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UNITED STATES NUCLEAR REGULATORY COMMISSION'S
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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694TH MEETING

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

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THURSDAY

APRIL 7, 2022

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The Advisory Committee met via teleconference at 8:30 a.m., Joy L. Rempe, Chairman, presiding.

COMMITTEE MEMBERS:

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DESIGNATED FEDERAL OFFICIAL:

CHRISTOPHER BROWN

P R O C E E D I N G S

(1:00 p.m.)

CHAIRMAN REMPE: So, good afternoon. It's 1:00 p.m. on the East Coast. We're back in session. And at this point I'd like to ask Member March-Leuba to introduce the discussion on the GE BWRX-300 Advanced Civil Construction and Design Approach.

MEMBER MARCH-LEUBA: Thank you, Member Rempe, Chair Rempe. We have a GEH, again, person come to us. And we are going to see a completely different topical report. And this time it's about construction engineering, civil construction.

George -- no, sorry. The staff is going to make an introduction. Mike Dudek, please go ahead.

MR. DUDEK: Thank you. My name is Michael Dudek. I'm the branch chief of new reactor licensing for NRR. Thank you, Senior Technical Member March-Leuba, and the members of the commission, and Chairman Rempe for hearing us again today on another important topic associated with BWRX-300 technology.

We first heard and presented on this topical report on March 18th, associated with the advanced civil construction and design approach. We had a very good discussion with the committee. Several questions and answers were raised.

We're here today for the full committee to answer some of those questions and provide a high-level overview of the topical report and the staff's review, which was approximately 8 months. And after several RAIs, the staff issued their SER earlier this year.

We've outlined several limiting conditions that were discussed for this SER. And that will be evaluated during future licensing activities.

So, without any further ado, I'll turn it back to you, Member March-Leuba, and GEH for the presentation.

MEMBER MARCH-LEUBA: Mike, before you go away, just a clarification. We had a rather long talk yesterday about the joint Canadian-NRC review for a different topical report. My understanding, there is no such thing for this report. Correct?

MR. DUDEK: That is correct. This topical report was independent and only conducted by the NRC.

MEMBER MARCH-LEUBA: Excellent. Thank you.

CHAIRMAN REMPE: Okay. I have a bit of an echo. Let me try again.

(Pause.)

CHAIRMAN REMPE: Thank you. Go ahead.

MEMBER MARCH-LEUBA: GE, George I believe it's your turn.

And everybody remember, this is an open session. You know, this is a non-proprietary document anyway.

MR. WADKINS: Yes.

CHAIRMAN REMPE: But don't divulge proprietary information.

MR. WADKINS: Good afternoon. My name is George Wadkins. I'm the vice president of New Power Plants and Products Licensing. Today we are going to discussing our licensing topical report, NEDO-33914, BWRX-300 Advanced Civil Construction and Design Approach.

It is a non-proprietary document, and we do not expect there to be the need for any proprietary discussions involving this LTR.

The BWRX-300 design is built upon many years of experience in plain water reactors. One of the most innovative features, though, of the BWRX-300 is in the design of the seismic Category I reactor building housing the safety-related components of the facility, including the reactor containment building and engineered safety features.

BWRX-300 reactor building is a deeply

embedded, vertical right cylinder structure that eliminates the traditional foundation construction method. Instead of a large initial excavation with large amounts of required engineered backfill, the reactor building is constructed inside a vertical right cylinder shaft.

This LTR describes the vertical shaft construction method and impacts on design, analysis, construction, and monitoring of the BWRX-300 reactor building.

I wish to thank the NRC staff for their thorough review. I wish to thank the ACR subcommittee for our previous meeting, which went very well, and for you hearing us today and considering the approval of the SER by the NRC staff.

So, with that, I will turn it over to Lisa Schichlein. She is the U.S. licensing manager, actually, for our naturing reactor, but also does work with our licensing topical reports for BWRX-300.

MEMBER MARCH-LEUBA: And, Lisa, before you start, the subcommittee will discuss how large this reactor building was deep underground. Can you tell us how large the building is? Say your name first.

MR. TODOROVSKI: My name is Luben Todorovski. I am physical engineer for GE-Hitachi.

The building is approximately 250 feet high. Also, this one, approximately 120 feet below ground. And it's 50 feet round.

MEMBER MARCH-LEUBA: So, wait. Half of it is underground, half of it is above?

MR. TODOROVSKI: Approximately, yes. Half of it is out, then half is below ground. And the rest is above ground.

MEMBER MARCH-LEUBA: And 250 feet is almost a football length. That will be 300.

MR. TODOROVSKI: Yeah. I actually know that it's one-half below ground, so it's 250 feet is more appropriate number.

MEMBER MARCH-LEUBA: Thank you.

MS. SCHICHLEIN: Good afternoon. My name is Lisa Schichlein, and I'm the U.S. licensing manager for new power plants and products at GE-Hitachi Nuclear Energy Americas.

I'd like the ACRS full committee for the opportunity to present the BWRX-300 advanced civil construction and design approach licensing topical report.

In addition to George Wadkins, we have in attendance from GEH, who you've already met, Luben Todorovski, a principal engineer in the civil structural area; Brandon Gomer, a geologist from Black & Veatch; Jesus Diaz, our U.S. licensing manager for BWRX-300; and Mr. Ossama Ali, the engineering manager for civil balance of plant systems.

On call in addition, supporting our meeting today we have Tanya Kirby, a senior project engineer for Jisukru (phonetic), a senior civil structural engineer; Ai-Shen Liu, one of our engineers; and David Hinds, principal engineer for plant integration.

And, in addition, we'll be also supported by a number of folks from the Black & Veatch team: Wei Zheng, a geotechnical engineer; Michael Tzang, the engineering manager; David Calhoun, the nuclear chief engineer for Black & Veatch.

GEH, Asuki (phonetic), and Jisukru have an alternative approach to the construction, analysis, and design of the BWRX-300 below-grade reactor build. To that end, the topical report presents design analysis and monitoring guidelines and requirements to support our request for approval for approach to the construction of the below-grade BWRX-300 small modular reactor, reactor building vertical right cylinder shaft.

The scope of the topical report includes the regulatory basis for this approach, guidelines for characterizing subsurface conditions, guidelines for performing the foundation interface analysis, the design requirements, acceptance criteria and guidelines for the analysis and design of the deeply embedded reactor building, an approach for adjusting Seismic Category II/I interactions in the reactor building and surrounding structures' foundations, and our generic seismic geotechnical design parameters.

This figure illustrates the conceptual site plot plans for a BWRX-300 single unit plant. The control building, turbine building, and rad waste building structures are located adjacent to the deeply embedded Seismic Category I reactor building structure, and are separated from the reactor building by seismic gap.

The rad waste building, as you can see, is categorized as RW2A. And the control building and turbine building are non-seismic.

This figure also illustrates the relative position at the ground level.

The design and analysis described in the topical report comply with all applicable regulatory requirements and guidance for the areas listed on the slide: so define site subsurface conditions, site design plan, seismic analysis, II/I interaction, and testing, inspection and monitoring.

The features presented here meet the intent of the current regulatory guidance for large light water reactors and addresses specifics related to the seismic structural design of deeply embedded SMRs.

GEH is not requesting NRC approval for exemptions from any regulatory requirements or exceptions to the regulatory guidance.

