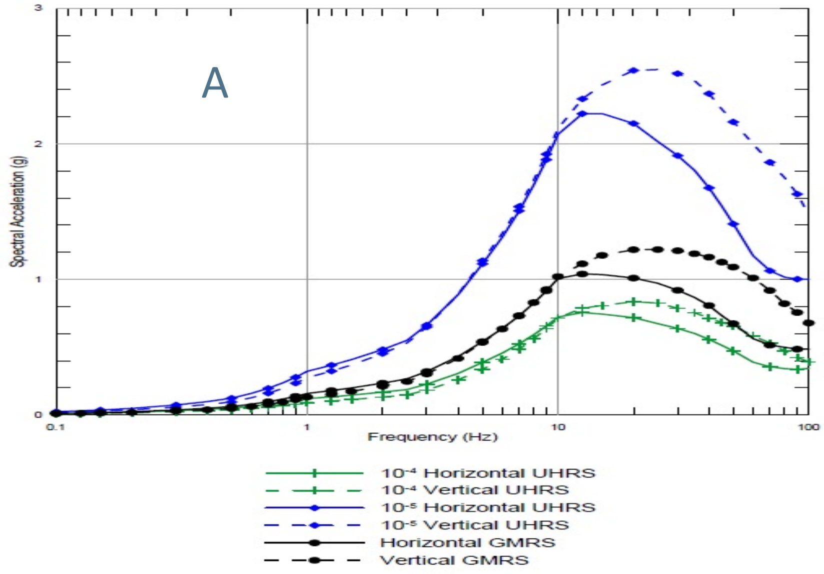


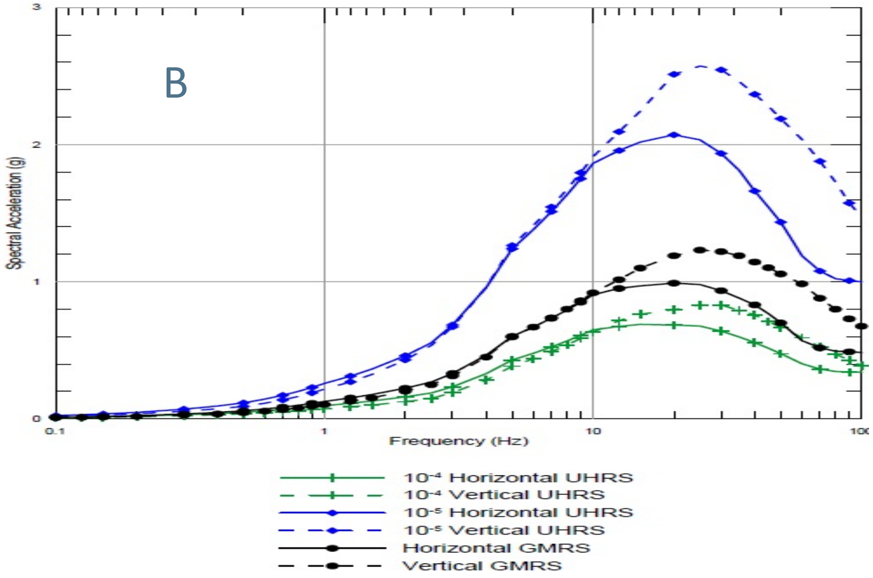
# GMRS Development – Hazard at Ground Surface



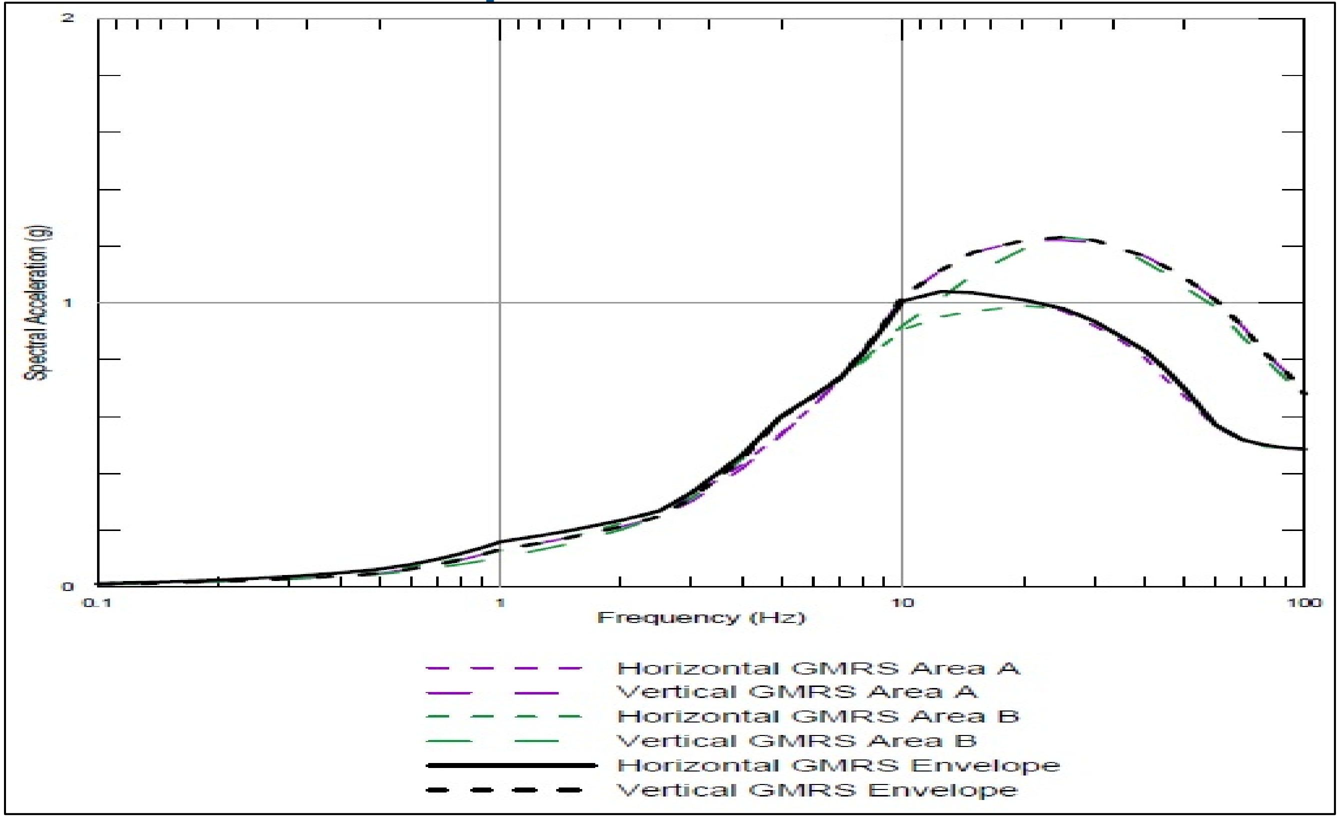

Mean Hazard at ground surface for the range of frequencies

# GMRS Development Area A and B



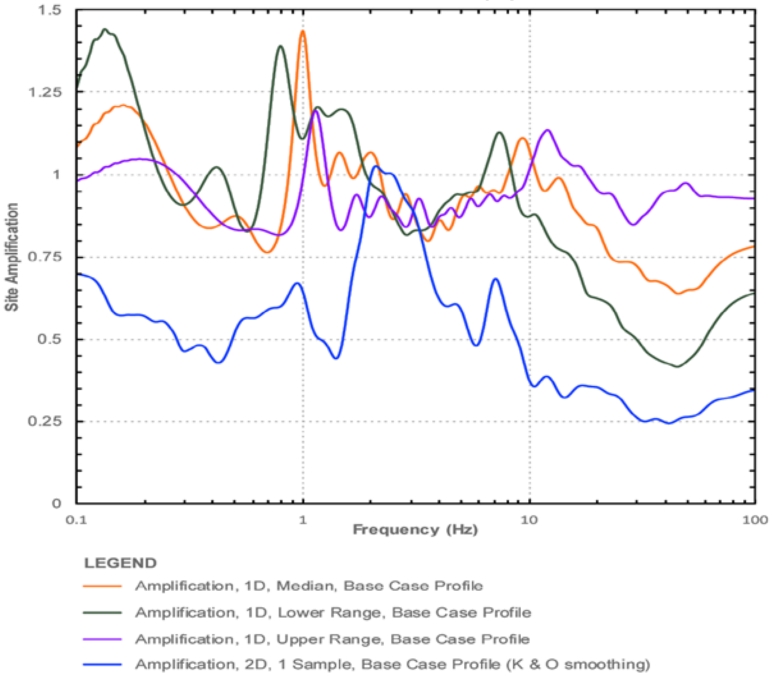



# GMRS Envelope

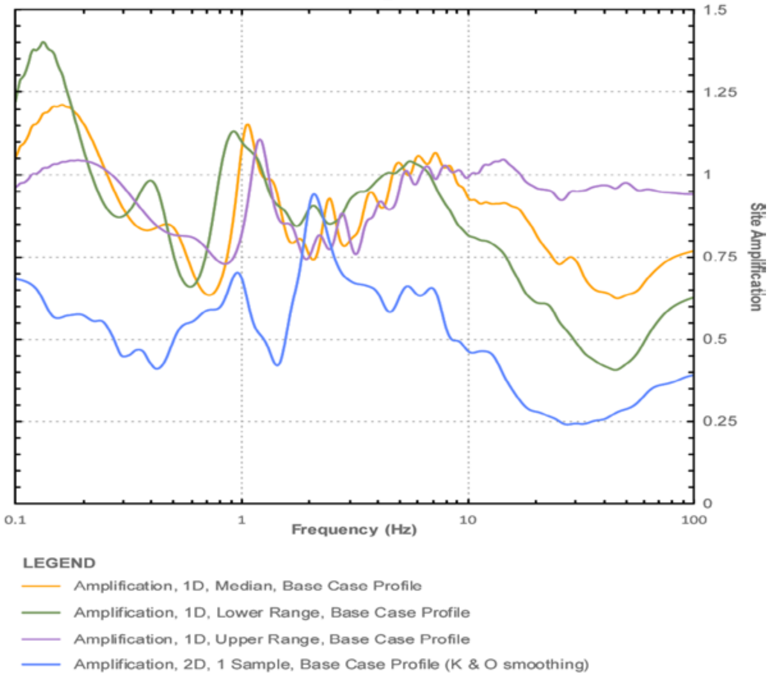


# Comparison of the 2D and the 1D RVT Amp Factors (all basecase profiles)

A




B



# 2D vs 1D Comparison

- The Random Vibration Theory (RVT) ID amplification factors used to calculate the GMRS significantly exceed the 2D amplification factors (smoothed) for the single time-domain sensitivity calculation across the full frequency range except at one frequency.
- 2D effects are not expected at the site because of the high shear wave velocity ($V_S$) of the underlying rock and the small impedance contrasts between rock layers.
- The use of multiple basecase velocity profiles in calculating the GMRS are expected to accommodate any potential 2D effects.