The topical report discusses the property characterization and monitoring approach which is driven by the reactor building structure being deeply embedded. This includes several investigation, testing, and monitoring programs that will be used in conjunction with the foundation interface analysis, including a site investigation program, a subsurface nuclear lab testing program, and construction and in-service monitoring program.

A 3-dimensional foundation interface analysis will be performed, which includes interface modeling, structural modeling, fluid soil interaction, and consideration of all plant life stages.

The methodology also includes static and seismic soil structure interaction analysis approaches for designing a deeply embedded reactor building structure, and a graded approach taken for the evaluation of Seismic Category II/I interaction between the Seismic Category I reactor building and the adjacent control building, turbine building, and rad waste building.

The topical report also includes the method for developing generic seismological and geotechnical site plans using generic design response spectra, subgrade dynamic properties, static properties, and NRC generic guidance.

VICE CHAIRMAN KIRCHNER: Can I ask a question?

MS. SCHICHLEIN: Yes, certainly.

VICE CHAIRMAN KIRCHNER: So, here you are following Appendix S in your approach, and you'll just use one -- can't see the slide.

MS. SCHICHLEIN: Oh, let me get that.

VICE CHAIRMAN KIRCHNER: GRDS.

MS. SCHICHLEIN: Yes.

VICE CHAIRMAN KIRCHNER: So, you will use just one spec?

MS. SCHICHLEIN: I'd like to defer that to Luben, please.

MR. TODOROVSKI: Yes. The generic design

for the --

VICE CHAIRMAN KIRCHNER: A little louder, please.

MR. TODOROVSKI: The intent of this is to develop a design that will be applicable for 80 percent of the sites, the sites in North America.

VICE CHAIRMAN KIRCHNER: Right.

MR. TODOROVSKI: And for the generic design we expect to use three sets of those spectra for firm, medium, and hard sites.

VICE CHAIRMAN KIRCHNER: So, three soil types?

MR. TODOROVSKI: Yes. Three, three types of soil.

VICE CHAIRMAN KIRCHNER: The bounds that you went for certified or standard design, that would bound, as you said, 80 percent of the sites you might consider?

MR. TODOROVSKI: Right. It's based on database of the reasonably --

MS. SCHICHLEIN: In conclusion, I would like to wrap up this presentation by restating that the design and analysis described in the licensing topical report comply with all applicable regulatory requirements and guidance.

The approaches discussed in the topical report meet the intents of the current regulatory guidance for large light water reactors, and address the specifics related to the seismic and structural design of deeply embedded small modular reactors.

And just to restate, that GEH is not requesting NRC approval for exemptions from any regulatory requirements or any exceptions to any regulatory guidance.

CHAIRMAN REMPE: And just remembering when we talked in the subcommittee, just to put it on the public record, we are always concerned about underground structures that will not be inspected for 40, 60, 80 years. And you told us that. That is not part of this topical report, what treatment you will provide for that circumstance?

MS. SCHICHLEIN: Correct.

CHAIRMAN REMPE: And we will be seeing it in a future topical report. We are only concerned with the structural right now.

MS. SCHICHLEIN: Right. That is correct.

And with that, if there's any additional questions or comments from the committee.

VICE CHAIRMAN KIRCHNER: Well, without getting into any -- this is not a proprietary report;

right?

MS. SCHICHLEIN: Correct.

VICE CHAIRMAN KIRCHNER: Okay. Fine. Then all right.

So, what did you see when you did your structural soil interaction analysis with the three different soil types? Did you see any dominant, especially if embedded in hard, hard soil types, did you see significant change in your spectra at the higher frequencies.

MR. TODOROVSKI: So, just to clarify, we tested with three types of -- soil types. But we have up to nine profiles. So, basically, they can change in terms of how the soil, what is the distribution of the soil with that. And depending on the location of the rock.

VICE CHAIRMAN KIRCHNER: So, for a deeply embedded structure of this size, what, what turned out to be dominant in terms of the actual g loads that are transferred?

MR. TODOROVSKI: Unlike, unlike above ground structures, this structure is driven by the soil. And softer soil conditions actually lead to higher structural demands for in the below ground.

But the type of soil will be bounding for the above ground. So, it's kind of different.

VICE CHAIRMAN KIRCHNER: That makes sense.

Did you see amplification in the high, for the hard soil types with this embedded concept on the higher frequency over --

MR. TODOROVSKI: Yes. There are certain local responses, local modes. But, in general.

VICE CHAIRMAN KIRCHNER: So, you didn't see anything that would impose significant change in terms of the g forces, the loading forces going in?

MR. TODOROVSKI: In general, the embedment helps, this was (audio interference). We had comparison with other technologies in terms of what demands we share from different components. And by the time that some of the components are below ground that it reduces the demand, seismic demand.

VICE CHAIRMAN KIRCHNER: Thank you.

MEMBER MARCH-LEUBA: On occasions that we have an expert here, I always have thought that putting it underground, as being an engineer, would be better than above ground. But you told me that indeed it put higher stresses (audio interference) circle.

MR. TODOROVSKI: If you have a big building, I'm not sure the building would determine the design. It doesn't mean that in this case because the structure is relatively small, when it's embedded in the soil then the response of the soil will determine the design of the structure.

So, that's why we have written this LTR to address those specifics, the differences between the design and what we are used to in the large light water reactor.

MEMBER MARCH-LEUBA: But I should expect an underground embedded structure to be more limiting from the point of view of seismic than above ground?

MR. TODOROVSKI: Yes. It helps.

MEMBER MARCH-LEUBA: It helps or it is bad?

MR. TODOROVSKI: No. The embedment helps. It helps.

MEMBER MARCH-LEUBA: It helps. Okay. So, I misunderstood what you said. I thought --

MR. TODOROVSKI: There's certain uncertainty related to the rock --

MEMBER MARCH-LEUBA: Yes. But I would have expected it to be better.

MR. TODOROVSKI: Not necessarily.

MEMBER MARCH-LEUBA: Okay, thank you.

Yeah?

VICE CHAIRMAN KIRCHNER: If you had a

really large building that's in -- a really large building that's in soft soil, that will amplify it.

MEMBER MARCH-LEUBA: Yeah. I would have expected an above ground to go like this, and teeter. And underground it just cannot go.

MR. TODOROVSKI: Correct. And this is a sleeve structure, it goes above ground in addition.

MEMBER MARCH-LEUBA: Okay. Thank you.

Anymore questions for GE? If not, we can take a very short recess so we don't have to keep a transcript while we're moving computers. And let's change.

Joy?

CHAIRMAN REMPE: Five-minute recess.

MEMBER MARCH-LEUBA: It's not five minutes. Just let's change, but there doesn't need to be a transcript of everything we say while we're moving computers. Thank you.

(Whereupon, the above-entitled matter went off the record at 1:18 p.m. and resumed at 1:23 p.m.)

CHAIRMAN REMPE: Okay. We're back in session. And I'm going to turn it back over to Member March-Leuba.

MEMBER MARCH-LEUBA: Thank you. And I want to go immediately to the NRR staff. Alina, are you in charge, or who's going to start?

MS. SCHILLER: Yes. I'll start.

MEMBER MARCH-LEUBA: Go ahead.

MS. SCHILLER: My name is Alina Schiller. I'm a project manager in the NRC Office of Nuclear Reactor Regulations, Division of New and Renewed Licenses, New Reactor Licensing Branch.

I'd like to thank the ACRS full committee for this time to allow the NRC staff to present its review of GEH BWRX-300 licensing topical report, advanced civil construction and design approach.

GEH submitted the Revision 0 of this licensing topical report on January 20th, 2021, and Revision 1 On November 18th, 2021. The NRC staff issued the advanced safety evaluation of the topical report on February 16th, 2022.

As stated in the advanced safety evaluation, the NRC staff will evaluate the compliance of the final civil construction and design features for the BWRX-300 small modular reactor during future licensing activities in accordance with 10 CFR Part 15, or 10 CFR Part 52, as applicable, with the limitations and conditions as outlined in Section 8-0 of the safety evaluation.

Today the staff will provide the high

level summary of the March 18th, subcommittee presentation, with an emphasis on the staff's limitations and conditions.

The NRC staff reviewers are Dr. Amitava Ghosh, who is the lead technical reviewer and presenter; Dr. David Heeszel, Edward Stutzcage, Angelo Stubbs, and Sujit Samaddar. I am the topical report project manager, supported by senior project manager James Shea.

Before I introduce Dr. Ghosh, I'd like to open the floor to NRC management, Joseph Colaccino, branch chief of the Structures, Civil, and Geotechnical Engineering Branch.

MR. COLACCINO: Thanks, Alina. I actually have nothing to add. So, I'd like to send it directly to Amit, unless you have other stuff, Alina.

MS. SCHILLER: Thank you, Joe. Okay. I'm turning now over to Dr. Ghosh to proceed with his presentation.

DR. GHOSH: Thank you, Alina. Good afternoon, everybody. I am Amit Ghosh. I am a geotechnical engineer at the NRR Structural, Civil, and Geotechnical Engineering Branch.

We have a group of five individuals who reviewed this entire LTR and developed this SER. So, today in my presentation I'll be presenting the highlights of our review.

First, I will discuss the main differences between the traditional light water reactor and the GEH BWRX-300, talk about the basis against which we reviewed, and then discuss highlights of the technical area as well which has less limitations and conditions, the L&Cs. And then I'll conclude.

The main difference is the major part of the reactor is placing a vertical right cylinder shaft which is located mostly below grade to mitigate some effects of the aircraft crashes, external hazards, the aircraft crashes, adverse weather, cladding class. And also, as we just heard about that.

Next slide, please.

CHAIRMAN REMPE: Excuse me. This is Jose.

DR. GHOSH: Yes, sir.

CHAIRMAN REMPE: Looking at this figure because we were talking about the advantages of positioning of the reactor building below grade. Is there a higher contact below grade between the containment and the structure and the soil? I mean, how is it packed, because obviously you have to dig a hole that is a little bigger than containment, and then you have to backfill it?

DR. GHOSH: Yes, sir. Yeah, you cannot have exactly or even very small. You need to have quite a bit of gap in there. And once the gap is there, they are supposed to put some backfill, which is kind of a cement mixture, not loose sand. But GEH will be probably able to give a better answer.

MR. TODOROVSKI: That is correct. Luben Todorovski with GEH. It is correct that our construction process is such that we are trying to minimize the amount of vector in excavation. But still there would be some gap between the hole and the escalation itself between these because the soil will be supported by escalation support.

And in the, the backfill material will be a material like a new concrete material.

DR. GHOSH: Yes.

MEMBER MARCH-LEUBA: You are aware, I mean, we talked about the alkali-silica reaction during the subcommittee, and all the plans to backfill with concrete around the containment, as long as that concrete expands. I'm sure you're aware of it.

MR. TODOROVSKI: Yes, we are aware. And estimation is not part of this LTR. The concrete as a vector does not have a structural role actually. So, actually, any contribution in strength from that vector will be reflected in the design.

Now, regarding the walls itself, the structure itself, our design is steel concrete construction. So, basically there will be steel plates and the concrete will be between those steel plates.

MEMBER MARCH-LEUBA: So, back to my original question. So, what you're saying is there is going to be a hard contact between the containment and the soil around it. There's not going to be a gap?

MR. TODOROVSKI: No. The contact -- actually, the containment, the contact between the soil and containment will be only at the base, at the basement.

MEMBER MARCH-LEUBA: At the ground level?

MR. TODOROVSKI: Around the structure actually we have a containment that we have a reactor building structure, additional structure so the containment will be between those structures. So, only at the basement elevation the containment will be.

MEMBER MARCH-LEUBA: Not even at ground level there will be contact?

MR. TODOROVSKI: (Audio interference.)

MEMBER MARCH-LEUBA: And I assume that --

now, now I'm going to go back to ask questions of the staff. I assume you have taken all this into account, right, when making the models, and when you do the final submittals.

Okay, staff, you can continue your presentation.

DR. GHOSH: Thank you, sir. We use this regulatory basis for subsurface conditions review, 10 CFR 100.20(c)(1), physical characteristics of the site. 10 CFR 100.22, geological assessment considerations.

And for development of site design parameters, 10 CFR 550, Appendix A, general design criterion to design for protection against natural phenomena.

Next slide, please. This is one of the pictures I used previously. And this picture shows rock masses fractures. Placing the reactor in a soft surface, we talked about the advantages, but there may be some technical challenges maybe given by the rock masses.

The rock mass, depending on the site condition it may totally in the soil, totally in rock, or mixture of both. The rock mass, the rock is stronger than the soil. But the fractures controls how the rock mass responds to a load, aspect load or the construction load. Because the fractures are significantly weaker than the intact rock, each fracture -- the fractures forming a network with the several sets of fractures in there.

Each fracture has a deep angle, the angle at which it is dipping from the horizon, the direction which -- direction it is dipping measured from the north. And within each set there is a stressing between the two consecutive fractures. In a geotechnical or geological excursion project, these fractures are generally mapped. And those are measured.

These are important parameters because the nature is stochastic. So, we will have a mean value and the distribution around these for deep angle, deep direction fractures placement. And as this is commonly done, and probably has been done for nuclear reactors where the nuclear island was placed on rock layers, we did not put any limitation and conditions. But in the site-specific application we'll review how the fracture network has been met, how the parameters have been developed and propagated into the next level of modeling.

Next slide, please.

So, in a very high level we, the LTR proposes approaches conceptual level to deal with differing technical issues, especially for deep embedment of the reactor.

We reviewed each and every of these proposed approaches and developed our SER. But in this presentation I'll limit my talk to these five areas where we have an L&T limitation and conditions:

Foundation interface analysis, FIA model, stability of the reactor shaft, soil-structure interaction (SSI) modeling, and development of the parameters for this analysis, strain-compatible dynamic properties, and non-linear SSI analysis which will be only some specific activities not a regular one.

Next slide, please.

GEH has proposed to do a FIA model, foundation interface model. This will have the shaft and the reactor, the reactor building will be in the shaft. But it will not be modeled in detail, it will be modeled at the high level where all the major components will be modeled, and the surrounding medium, and also the interfaces, the interface between the reactor building and the surrounding medium.

And that will have a special element,

called interface element, which we'll also model the rock fractures which are joints, spreading place, maybe small first. And this model, theoretical model has many different parameters to be present how the interface behaves. Or, I mean, its stiffness and its displacement properties under a given load.

These parameters as developed are determined using laboratory test called direct shaft test. The samples will be collected during the site investigation. And this is bottom half of the sample. The top of the sample will have the majority major fit. And these samples shows like it is a very rough surface.