# Seismology Conclusions

- The Probabilistic Seismic Hazard Analysis performed for the Clinch River Site, specifically Sites A and B, :
  - Followed 10 CFR 100.23 and the guidance of RG 1.208
  - Represents the regional and local hazards
  - Includes the local subsurface properties
  - Evaluated the potential for 2D effects due to dipping angle

# ESPA Part 2,
# SSAR Section 2.5
# Geotechnical Engineering

# SSAR Section 2.5 - Geotechnical Engineering

Information presented within these subsections 2.5.3, 2.5.4, and 2.5.5 has been developed in accordance with RG 1.208 and is intended to demonstrate compliance with 10 CFR 100.23, Geologic and Seismic Siting Criteria

- Specifically, this subsection addresses the following issues: Potential surface deformation associated with active tectonism, including any significant neotectonic features (faults).Potential surface deformation associated with non-tectonic processes such as collapse structures (karst collapse), slope failures, and anthropogenic deformation (e.g., mine collapse).
- This geological, geophysical and geotechnical information is used as a basis to evaluate the stability of subsurface materials and foundations at the CRN Site.
- The information presented in this subsection is based on the results of the site-specific subsurface investigation performed at the Clinch River Nuclear Site.

# Surface Deformation

- TVA performed geological, seismological and geophysical investigations and analysis for the region and the site
- TVA concluded in the application that the potential for tectonic deformation at the site is negligible
- Non-tectonic deformation is possible with karst conditions
- Detailed mapping of excavation walls and foundations will be performed during construction for a confirmation of the conclusions reached in the application

# Stability of Subsurface Materials and Foundations

- CRBRP subsurface investigations
- Clinch River site subsurface investigations:
  - 82 geotechnical core borings (includes 6 soil borings)
  - 3 test pits
  - 44 observation wells
  - Seismic reflection and refraction tests
  - Downhole geophysical testing in 28 borings
  - Field permeability and pumping tests
  - Groundwater level monitoring in the observation wells
  - Rock pressure meter tests in two borings
  - Laboratory testing of boring soil and rock samples
- These programs followed RG 1.132, Site Investigations for Foundations of Nuclear Power Plants

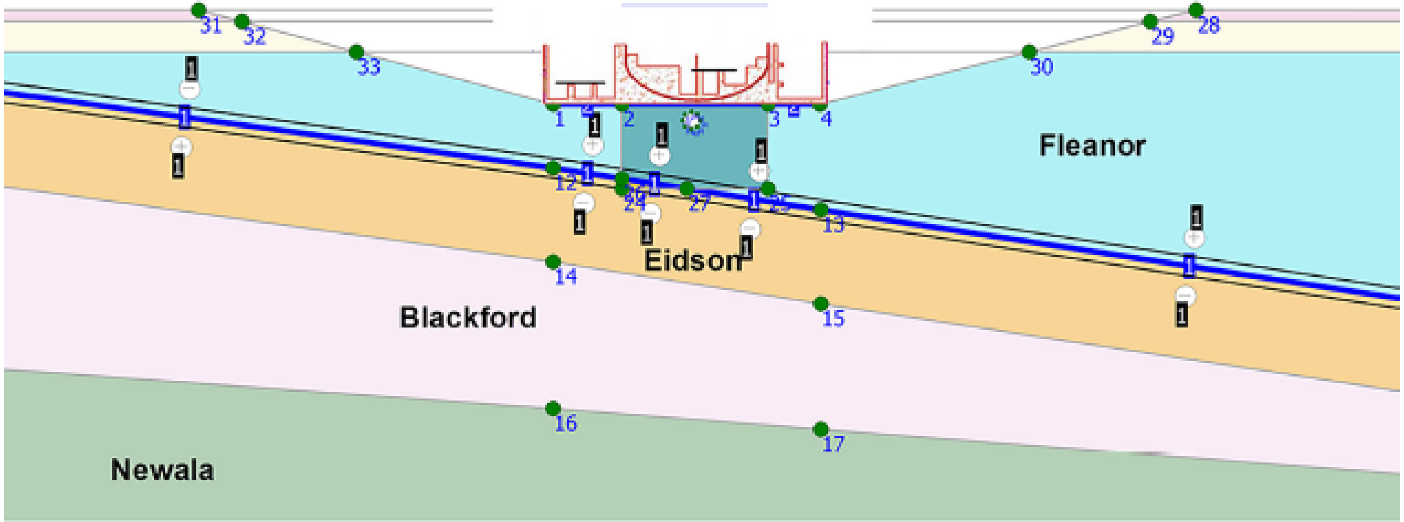
# Engineering Properties

- Ultimate Bearing Capacity
- Allowable Bearing Capacity
- Settlement and Heave Analysis
- Additional engineering properties were also developed per regulatory requirements

# Foundation Assessment Model for Karst Voids

- A PLAXIS 2D analysis was performed to demonstrate foundation acceptability
- A large PWR foundation was selected due to limited design information available for the SMRs considered in the Plant Parameter Envelope
- Finite Element Models were developed for both Site A and B
- Three embedment depths (40 ft, 90 ft and 140 ft) were evaluated
- Two different cavity depths below the foundation level were evaluated (5 ft and 30 ft) for each embedment depth
- Additionally, three locations for cavity placement were also evaluated for each of the above cases:
    - At the edge of the Nuclear Island (for tipping)
    - At the center of the Nuclear Island
    - Along the appropriate bedding plane for the Site

# PLAXIS Model Example




Note: Reference 2.5.4-59 Figure 2-29
Cavity Diameter: 15 ft
Embedment Depth: 90 ft
Cavity Depth: 5 ft Below Foundation
Cavity Location: Center of Common Basemat
Interface Elements at Formation Contact

# Foundation Model Results

- Approximately 99 percent of the cavities observed in Site A and B borings are significantly less than 11 ft in inferred height.
- Cavity development in CRN Site areas is generally limited to the most markedly weathered zone immediately below ground surface, to depths less than 100 ft; 75 percent of reported cavities in Site A and B borings occur at depths less than 55 ft which will consequently be excavated to the embedment depths of 80-140ft. Depending on the technology selected.
- Cavity-related failure has a higher potential to occur at relatively shallow depth, less than about 30 ft. Given that foundation embedment depths are deeper than 30 ft and that the 15 ft critical cavity diameter determined by PLAXIS 2D modeling is significantly larger than the 11 ft height that bounds 99 percent of the cavities observed in CRN Site borings, Sites A and B are suitable for SMR foundation.

# Foundation Model Results (continued)

- At COLA, foundation performance will be re-evaluated on selection of a final technology, taking into account specific plant design, specific plant loads, and any potential ground improvement or grouting plans.
- Final foundation locations will also be re-evaluated using specific plant information.

# Stability of Slopes

- Given the existing topography, the natural topography and the planned finished grade, a flat site with no safety-related slope is planned in the vicinity of safety-related structures.
- The stability of slopes will be evaluated during the COLA phase once a reactor technology has been selected.

# Summary

- The efforts associated with the Pre-Application Readiness Review and the site audit and visit were very helpful in ensuring that the right level of detail and supporting information was available in the Application
- The Clinch River Site is capable from a geologic and seismic perspective for the construction of a Small Modular Reactor
- The potential geological hazard, karst, is identifiable and can be mitigated through approved regulatory processes.

Advisory Committee on
Reactor Safeguards

# Presentation to the ACRS Subcommittee

## Safety Review of the Clinch River Nuclear (CRN) Site, Early Site Permit Application

## Chapter 2, Section 2.5: Geology, Seismology, and Geotechnical Engineering

October 17, 2018

**Technical Reviewers from NRO/DLSE/RGS**
Gerry Stirewalt, Ph.D., P.G., C.E.G.
Jenise Thompson, M.S., PMP
David Heeszel, Ph.D.
Luissette Candelario, M.E
Weijun Wang, Ph.D., P.E.

# CRN Site Audits and Site Visit

U.S.NRC
United States Nuclear Regulatory Commission
*Protecting People and the Environment*

- **July 17 & 18, 2013 - Site Audit:** Staff visited the proposed site before the ESP application was submitted to observe the initial field activities being conducted by the applicant for collecting subsurface geotechnical and geologic data (Report ML13210A3070).
- **May 8 & 9, 2017 - Site Audit:** Staff visited the proposed site to discuss information derived from the continuing geologic, seismic, geophysical, and geotechnical investigations being conducted by the applicant for characterizing the site (Report ML17223A428).
- **January 30 & 31, 2018 - Site Visit:** Staff visited the proposed site to confirm the applicant's interpretations regarding faults, shear-fracture zones, and karst features (Report ML18220A749).

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

# Section 2.5.1 - Geologic Characterization Information

# Section 2.5.3 - Surface Deformation

# Content of CRN Site ESP SSAR Section 2.5.1

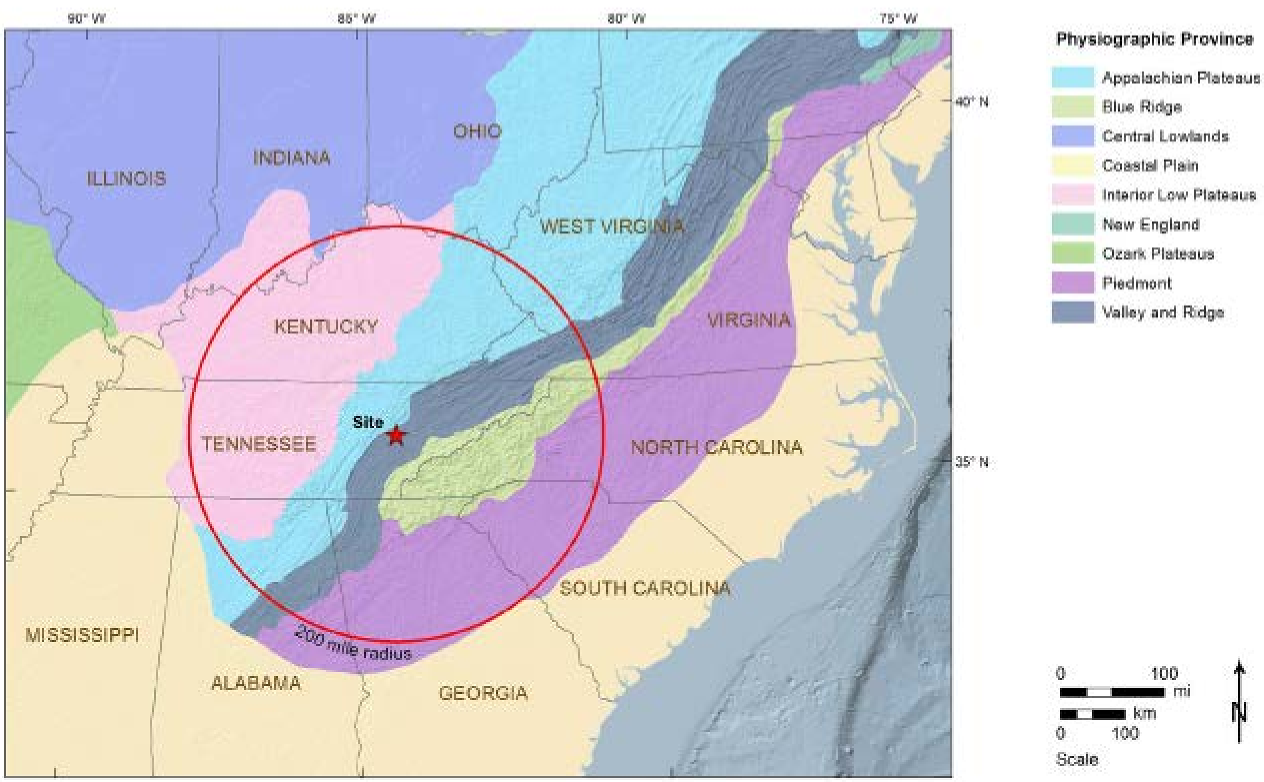
U.S.NRC
United States Nuclear Regulatory Commission
*Protecting People and the Environment*

## Section 2.5.1 - Geologic Characterization Information

- 2.5.1.1 - Regional Geology within 320 km (200 mi) of the site: Physiography and geomorphic processes, geologic history and tectonic evolution, stratigraphy, tectonic setting (including distribution of seismicity and stress in the eastern U.S.), and non-tectonic geologic hazards (including karst).

- 2.5.1.2 - Local Geology within 40 km (25 mi), 8 km (5 mi), and 1 km (0.6 mi) of the site: Physiography and geomorphic processes, geologic history, stratigraphy and lithology, structural geology (including faults and shear-fracture zones), geologic hazards (including karst), and site engineering geology (including potential effects of human activities).

# Physiographic Provinces in the CRN Site Region




Parallel ridges and valleys of the Valley and Ridge province developed as a result of differential weathering and erosion of folded and faulted sedimentary rock units that occur in the province.

(Reproduced from SSAR Figure 2.5.1-1)

# Key Geologic Features of Interest for Section 2.5.1

U.S.NRC
United States Nuclear Regulatory Commission
*Protecting People and the Environment*

Regional Thrust Faults and Localized Shear-Fracture Zones

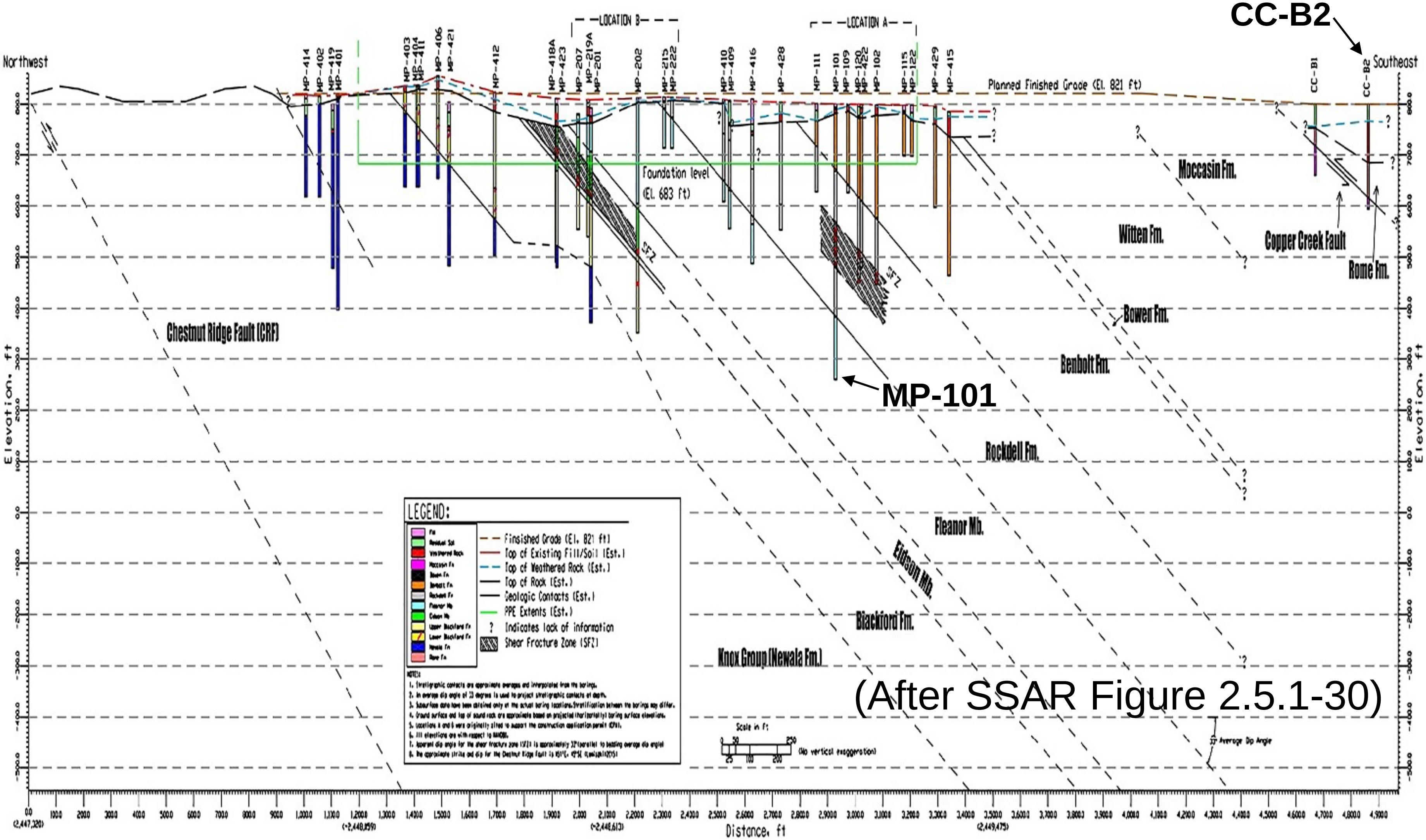
- Neither of these features is well-exposed at the surface at the site. Staff examined them in rock core samples provided by the applicant during the site audits and site visit. Both features are generally parallel to bedding

- Thrust faults are tectonic in origin and regional structures. Shear-fracture zones are more localized and contain features of both non-tectonic and probable tectonic origin

- Staff focused on documenting that the thrust faults and the shear-fracture zones are older than Quaternary (i.e., > 2.6 Ma in age) and, consequently, pose negligible hazard for the site.