And this roughness gives the strength and deformation values. Whitish part and the red part, those are the high peaks. And the blue part is the valleys. So, you can see there is a lot of features in this sample.

We put in L&T limitation and conditions that use large sample laboratory test. The reason is if we take a very small sample, maybe quarter inch, half inch, or inch size, something like that, we will be missing a lot of these features. So, the actual, the parameters determined from the laboratory test may not be properly representative of the site, or adequately representing the site characteristics.

So, in a site-specific application we'll go and look at how the samples have been collected, the testing that has been done in the laboratory to estimate the properties, and how these properties has been transferred to the FIA model and beyond.

Next slide, please.

The next one is the stability of the reactor shaft. And in my opinion, this is the most important aspect of it.

In this figure, we have this sketch. I have excavated the shaft. And you can see, like, the small blocks or deep blocks have started sliding. Because, previously, before the excavation that place was full. There was no place for these blocks to slide into.

Because the void has been created, there is a space now to move. That is the small blocks which will go into the area, in the excavated area. And that typically happens in every project, temporary supports are given and they are not considered as a formal type of support.

Like, if you go to the Washington, D.C., Metro, and beyond the stations you will see shotcreting. Those are temporary support to give mainly for the life safety point of view, that nobody should get hurt.

But we do not want big blocks of the block or blocks to move or slide into that. First of all, before placing the reactor, then it sort of defeats the purpose because it's -- we excavated it and that is getting full.

Second thing is because if the thing started moving it creates some instability around the material because now everybody starts -- all the blocks started moving, starts moving.

And if we have the reactor in place, then these big blocks will start giving concentrated load on the side of the reactor, which was not put into the design. So, very prudently GEH says that there will not be any unstable blocks in the upper region.

First of all, like, if they put parameter, and there will not be any problem in support, because if they put a parameter in support, it may not be accessible after the reactor has been placed. And to guarantee stableness for the entire life of the reactor is a very tall order.

So, there will be section for unstable blocks within the surrounding medium. We have several ways it can be done. One is key block theory which is a very elegant geotechnical approach by Thomas Goodman and Gen-Hua Shi at UC Berkeley. But it's very time consuming because it takes a lot of manual work on that.

Another approach is like FIA model. It's that it has been constructed appropriately, the numerical analysis where we have the shaft excavation and also the rock and the soil features, fractures and joints, if they are simulated.

And then you start excavating the shaft numerically in the model. And we'll see that how the stress concentrations are changing around the shaft. And also where is there a large displacement taking place in nearby.

GEH can verify that because they have instrumentation in the field, so they can calibrate the model at each stage and go further.

Next slide, please.

So, we put in L&C stable excavation that in a site-specific application staff will review the methods to identify the unstable blocks, block or blocks, and to assess the pressure to determine whether the subgrade is acceptable.

It may so happen, like, there are unstable blocks which can be well excavated and backfilled, or cement, or something can be done. So, that kind of mitigation measure has been done. We'll also review that and their efforts.

Next slide, please.

Number three is the soil structure interaction analysis and how the measured properties have been determined and used. They want to do the -- the soil structure interaction analysis will be done using the SASSI code, which is System for Analysis of Soil Structure Interaction.

This is, this code has been used extensively in the nuclear industry. You can have extensive experience on that, but mostly on the soil side. When it comes to the rock side, or at least partial rock, the rock mass model must be set into this model. And the rock mass has fractures in that.

So, GEH has proposed to use rock mass classification system to determine the rock mass model mass.

The rock mass classification system used by the rock engineering projects or mining engineers to classify the rock into different groups according to their behavior. In this case there are two methods proposed by GEH. One is RMR, Rock Mass Rating system.

Another way is the GSI, Geological

Strength Index.

Each has brought some own parameters. And each parameter depending on what is available at the site to give it numerical validity. And if they add all the values to get the final rock mass rating.

There are many empirical iterations available to explore the rock mass that I now reckon with the rock mass model less. And GEH will be using one or more of those.

But one aspect -- the assumption is we are getting like one number of the rock modulus. That means it assumes, is rock mass is isotropic and homogeneous. That may not be true for all cases. Like, say there's a horizontal rating because it is different rates at certain intervals, like limestone, sandstone, and layers of that.

That rock mass, if you take the model, we have differently across the fractures than along the fractures. So, in a site-specific applications we will be looking for the number of fracture sets present in the rock mass so that can we measure the deformational behavior, isotropic and homogeneous. So, this is one of the L&Cs we have proposed that we'll be reviewing it in the site-specific application.

Next slide, please.

Site-specific application of HCSCP. It is Hazard Consistent Strength Compatible Properties. Because SSI analysis is generally deterministic. We get the motion, one motion but this soil sector, the different soil properties we just have been used to develop the site's down motion using the site response analysis. So, they need to be consistent with that.

And GEH has a proposed method called HCSCP. We reviewed the method and found it is reasonable. But it has not been used before. So, building a future application, we'll be watching that go through the calculations and analysis process to see how that has been used.

Next slide, please.

I did not talk much today about the non-linear aspects of it. But imagine if the reactor, if the site is highly seismic again, high seismicity, or highly non-linear subgrade materials. It may happen like the active motion is so high that there may be sliding along the structure and the subgrade mediums, or opening up. It may open up.

Other factors may slide over each other.

So, these are all non-linear behaviors. And GEH has proposed on that sensitivity analysis, like, how sensitive the impact is on this non-linear process at that particular site.

This is a very complex analysis and never -- it has not been used in nuclear application before. So, the application, in the future application this non-linear SSI will go to the characterization of modeling of each of the non-linear behavior, and also the analysis part. Because all this non-linear analysis, the numerical instability can develop quickly.

Next slide, please.

MEMBER MARCH-LEUBA: No, before you move.

DR. GHOSH: Yes, sir.

MEMBER MARCH-LEUBA: This is Jose.

Do you take this non-linear analysis to be site-specific for every location where we build the reactor? We don't have a submittal yet, so we don't know. But we strongly suspect that we're not going to have a certified design, but a R50 type application for every site.

Have you given any thought of how we will do review of Plan No. 2? Is there going to be an analysis that defines the structure and says it's good for an envelope of soils like this. I don't know how to define an envelope.

And then for Plan No. 2, they just check that the soil is within the envelope? Or will you expect all this analysis to be performed for Plan No. 2. And especially for the non-linear effects that might be difficult to do.

So, I will ask the staff first, have you given any thought of how to define an envelope where the analysis of Plan 1 is applicable to Plan N, and then will transfer to G -- sorry, yeah, to the applicant to see what their opinion is. So, I mean, that, what do you think about that?

DR. GHOSH: Yes. That's a very good question, very intriguing question. And let me try to address it as best as I can.

If we look at the -- can I go back to that rock face picture, any of those? Yes, yes.

So, if we look at this, it is also not only the properties, but it is also the geometry which is involved. And geometry is a site-specific parameter.

So, whether, yes, I can have a high seismicity, I can define, okay, this is my envelope of high seismicity. This is my envelope of properties, soil properties, rock properties. But the soil rock properties are most -- I mean, very much dependent on other factors, geometries, and geometry given by deep angle and all. Like, it's site parameters.

So, although it may be relatively easier, I'm not talking is easy, it's denotably easier in the soil side, but in the rock side it's a big challenge. The question you posed is something we really need to think about.

MEMBER MARCH-LEUBA: So, I don't know if I'm understanding between lines. Are you saying it would be very difficult to define an envelope in every case?

VICE CHAIRMAN KIRCHNER: No, I don't think so. Obviously, if you pick a site like that you're going to have problems. But we've seen this before from other applicants, they've defined a generic envelope by soil types, by seismic factor. They analyze all the above and they can envelope to first order most of the sites that they would go to.

Now, if you go to my house in Santa Fe, New Mexico, it's highly non-linear because we have magma, and then you have soot, which is volcanic ash, and then you have another layer of fractured rocks, and all this. Now, my house is on a non-linear site and it already cracked.

So, they're not going to do that. They're not going to pick a site like that where you'll hit a potential for a massive split between different formations. So, but in general, you can do, you can envelope that for most sites.

CHAIRMAN REMPE: I don't have an opinion.

VICE CHAIRMAN KIRCHNER: Just when they inspect at the actual site.

CHAIRMAN REMPE: And we'll ask GE. And state your name, state your name on the microphone, and speak directly into the microphone so it's clear.

MR. TODOROVSKI: Right. I will do just that.

My name is Luben Todorovski.

First, I want to emphasize that when we address non-linearities we address the non-linearities of the site, of the rock and the soil, not the site. So, basically, those, those parameters are highly site-specific. So, the analysis will have to be site specific. It will be very, very difficult to do a generic or standard analysis of any site. You have to assume a lot of, lot of things.

Like, for example, as mentioned, formation of the rock surfaces, discontinuities and so on. So, basically, the analyses are sensitivity analyses. They will be geared to find what are those effects and use the design envelopes, those in that effect.

Also, I have to mention that the design generic, and the site-specific later, are all based on we took site parameters which are conservative in order to provide a bound in effects which will bound these effects of non-linearity.

And in the LTR which we have proposed two methodologies to address to ensure that the design envelopes with sufficient margin to address the uncertainties, the non-linear effects of the soil response, but in the static sense. And this is another aspect when we are coming to the site which are characterized by also seismicity and also very non-linear. This is a methodology to apply at this site, not only seismic SSI.

MEMBER MARCH-LEUBA: So, if I can summarize what I understood you said. And let me know if I misunderstood.

You would prefer to have a generic envelope if your site is benign. And then if you happen to have a site where there is too much non-linearity, you will have to re-do the analysis at the specific.

Is that what you said?

MR. TODOROVSKI: I mean, the design will

still be based on the linear elastic analysis because the whole design process and the, like the spectra, is a spectra is designed for linear elastic analysis because it's the envelope. Many, many earthquake events, not just one.

But the sensitivities, sensitivity analysis and the motivational analysis don't ensure that the design which is based on linear elastic properties will bound those non-linear effects with sufficient margin because there will be always uncertainty in the, you know, how accurate we are going to predict those non-linearities.

MEMBER MARCH-LEUBA: Thank you.

Board, do you have anymore questions?

I think Mike Dudek wants to say a few words.

MR. DUDEK: Yeah. So, thanks. Thank you. This is Michael Dudek.

So, I think there is a technical component that you heard from both staff members. And I also think that there is a licensing component to your question, Member March-Leuba, and the fact of how you envelope that and how you solve that and, second, and the time designs.

And I think that's, you know, discussions get to be how do we create them and whether they want to -- after they have the CP application, whether they want to certify the design under Part 52 or, you know, they could, they could finalize it in the topical report. There's several licensing venues in which they could do this to put it more solidly, put it on the books.

MEMBER MARCH-LEUBA: Okay, thank you.

Yeah, basically, we are not there because we're just with topical reports and individual concepts. When there is a submittal, we'll know for sure.

Any staff -- Mita, were you done? Or you were going to go into your conclusions?

DR. GHOSH: I have one more slide, yeah, conclusions. Thank you, sir.

In conclusion, we reviewed the approaches and we found the approach as to character is the surrounding media site and of the rock are reasonable.

The design importance for the deeply embedded RB structure are reasonable.

I got muted. I have to repeat. You told me, like, I got muted.

The design importance for the deeply embedded RB structures are reasonable.

I did not talk about the construction methods in this, my presentation. But there is in the LTRs they have a discussion on that. And we found it acceptable.

And the staff will make its final regulatory determinations during its review of any future license application.

That concludes my talk. And any questions?

MEMBER MARCH-LEUBA: Thank you. Any questions from the table members or members on the phone line?

(No response.)

MEMBER MARCH-LEUBA: Okay, five seconds have gone through. I'm going to open the table for our microphones for public comments.

Any member of the public that wants to place a comment on the record, please identify yourself and say so. If you are on the Teams meeting, just unmute yourself. If you are on the phone line, press star-6.

(No response.)

MEMBER MARCH-LEUBA: Five second rule again. Nobody wanted a comment.

We are going to open the table of members again if they want to make a comment.

Yes, Charlie?

MEMBER BROWN: Yeah. I'm trying to, trying to think of addressing your last question.

Correct me if I'm wrong. But one of our previous reviews, maybe even probably in two of them, there was a considerable amount of evaluation of the site. And there was a lot of excavation and tailoring of the site. So, in terms of depth that they went down to that they then filled and backfilled, put columns in, and everything else in order to put the facility on top of it.

And I guess I didn't think to ask the question at the subcommittee meeting the way you did. But I guess I kind of assumed that even with the design the way it was there would be some amount of site within a generic envelope of some sort that you could backfill, excavate, and then tailor to some extent to make an overall generic set.

I mean, maybe I'm wrong, but I just, it seemed to me that if you had the capability you could do that. I'm not -- this one's unusually deep. What was it, 120 feet or a hundred and --

MEMBER MARCH-LEUBA: This one is 120 feet deep below ground level and 120 above.

MEMBER BROWN: Right. I can't remember whether the ones, at least one or two we looked at, we did have at least a couple that had pretty detailed -- and this was some years ago -- lost the bubble in my own time. So, I guess the question was why couldn't -- it's an interesting design and it seemed like an interesting way. I don't know why, I guess I don't understand why it couldn't be tailored to a kind of a set of boundary conditions.

MEMBER MARCH-LEUBA: My train of thought was the point if I was the applicant I would create a generic design.

MEMBER BROWN: Exactly.

MEMBER MARCH-LEUBA: And I would build the same design on every plan. Because that's a cost savings and I don't have to re-do the analysis.

But then I have to either analyze it, what I'm designing for, for the facility, for the site, see which one is worth, or the final envelope. That's why I asked for the envelope because I expect the fourth BWRX-300 to be exactly the same as the first one as far as concrete is concerned.

VICE CHAIRMAN KIRCHNER: And just to refresh everyone's memory, we had another applicant also, and the NRC reviewed the applicant's submittals and its topical report that basically dealt with the same thing, and much similar to what GEH team explained.

They, they looked at three soil generic types, and they looked at five or six certified seismic design spectra. And then they looked at their plant design and put it into that configuration, tried to find -- ran it through five spectra, ran it through three soil types. And then determined the loads of the soil structure interaction, how that changed the loads inside, and transmitted the frequencies inside the actual plant. And determined that at this level of stiffness, et cetera, et cetera, they could survive an earthquake of X g's.

MEMBER MARCH-LEUBA: The problem is then, let me just point out if somebody wants to build one of these facilities in Hawaii where you have unstable and non-linearity.