# CRN Site Subsurface Stratigraphy, Faults, and Shear-Fracture Zones

U.S.NRC
United States Nuclear Regulatory Commission
*Protecting People and the Environment*



# Carbonate Strata Examined by Staff during the 01/2018 Site Visit

U.S.NRC
United States Nuclear Regulatory Commission
*Protecting People and the Environment*

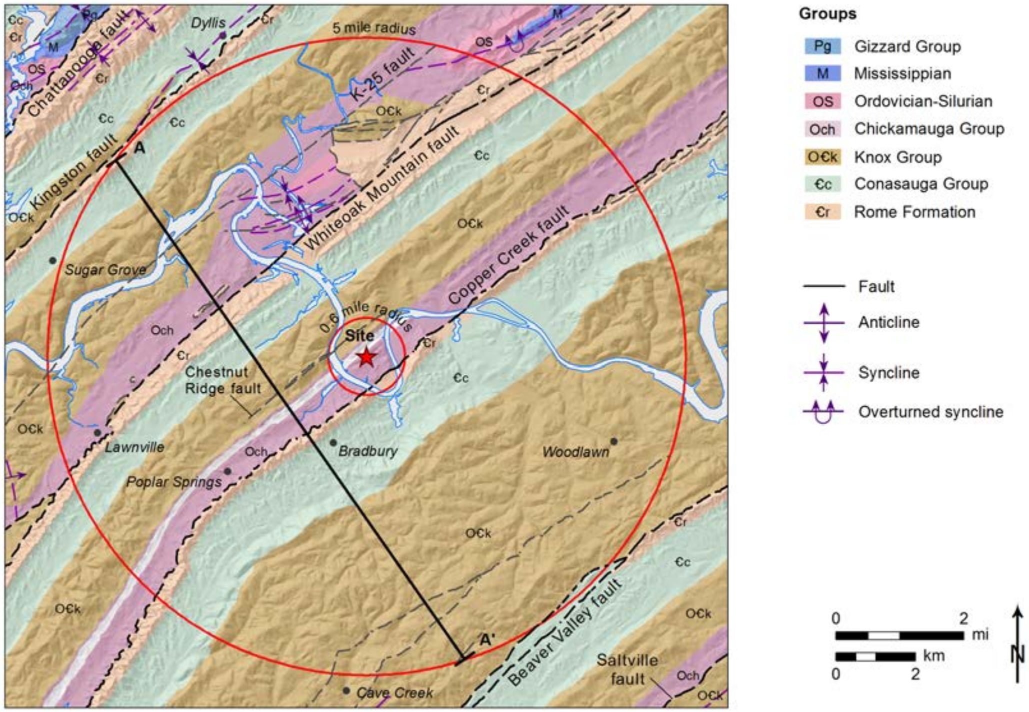
Exposure of the Fleanor Formation at the site location showing amount and direction of dip of bedding commonly seen at the CRN Site (i.e., about 33 degrees southeast).

# Thrust Faults

- Thrust faults are characteristic of the Valley and Ridge Province in which the site is located and do occur in the site area. There is no surface expression of any thrust faults in the site area.
- Although not exposed at the surface, the Copper Creek and Chestnut Ridge faults are located within 1 km (0.6 mi) of the site.
- During the site audits and site visit, staff examined the Copper Creek Fault in core from Borehole CC-B2. We will look at the subsurface expression of the fault in that borehole!

# Geologic Map Showing Locations of Thrust Faults in the Site Area






(Reproduced from SSAR Figure 2.5.1-34)

Fault gouge produced by crushing and grinding of rock units due to displacement along the Copper Creek Fault is dated at **279.5 +/- 11.3 Ma**. Reported displacement along the fault is 12-50 km (7.4-31 mi).

Note that the site lies between the northeast-striking, southeast-dipping Copper Creek and Whiteoak Mountain thrust faults.

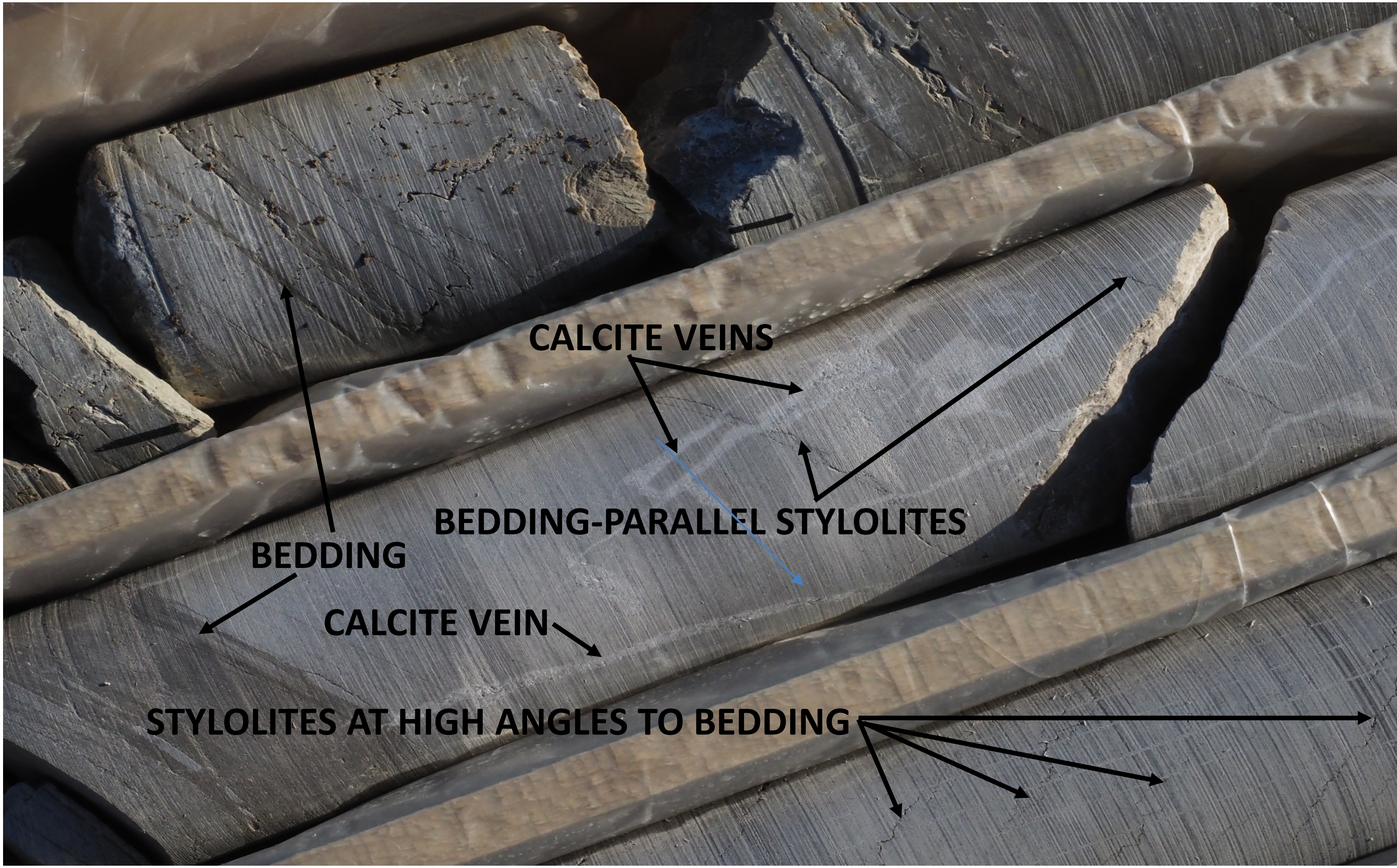

Fault gouge marking the Copper Creek Fault in Borehole CC-B2. Note the clear distinction between the gouge, dated at ~280 Ma, and intact rock. (G. Stirewalt image, January 2018)

# Shear-Fracture Zones

- Shear-fracture zones at the site contain pressure solution features (stylolites) oriented parallel and perpendicular to bedding. These features tell a story about orientation of stresses that affected the shear-fracture zones.

- Non-tectonic bedding-parallel stylolites (earliest) formed during deposition and lithification of sedimentary units due to vertical overburden pressures. Bedding-perpendicular stylolites (latest) likely formed in response to near-horizontal stresses related to transport of thrust sheets (~280 Ma) and suggest tectonic overprinting.

- During the site audits and site visit, staff examined the shear-fracture zone that occurs in the Rockdell Formation in core from Borehole MP-101.




Shear-fracture zone penetrated in borehole MP-101. The stylolites must have developed at two different times because they form essentially perpendicular to the causative stress. (G. Stirewalt image, January 2018)

# Staff's Conclusions for CRN ESP SSAR Section 2.5.1

- No tectonic features with the potential for adversely affecting suitability of the site occur in the site region, site vicinity, site area or at the site location (i.e., no data suggest the presence of Quaternary tectonic features). The primary tectonic event registered in the rock units, regional thrust faults, is dated at ~280 Ma. No field evidence suggests the shear-fracture zones are younger than that event.
- Karst is the primary non-tectonic feature with the potential to adversely affect suitability of the site.
- The applicant described geologic characteristics of the site region, site vicinity, site area and site location in SSAR Section 2.5.1 in full compliance with regulatory requirements in 10 CFR 52.17(a)(1)(vi) and 10 CFR 100.23(c) and in accordance with guidance in RG 1.208.

# Content of CRN ESP SSAR Section 2.5.3

## Section 2.5.3 - Surface Deformation

- 2.5.3.1 through 2.5.3.8 - Information related to assessment of features that might indicate a potential for tectonic (including geologic features observed in the East Tennessee Seismic Zone) and non-tectonic (i.e., specifically karst-related features) surface deformation at the site.

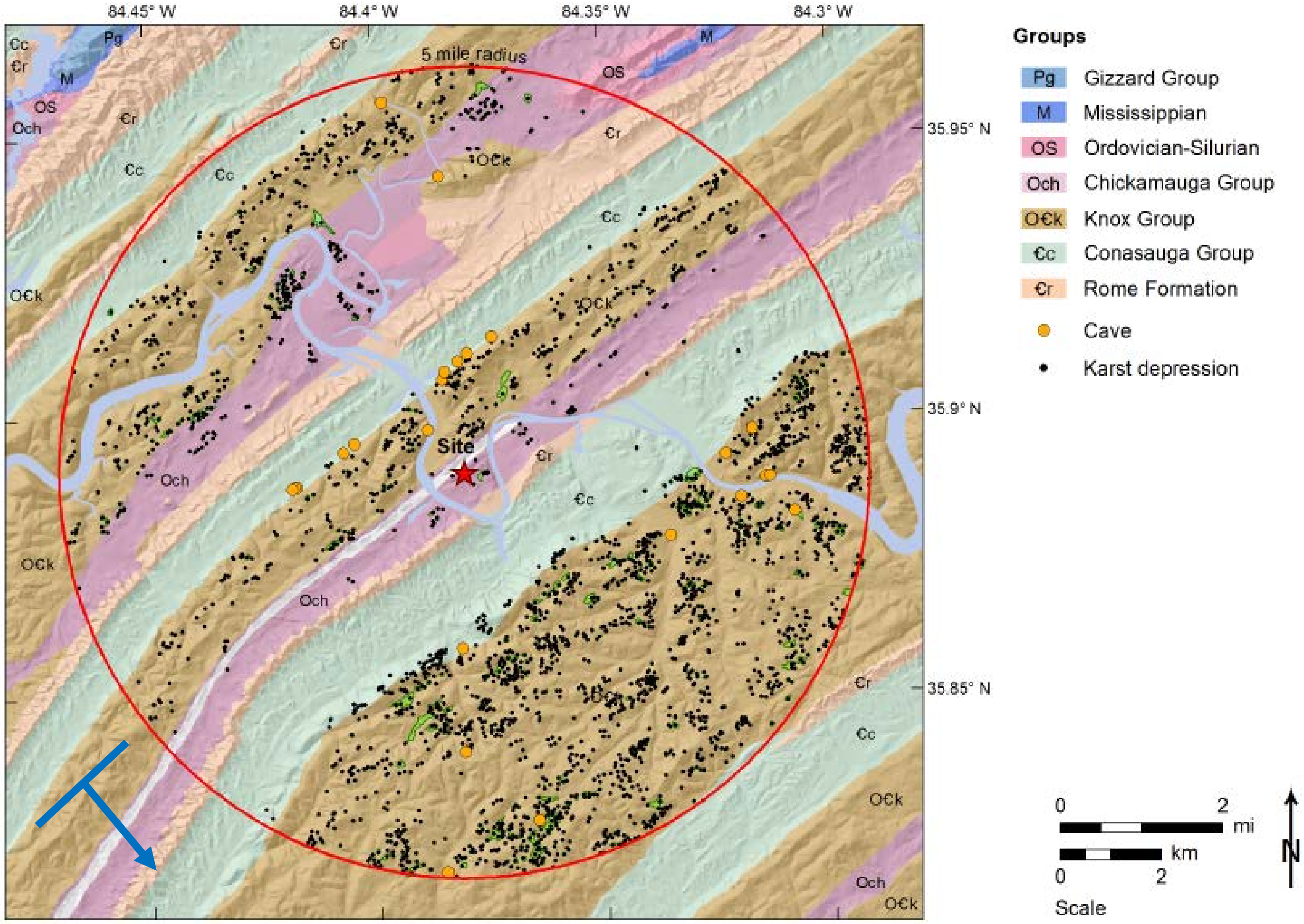
# Key Review Topics of Interest for Section 2.5.3

The staff reviewed the following key topics for the potential for tectonic and non-tectonic surface deformation at the CRN site.

- The relationship of potential tectonic surface deformation to observed seismicity in the East Tennessee Seismic Zone is undetermined.
- Due to carbonate rocks in the subsurface, direct observation of karst features and ongoing dissolution processes in site vicinity, and interpreted cavities in core as indicated by missing segments, karst has the potential to cause surface deformation at the CRN Site

# Distribution of mapped karst features in the CRN site area

U.S.NRC
United States Nuclear Regulatory Commission
*Protecting People and the Environment*




**Swale**: small wet depression

**Swallet**: slightly larger depression through which water drains

**Sinkhole**: surface depression as a result of subsurface collapse due to dissolution

(After SSAR Figure 2.5.1-47)

# Cavities in core from borings


Interpreted cavities of varying thicknesses recorded in numerous boreholes.

# Pinnacle and cutter surficial karst features

United States Nuclear Regulatory Commission

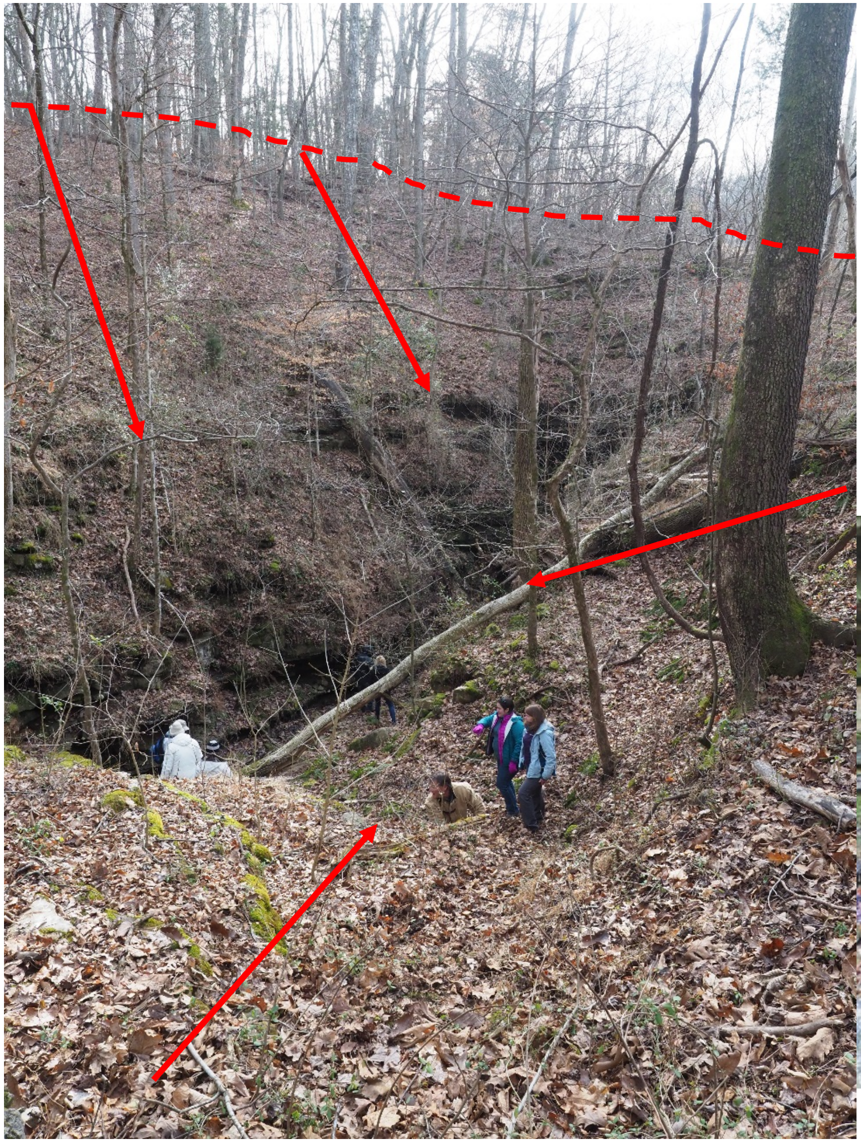
*Protecting People and the Environment*

Dissolution features along joints and bedding planes resulting in cavities in the exposed rock

# Swales, swallets, and sinkholes as surficial karst features


Sinkhole within the site area with steep slope and ponded water

# Entrance to Copper Ridge Cave



Copper Ridge Cave is the largest cave the staff visited in the Clinch River site area

Drainage flows into the cave entrance from the surrounding depression with dissolution along joints and bedding planes, including a 90-degree turn

# Geologic Mapping Permit Condition

In SSAR Section 2.5.1.2.6.10, the applicant acknowledged the need to perform detailed geologic mapping for documenting the presence or absence of karst features, faults, or shear-fracture zones in plant foundation materials. To address this need, the staff identified Permit Condition 1 in SER Section 2.5.3.5 as stated below:

- The applicant for a combined license (COL) or a construction permit (CP) that references this early site permit (ESP) shall perform detailed geologic mapping of excavations for safety-related engineered structures; examine and evaluate geologic features discovered in those excavations; and notify the Director of the Office of New Reactors, or the Director's designee, once excavations for safety-related structures are open for examination by NRC staff.

# Staff's Conclusions for CRN ESP SSAR Section 2.5.3

- Negligible potential exists for tectonic surface deformation that could adversely affect suitability of the CRN Site. Karst is the primary potential hazard for non-tectonic surface deformation at the CRN Site.
- The applicant described information related to assessment of features that might have a potential for producing tectonic and non-tectonic surface deformation at the site in SSAR Section 2.5.3 in full compliance with regulatory requirements in 10 CFR 52.17(a)(1)(vi) and 10 CFR 100.23(d) and in accordance with guidance in RG 1.208.