VICE CHAIRMAN KIRCHNER: Well, as the staff said on this last vugraph, the last bullet, the staff will always check, and so will the applicant. I mean, they're the applicants and they do all the soil bore holes and all the rest of it, determine the soil type and composite. But the staff's always going to check that. And that will always be site-specific.

But you can envelope this. And I think they have, and we've seen that with other applicants.

MEMBER BROWN: That was my thought. You can see that for a reasonable --

VICE CHAIRMAN KIRCHNER: Yeah. I think they said, I think 80 percent of the sites they could bound that.

MEMBER MARCH-LEUBA: Let GE enlighten us.

MR. TODOROVSKI: Yes. This is Luben again, Todorovski.

Our design the aim is to have a product which will be applicable for 80 percent of the sites. But when they address certain uncertainties, and I want to point out, unlike the others, the previous designs featured big structures on the soil. This design is far more dependent on the site-specific conditions.

And when we go to non-linearity there are so many parameters that can change that it's very difficult to envelope everything possible. So, the idea is to have a generic design which is, we believe, conservative, and it will envelope those non-linearities and other site-specific features. But at the end, we will have to demonstrate for each site that the design is safe.

And so, that is the basic approach.

MEMBER MARCH-LEUBA: Thank you. I think that's a good plan on this one.

We went to public comments. There's no public comments. Anymore discussion on the table?

(No response.)

MEMBER MARCH-LEUBA: Chair Rempe, the floor is yours.

CHAIRMAN REMPE: It's my understanding that -- microphone. Thank you again. Thanks, everyone, for their presentation. It's my understanding that we have a draft letter. And we would like to read it in in the near future.

MEMBER MARCH-LEUBA: Fine.

CHAIRMAN REMPE: So, let's take a break and come back at 2:15 p.m. on the East Coast and we'll read in your letter. Thank you.

(Whereupon, the above-entitled matter went off the record at 2:04 p.m.)

U.S.NRC

United States Nuclear Regulatory Commission

Protecting People and the Environment

Staff Presentation to the ACRS Full-Committee

GEH Licensing Topical Report
BWRX-300 Advanced Civil Construction and Design Approach
(NEDO–33914, Revision 1)

April 7, 2022

NRC Staff

Reviewers:

- Amitava Ghosh, Ph.D., Geotechnical Engineer, Presenter, NRR/DEX/ESEB
- David Heeszel, Ph.D., Geophysicist, NRR/DEX/EXHB
- Edward Stutzcage, Health Physicist, NRR/DRA/ARCB
- Angelo Stubbs, Sr. Safety and Plant Systems Engineer, NRR/DSS/SCPB
- Sujit Samaddar, Sr. Structural Engineer, NMSS/DFM/MSB

Project Managers:

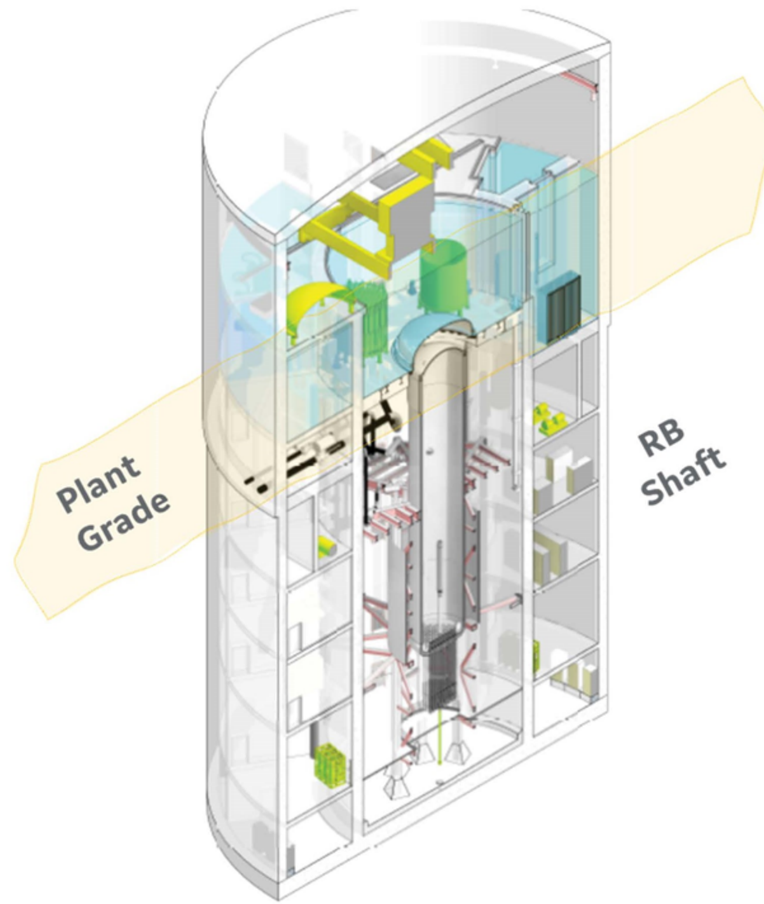
- Alina Schiller, TR Project Manager, NRR/DNRL/NRLB
- James Shea, Sr. Project Manager, NRR/DNRL/NRLB

Agenda

- Introduction
- Difference Between Traditional Light Water Reactor and GEH BWRX-300
- Regulatory Bases
- Staff Limitations and Conditions (L&Cs)
- Staff Conclusions

GEH BWRX-300 Reactor

- Reactor Building (RB) is placed in a vertical right-cylinder shaft and located mostly below-grade to mitigate effects of possible external events, including aircraft crashes, adverse weather, flooding, fires, and earthquakes



LTR Figure 1-3

Regulatory Bases

- Defining Subsurface Conditions
  - 10 CFR 100.20(c)(1): physical characteristics of the site
  - 10 CFR 100.23: geologic and seismic considerations
- Development of Site Design Parameters
  - 10 CFR Part 50, Appendix A, General Design Criteria 2: Design bases for protection against natural phenomena

Rock Fracture Network

- Fractures control the response of a rock mass
- Fracture network:
  - Dip angle
  - Dip direction
  - Fracture spacing
  - Number of fracture sets
- Staff will review rock fracture network characterization in a site-specific license application

From: Cao, et al. 2016. An Experimental and Numerical Study on Mechanical Behavior of Ubiquitous-Joint Brittle Rock-Like Specimens Under Uniaxial Compression. Rock mechanics and Rock Engineering.

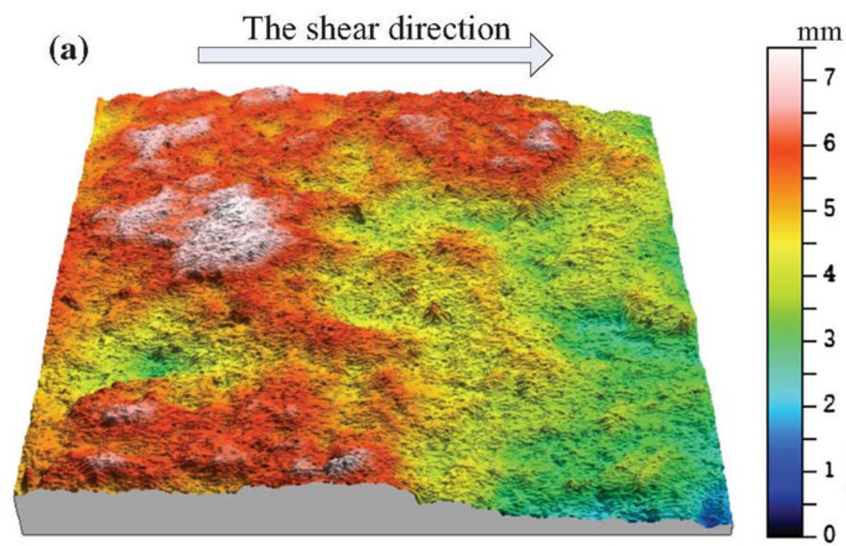
NRC Staff Review

- LTR proposes approaches at conceptual level to deal with the technical issues
- Staff conducted a comprehensive review of each proposed approach(es)
  - Foundation Interface Analysis (FIA) (LTR Section 4)
  - Stability of reactor shaft (LTR Section 5.1.2 and others)
  - Soil-Structure Interaction (SSI) modeling (including parameter estimation of equivalent linear elastic materials) (LTR Section 5.1.2)
  - Strain-compatible dynamic properties (LTR Section 5.2.4)
  - Nonlinear SSI analysis (sensitivity) (LTR Section 5.3.11)

L&C #1: Interface Testing

- Large size samples collected at a site tested in the laboratory to have an acceptable estimate of the measured discontinuity, strength and deformation parameters

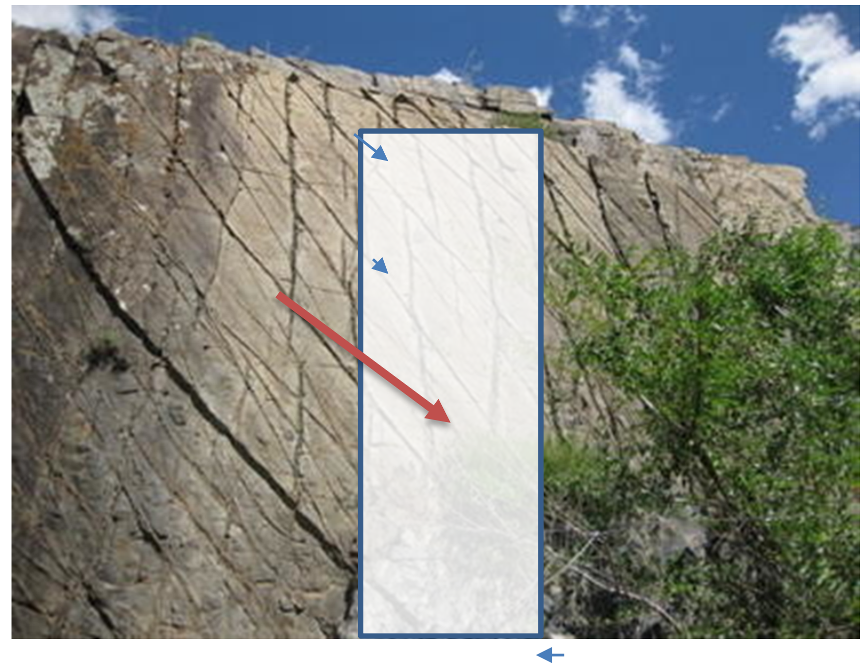
- Staff will review the sizes of the samples and their testing at the laboratory to estimate the properties of the discontinuities and interfaces in a site-specific license application with a BWRX-300 SMR



From: Fan, et al. 2019. Geotechnical and Geological Engineering. Experimental and Numerical Study on the Damage Evolution of Random Rock Joint Surface During Direct Shear Under CNL Condition.

Stability of Reactor Shaft

- Stability of Embedded Reactor: Unstable rock mass without any permanent support systems is not acceptable
- Unstable blocks in surrounding region
  - Key block theory (Goodman and Shi, 1985)
  - Numerical simulation e.g., FIA model (LTR Section 4.0)
  - Results verified by instrumentation installed (LTR Section 3.3)



From: Cao, et al. 2016. An Experimental and Numerical Study on Mechanical Behavior of Ubiquitous-Joint Brittle Rock-Like Specimens Under Uniaxial Compression. Rock Mechanics and Rock Engineering.

L&C #2: Stable Excavation

- A stable shaft excavation would have no unstable blocks in its surrounding that may slide into the excavation

- A self-supported (even with some temporary reinforcement) excavation would be needed to place the RB and to estimate the earth pressure loads to be considered in the generic design of the RB structure

- Staff will review method(s) used to identify the unstable rock blocks and to assess the earth pressure imparted on the RB shaft for determining whether the subgrade is acceptable for siting the reactor in a site-specific application

- Any mitigation measures used to stabilize the surrounding materials would be reviewed by the staff

L&C #3: Isotropic and Homogeneous Rock Mass

- Rock mass classification systems inherently assume isotropic and homogeneous rock mass to determine rock mass modulus for use in Soil-Structure Interaction (SSI) analyses

- A jointed (or a fractured) rock mass is assumed to contain a sufficient number of fracture sets so that its deformational behavior may be assumed to be isotropic and homogeneous

- Staff will review whether the fracture sets at the selected site would make the rock mass behavior isotropic and homogeneous in any future site-specific licensing application

L&C # 4: Site Specific Application of the HCSCP

- GEH has proposed to develop Hazard Consistent Strain-Compatible Properties (HCSCP) so that properties used as input for SSI analysis to be consistent with soil/rock properties used in generation of input motion

- During review of future licensing applications, staff will audit the HCSCP approach

L&C # 5: Sensitivity Nonlinear SSI Analysis

- May be important for sites with high seismicity and/or with highly nonlinear subgrade materials
- Separation and/or sliding at soil/rock-structure interface
- Nonlinearity at rock fractures
- NRC staff plans to review the characterization and modeling of the nonlinear behavior of the materials surrounding the reactor in any future licensing application utilizing a nonlinear SSI analysis approach

Staff Conclusions

- The approaches to characterize the surrounding media (soil and/or rock) are reasonable
- The design approaches for a deeply imbedded RB structure are reasonable
- The construction methods for the BWRX-300, as described in this LTR, are acceptable with the associated L&Cs.
- The staff will also make its final regulatory determinations, as applicable, during its review of any future license application

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Washington, D.C. 20555-0001

Canadian Nuclear Safety Commission
280 Slater Street
P.O. Box 1046, Station B
Ottawa, Ontario, K1P 5S9, Canada

Subject: ACRS Full Committee Presentation Slides for NEDO-33914, BWRX-300 Advanced Civil Construction and Design Approach Licensing Topical Report

Enclosed are the presentation slides that GE-Hitachi Nuclear Energy Americas, LLC (GEH) will present during the upcoming Advisory Committee on Reactor Safeguards (ACRS) Full Committee Meeting on April 7, 2022. These slides support the ACRS review of NEDO-33914 Revision 1, BWRX-300 Advanced Civil Construction and Design Approach, and the corresponding NRC Advanced Safety Evaluation Report (SER) with No Open Items.

Enclosure 1 contains non-proprietary information and may be made available to the public.

If you have any questions, please contact me at 910-200-3295.