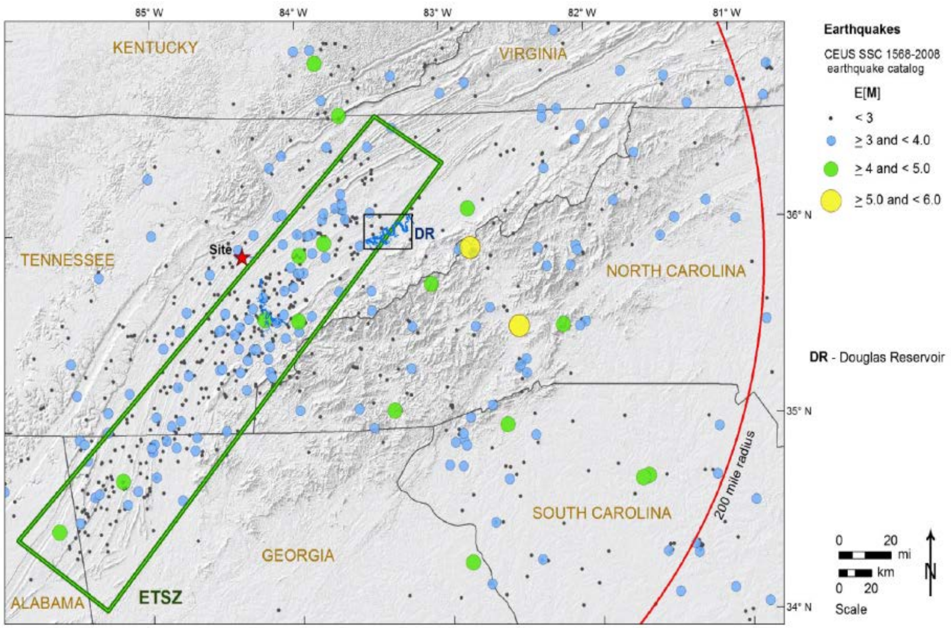
# Section 2.5.2 – Vibratory Ground Motion

# Key Review Topics of Interest for Section 2.5.2

- Treatment of Eastern Tennessee Seismic Zone
- Approach to developing site-response analysis
- Development of 2-D site response analysis

# Treatment of Eastern Tennessee Seismic Zone (ETSZ)

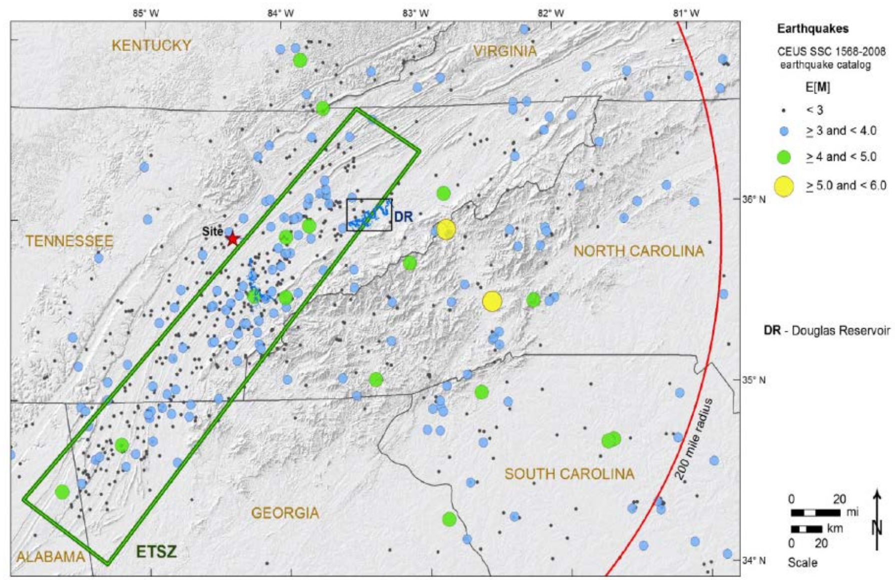
- ETSZ is region of elevated seismicity rates.
  - Small magnitude earthquakes
  - Occur within basement rocks below sedimentary section
- Included in NUREG-2115 within seismotectonic and $M_{max}$ source zones
  - Sensitivity studies done during study to ensure that source zones adequately capture seismicity in ETSZ
- Recent geologic studies interpret potential for larger (**M**≥6.5) earthquakes




SSAR Figure 2.5.2-26

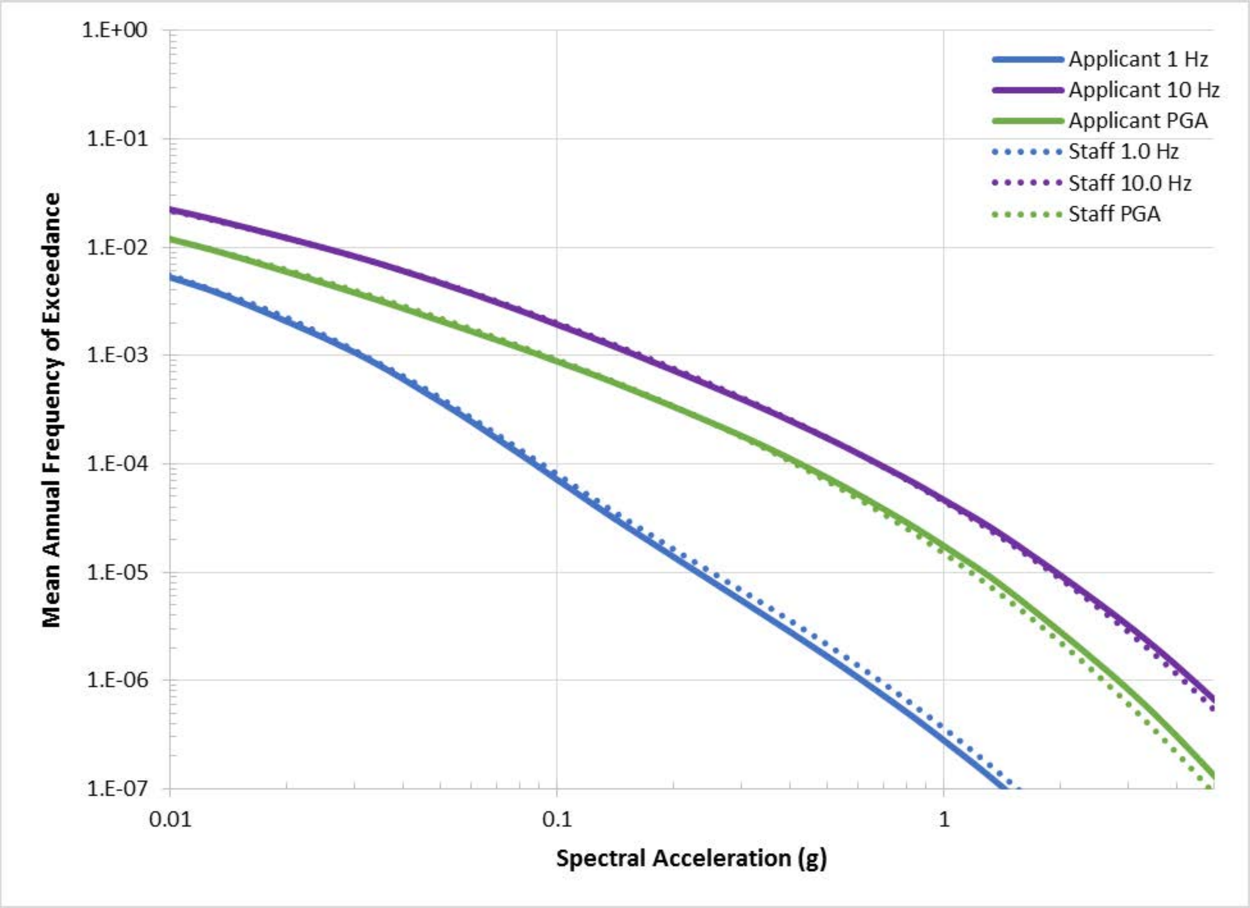
# Treatment of Eastern Tennessee Seismic Zone

- Applicant performed two sensitivity studies following SSHAC guidance for Level II study
  - Evaluate $M_{max}$
  - Evaluate Magnitude-Frequency relations
- $M_{max}$ values in NUREG-2115 encompass proposed $M_{max}$ developed using new data
- Recurrence of large magnitude events in NUREG-2115 consistent with proposed values in new geologic studies
- Staff concludes that NUREG-2115 adequately captures current understanding of seismic hazard in the Eastern Tennessee Seismic Zone




SSAR Figure 2.5.2-26

# Probabilistic Seismic Hazard Analysis (PSHA) Confirmatory Calculations




Staff independently calculated seismic hazard curves at the Clinch River site. Comparisons show that the seismic hazard curves are in good agreement at the annual frequency of exceedances of interest: $10^{-4}$, $10^{-5}$, and $10^{-6}$