Sincerely,

George E. Wadkins

George E. Wadkins
Vice President, New Power Plants and Products Licensing
GE-Hitachi Nuclear Energy Americas, LLC

Enclosure:

1. ACRS Full Committee Presentation Slides for NEDO-33914, BWRX-300 Advanced Civil Construction and Design Approach Licensing Topical Report – Non-Proprietary Information

cc: James Shea, US NRC
Chantal Morin, CNSC
PLM Specification 006N9431 Revision 3

Document Components:
001 M220048 Cover Letter.pdf
002 M220048 Enclosure 1 Non-Proprietary.pdf

ENCLOSURE 1

M220048

ACRS Full Committee Presentation Slides for NEDO-33914,
BWRX-300 Advanced Civil Construction and Design Approach
Licensing Topical Report

Non-Proprietary Information

ACRS Full Committee Presentation

GE Hitachi (GEH)
Licensing Topical Report (LTR) NEDO-33914
BWRX-300 Advanced Civil Construction and Design Approach

April 7, 2022

Licensing Topical Report Purpose

GEH is seeking NRC approval for the application of an alternative approach to the construction, analyses, and design of the BWRX-300 below-grade Reactor Building.

The purpose of the LTR is to present design, analysis, and monitoring guidelines and requirements to support the request for NRC approval of the innovative and comprehensive construction approach for the construction of the below grade BWRX-300 small modular reactor Reactor Building vertical right cylinder shaft.

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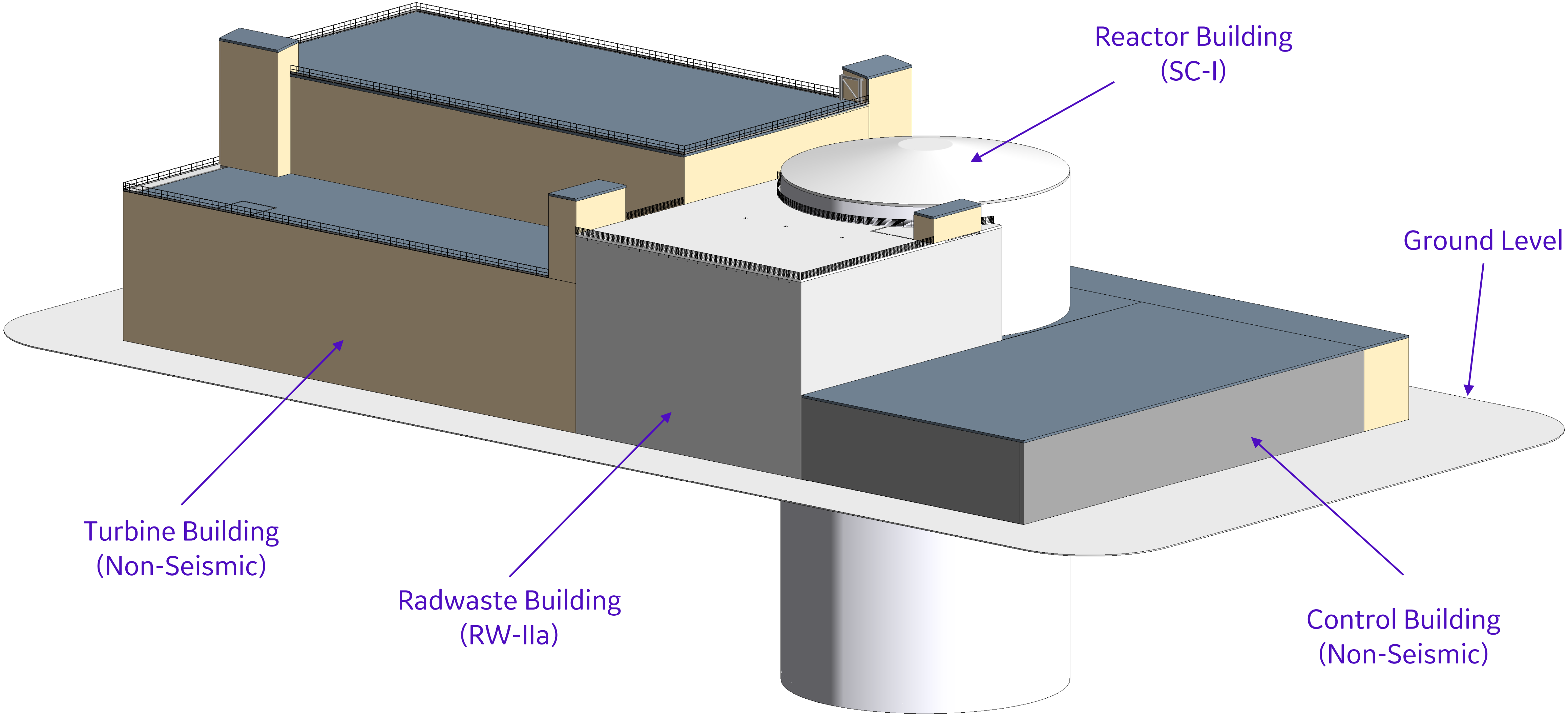
Licensing Topical Report Scope

This request is supported by the following information in the LTR:

- Regulatory basis specific for the innovative approaches
- Guidelines and requirements for characterizing subsurface conditions, including geotechnical site investigations and laboratory testing programs, as well as the inspection and monitoring programs
- Requirements and guidelines for performing the foundation interface analysis
- Design requirements, acceptance criteria and guidelines for the deeply embedded Reactor Building
- An approach for addressing Seismic Category (SC) II/I interactions
- Generic seismic and geotechnical design parameters

HITACHI

BWRX-300 Building Seismic Categories



Regulatory Basis

- The design and analyses described in the LTR comply with all applicable regulatory requirements and guidance for:
    - Defining Site Subsurface Conditions
    - Site Design Parameters
    - Seismic Analysis
    - II/I Interactions
    - Testing, Inspection and Monitoring

- The implemented innovative approaches meet the intent of the current regulatory guidance for large light water reactors and address the specifics related to the seismic and structural design of deeply embedded small modular reactors.

- GEH is not requesting NRC approval for exemptions from any regulatory requirements or any exceptions to any regulatory guidance.

HITACHI

BWRX-300 Monitoring, Analysis and Design Process

- Innovative property characterization and monitoring approaches driven by the RB structure being deeply embedded
- Investigation, testing, inspection, and monitoring programs, in conjunction with the results of a set of foundation interface analyses, ensure the safe siting of the BWRX-300 plant
- Non-linear constitutive 3D foundation interface analysis numerical modeling includes interface modeling, structural modeling, fluid soil interaction, and consideration of all plant life stages
- Static and seismic soil-structure interaction analysis approaches for designing the deeply embedded RB structure
- Graded approach for the design and II/I interaction evaluations of the structures adjacent to the deeply embedded Safety Classification I RB structure.

HITACHI

BWRX-300 Generic Design Approach

- Methodology for development of generic seismological and geotechnical site parameters for the conceptual design of the BWRX-300
  - Generic Design Response Spectra (GDRS)
  - Generic subgrade dynamic properties
  - Generic static properties for different subgrade materials
  - Friction coefficient values and groundwater table elevations

HITACHI

Conclusion

In summary…

- The design and analyses described in the LTR comply with all applicable regulatory requirements and guidance.
- The innovative approaches meet the intent of current regulatory guidance for large light water reactors and address the specifics related to the seismic and structural design of deeply embedded SMRs.
- GEH is not requesting NRC approval for exemptions from any regulatory requirements or any exceptions to any regulatory guidance.

HITACHI

Questions or Comments