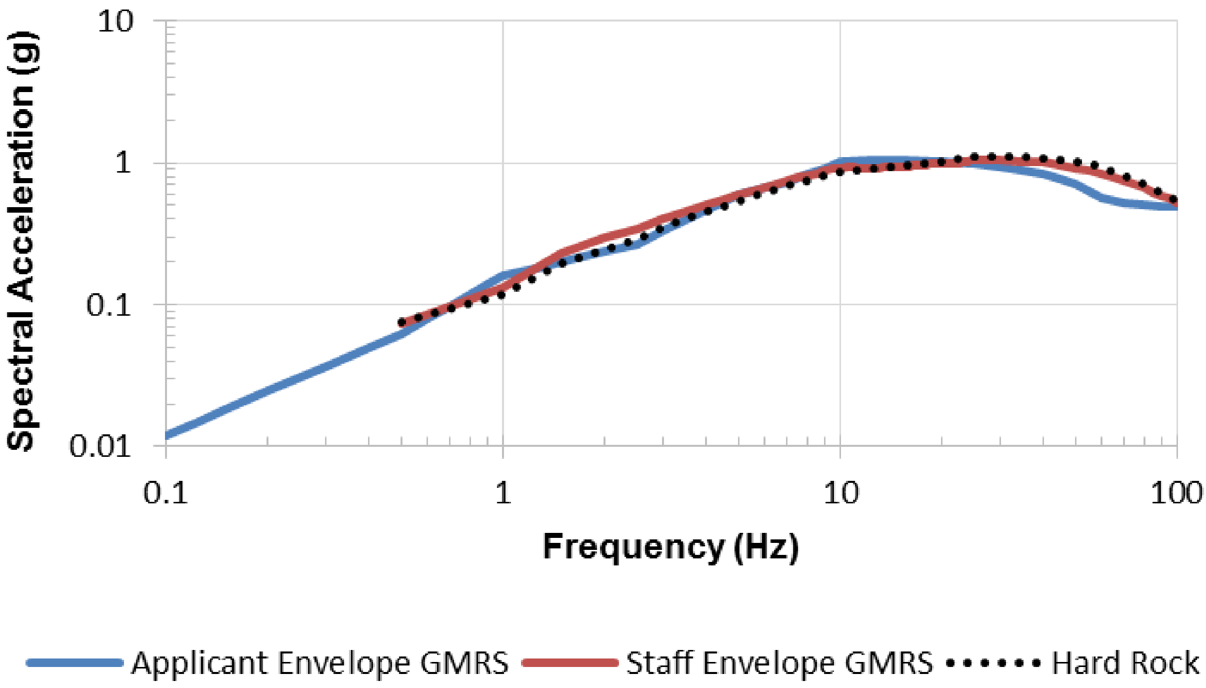
# Approach to Site Response Inputs

United States Nuclear Regulatory Commission
*Protecting People and the Environment*

- Clinch River site has significantly dipping rock layers
  - Approximately 30 degrees
- High seismic velocities
  - 5,000 to >10,000 fps
- Applicant developed site response inputs using
  - 3 profiles for each location
  - Log mean seismic velocity as function of depth as base case
  - Upper and lower case using log standard deviation
  - Effect of smearing geologic units together

- Staff requested that applicant explain how the use of multiple base cases accurately accounts for dip across site
- Applicant responded the smearing of units is appropriate because mean and range of values at a specific depth is maintained, implicitly accounting for stratigraphic variations.
- Staff performed confirmatory site response considering dip explicitly (i.e. upsection; middle; and downsection profiles)
- Staff truncated profiles at the top of the Knox Group due to thickness and velocity of layer
- Staff's results are consistent with applicant's

# Ground Motion Response Spectrum (GMRS) Confirmatory Analysis

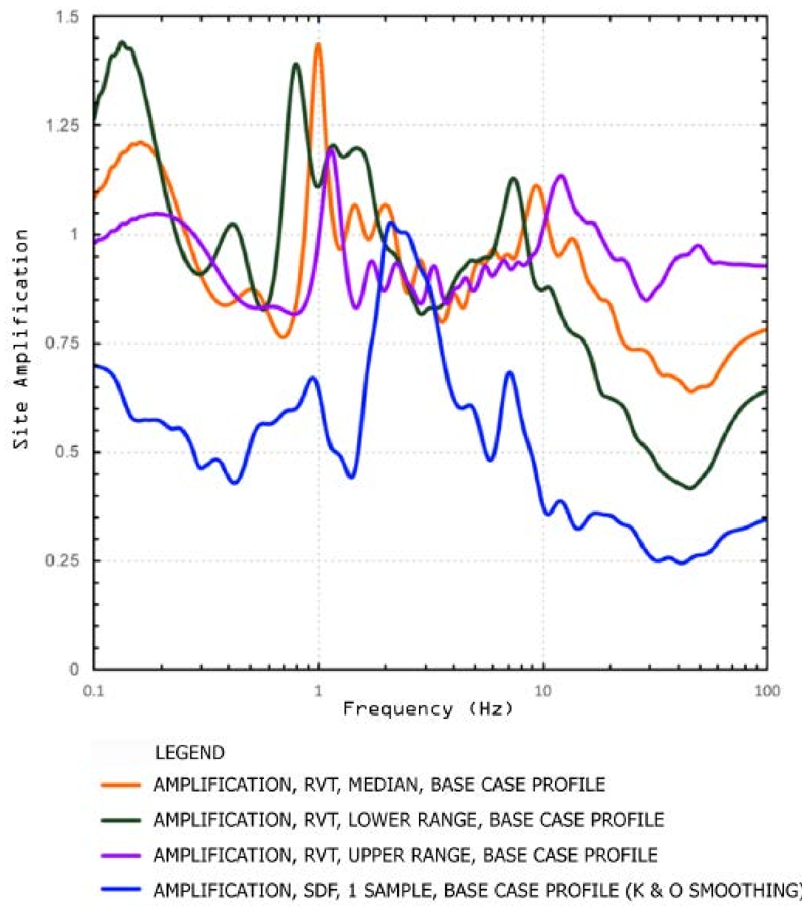



Staff developed alternative input parameters for site response analysis. Staff independently calculated site response and developed a site ground motion response spectrum (GMRS) based on its preferred inputs. Site GMRS developed by staff is consistent with that developed by the applicant.

# 2-D Site Response

United States Nuclear Regulatory Commission
*Protecting People and the Environment*

- Clinch River site has significantly dipping (>30 degrees) rock layers in subsurface
- RG 1.208 states that for sites with complicated subsurface structure, a multi-dimensional approach to site response may be necessary
- Applicant developed a 2-D site response analysis and compared amplification functions to 1-D results developed using 2-D inputs
- Staff requested that applicant compare 2-D results to 1-D results used in developing GMRS
- Applicant's 2-D results compare favorably with 1-D results, satisfying staff's concern




SSAR Figure 2.5.2-108

# Staff Conclusions - Section 2.5.2

- The applicant provided a thorough characterization of the seismic sources surrounding the site, as required by 10 CFR 100.23
- The applicant adequately addressed the uncertainties inherent in the characterization of these seismic sources through a PSHA, and its PSHA follows the guidance provided in RG 1.208
- Applicant's GMRS adequately represents the regional and local seismic hazards and accurately includes the effects of the local site subsurface properties

U.S.NRC
United States Nuclear Regulatory Commission
*Protecting People and the Environment*

# Section 2.5.4 - Stability of Subsurface Materials and Foundations

# Summary of CRN ESP SSAR Section 2.5.4

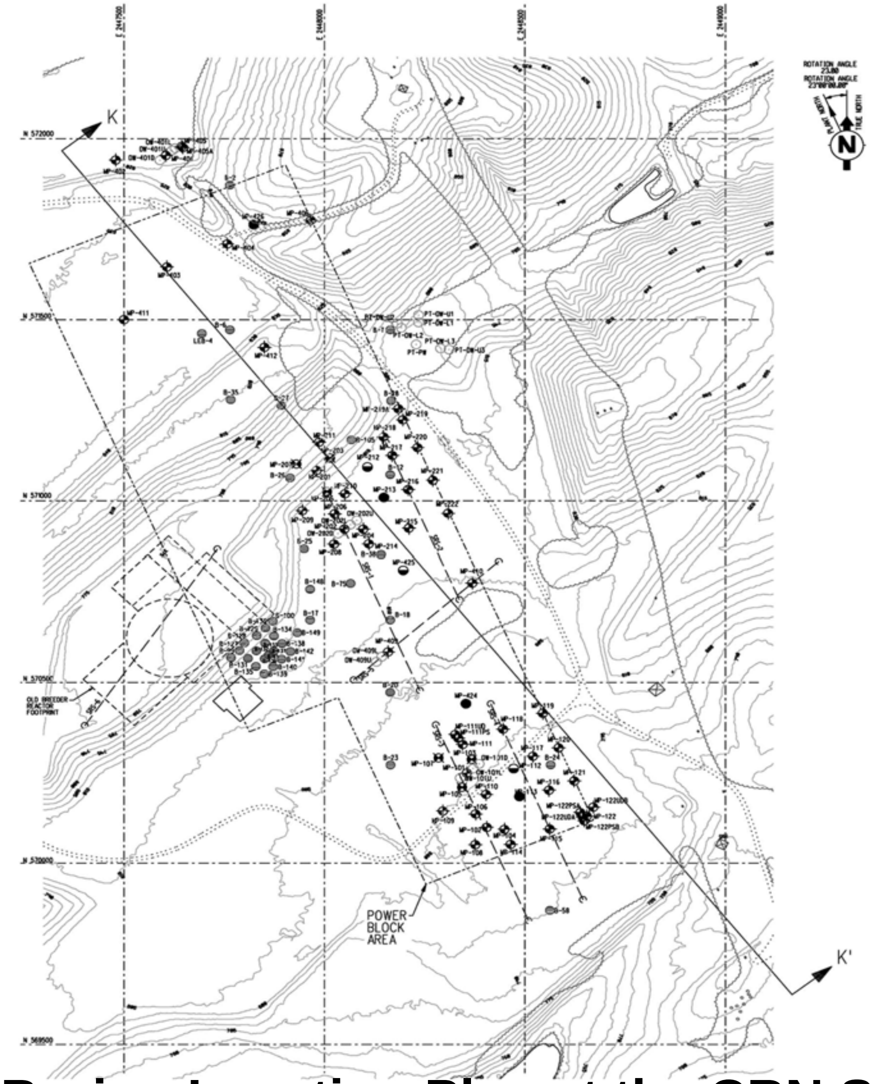
- SSAR Section 2.5.4 presents the engineering properties of subsurface materials, and evaluation of stability of subsurface materials and foundations at the CRN Site.
- SER Section 2.5.4 includes:
  - The staff's evaluation of engineering properties of subsurface materials; foundation interfaces; geophysical surveys; excavation and backfill; groundwater conditions; response of soil and rock dynamic loading; liquefaction potential; stability of foundations
  - 16 COL Action Items
  - 1 Permit Condition

# Plant Parameter Envelope

- In order to provide sufficient geotechnical information at the site without having a specific design, the applicant provided a surrogate design in its application. The surrogate plant approach covers a set of bounding parameters: the plant parameter envelope (PPE).

- Under the PPE approach, the resulting ESP will be applicable for a range of reactor designs if their relevant design parameters fall into the PPE.

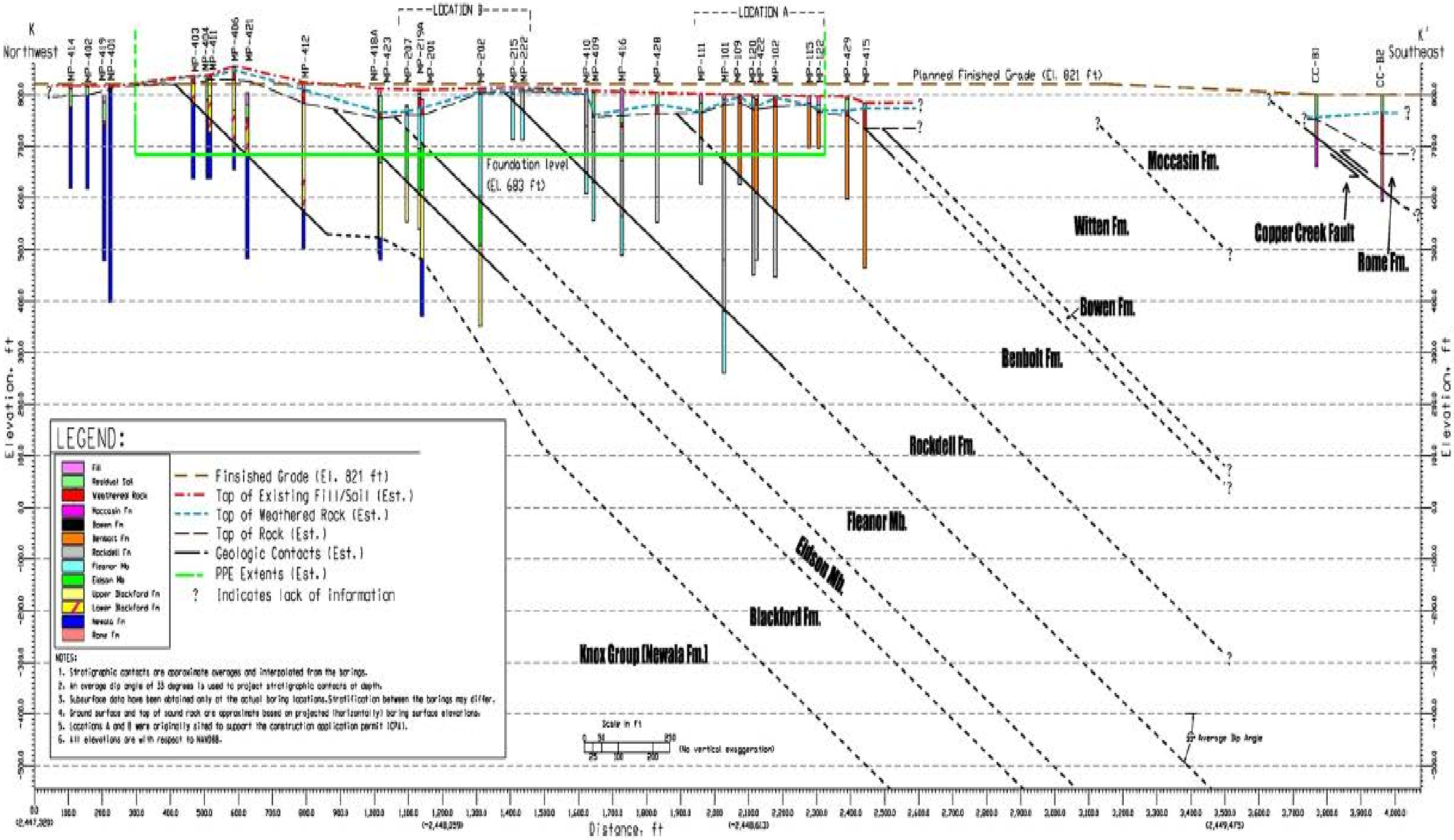
# CRN ESP Site Exploration




**Boring Location Plan at the CRN Site**

**(Reproduced from SSAR Figure 2.5.4.)**

# Site Stratigraphy




**Geotechnical Cross-Section of the Stratigraphy of the Power Block Area**

**(Reproduced from SSAR Figure 2.5.4-1)**

# Key Review Topics of Interest for Section 2.5.4

United States Nuclear Regulatory Commission
*Protecting People and the Environment*

Assessment of the Effects of Underground Voids on Foundation Stability

- Karst exists at the CRN Site and the underground voids may adversely affect the foundation stability.
- The applicant's site investigation for the ESP application provided preliminary information on void distribution and size.
- The staff reviewed the applicant's PLAXIS 2-D Finite Element (FE) model that assessed the effects of postulated underground voids on foundation stability at the CRN Site.
- The staff concludes that the applicant conducted an appropriate preliminary evaluation to determine potential karstic cavity impacts on the foundations.
- This analysis should be site location and technology specific, therefore the staff identified COL Action Item 2.5-2 which establishes that a future applicant referencing this ESP should reevaluate the potential of karstic cavity impacts, within the zone of influence of the foundation under all design loading conditions, on foundation stabilities for safety-related structures.

# Key Review Topics of Interest for Section 2.5.4

## Foundation Stability Analysis for CRN Site with Inclined Strata

- The CRN Site consists of multiple inclined layers of various rock formations with possible weakened interfaces between the formations.
- The staff reviewed the applicant’s multiple traditional methods and Finite Element (FE) methods used to assess foundation stability at the CRN Site.
- The staff concludes that the traditional methods results are in good agreement with those obtained from the finite element model and that the selected PPE values related to the site stability analyses are appropriate.
- The staff identified COL Action Items 2.5-12 through 2.5-14 for the COL or CP applicant to address the foundation stability of the site once a reactor technology and the specific location and extent of Seismic Category 1 structures is identified.

# COL Action Items

COL Action Items 2.5-1 through 2.5-16 pertain to reactor technology and site location specific actions that need to be addressed by the COL or CP applicant when referencing this ESP. Those COL Action Items are related to the following site characteristics:

- Site Geologic Features
- Properties of Subsurface materials
- Excavation and backfill
- Groundwater condition
- Static and dynamic stability
- Design criteria
- Techniques to Improve Subsurface Conditions

# Permit Condition



The site investigation data shows that the discontinuities, shear fractures zones, and weathered fracture zones typically exist within weathered rock in the uppermost 30.5 m (100 ft), where most of the cavities are encountered at the CRN Site. The rock mass characterization described in the application is mainly for bedrock stratigraphic units below 24.4 m (80 ft) (El. 225.9 m (741 ft) NAVD88), the staff identified **Permit Condition 2** in SER Section 2.5.4.5 as stated below:

> An applicant for a combined license (COL) or a construction permit (CP) that references this early site permit shall remove the material above El. 225.9 m (741 ft) NAVD 88 in areas where safety-related structures will be located, to minimize the adverse effects of discontinuities, weathered and shear-fracture zones, and karst features on the stability of subsurface materials and foundations. The applicant shall also perform additional geotechnical investigations, in accordance with RG 1.132, at the excavation level to identify any potential geologic features that may adversely impact the stability of subsurface materials and foundations.

# Staff Conclusions – Section 2.5.4

- The applicant adequately determined the site-specific engineering properties of the subsurface materials underlying the CRN Site, and conducted sufficient evaluation of the stability of subsurface materials and foundations, based on the results of field and laboratory tests and the state of the art methodology, and in accordance with RG 1.132, RG 1.138, and RG 1.198.
- The staff concludes that the applicant meets the requirements of 10 CFR Part 52.17(a)(1)(vi) and 10 CFR Part 100.23(c) for this ESP application regarding the stability of subsurface materials and foundations.

# Section 2.5.5 - Stability of Slopes

# Section 2.5.5- Stability of Slopes



- The NRC staff reviewed SSAR Section 2.5.5, which provides general description of the site related to slope stability analysis.
- There are no existing slopes on the site at this time, either natural or manmade, that could affect the stability of the site.
- The applicant deferred the actual slope stability analysis to the COL or CP application.
- To address the need for future slope stability analyses, the staff identified COL Action Item 2.5-17 as stated below:

> An applicant for a COL or CP application that references this early site permit should perform a slope stability analysis of any safety-related slopes, including dams and dikes, consistent with the selected reactor technology.

United States Nuclear Regulatory Commission
Protecting People and the Environment

# Staff Conclusions – Section 2.5.5

- The applicant provided necessary information on site topography and geologic characteristics, and adequately described the slope characteristics at the site.
- The staff concludes that the SSAR Section 2.5.5 is adequate and acceptable because it meets applicable requirements of 10 CFR Part 50, Appendix S, 10 CFR Part 52.17(a)(1)(vi) and 10 CFR Part 100.23.