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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

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NATRIUM REACTOR DESIGN-CENTERED SUBCOMMITTEE

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TUESDAY

JULY 9, 2024

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The Subcommittee met via Teleconference, at 1:00 p.m. EDT, Thomas Roberts, Chair, presiding.

COMMITTEE MEMBERS:

THOMAS ROBERTS, Chair

RONALD G. BALLINGER, Member

VESNA B. DIMITRIJEVIC, Member

GREGORY H. HALNON, Member

CRAIG A. HARRINGTON, Member

WALTER L. KIRCHNER, Member

ROBERT MARTIN, Member

DAVID A. PETTI, Member

ACRS CONSULTANTS:

DENNIS BLEY

STEPHEN SCHULTZ

DESIGNATED FEDERAL OFFICIAL:

KENT HOWARD

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P-R-O-C-E-E-D-I-N-G-S

1:01 p.m.

CHAIR ROBERTS: Okay. This meeting will now come to order. I want to confirm the court reporter can hear me. Thank you very much.

This is a meeting of the Advisory Committee on Reactor Safeguards, Natrium Reactor Design-Center Subcommittee. I'm Tom Roberts, chair of this meeting. The attendants today are members Ron Ballinger, Craig Harrington, Walt Kirchner, Dave Petti, Greg Halnon, and Robert Martin; and online have -- is Vesna Dimitrijevic online?

MEMBER DIMITRIJEVIC: Yes, I'm here.

CHAIR ROBERTS: Thank you, Vesna. And we also have our consultant, Steve Schultz, online. Kent Howard is the designated federal officer for the meeting.

Today, TerraPower and the NRC staff will present their work on a Natrium topical report entitled An Analysis of Potential Volcanic Hazards at the Proposed Natrium Site Near Kemmerer, Wyoming. The topical report is incorporated by reference in the construction permit application that the staff recently accepted for review. This meeting gives us an opportunity for an early review of this important part of the safety analysis.

Additionally, this report describes the first volcanic hazard analysis completed per Reg Guide 4.26, which was issued in 2021. It's entitled Volcanic Hazards Assessment for Proposed Nuclear Power Reactor Sites. We reviewed this reg guide in 2021. One of our recommendations observed a trial use of the guide was needed and timely revisions should be made, as needed, based on that experience. So, in addition, it counts as a topical report and assists in a safety evaluation. This meeting gives the opportunity to hear feedback on the reg guide and understand the staff's plans to revise it.

The ACRS was established by statute and is governed by the Federal Advisory Committee Act (FACA). The NRC implements FACA in accordance with its regulations found in Title 10 of the Code of Federal Regulations, Part 7. Per these regulations, the committee can only speak through its published letter reports. We hold meetings to gather information and perform preparatory work and will support our deliberations at a full committee meeting. All member comments should be required as the opinion of that member, not a committee position.

The rules for participation in all ACRS

meetings was previously announced in the Federal Register. The ACRS section of the U.S. NRC public website provides our charter, bylaws, agendas, letter reports, and full transcripts of all full and subcommittee meetings, including slides presented there. The agenda for this meeting was posted there.

We and the staff do not expect to discuss any proprietary or export controlled information today, so the entire meeting will be open to the public.

As stated in the Federal Register notice and the public meeting notice posted to the website, members of the public who desire to provide written or oral input to the subcommittee may do so. We have not received any written input or advanced requests to make oral statements from members of the public regarding today's session. There will be an opportunity for public comment, and we have set aside time in the agenda for comments from members of the public listening to this meeting.

Today's meeting is being conducted as a hybrid meeting with participants both remote and in our meeting room. A transcript of the meeting is being kept and will be made available on our website. We, therefore, request that participants in this meeting identify themselves and speak with sufficient clarity and volume, so they may be readily heard. All presenters please pause from time to time to allow members to ask questions. Please also indicate the slide number you are on when moving to the next slide.

We'll take a short break after each presentation to allow time to adjust screen sharing. We'll take breaks during longer presentations at my discretion.

Based on our experience from previous virtual and hybrid meetings, please do not use any virtual meeting features to conduct sidebar discussions related to the presentations. Rather, limit the use of meeting chat to report IT problems, such as inability to hear or see the presentations.

Also, everybody on the MS Teams link or phone line should mute themselves when not speaking. Everybody in the room, please make sure your electronic devices are on silent mode.

With that, we'll now proceed with the meeting, and I'll call upon Dr. Barbara Hayes, who is the branch chief of external hazards in the Division of Engineering and External Hazards from the office of NRR, to make introductory remarks to begin today's presentation. Dr. Hayes.

DR. HAYES: Good afternoon, all. My name is Barbara Hayes. I'm the chief of the Eternal Hazards Branch. And as Member Roberts described, the purpose of this subcommittee meeting is to discuss TerraPower's topical report characterizing the volcanic hazards at the proposed Natrium site near Kemmerer, Wyoming.

This topical report is used and referenced in the construction permit application for the Natrium reactor design called Kemmerer Power Station Unit 1. The construction permit was received in March of this year, and the NRC staff accepted the application for review on May 21st.

The topical report provides TerraPower's characterization of volcanic hazards in accordance with NRC's Regulatory Guide 4.26. As Member Roberts pointed out, this is the first use of the regulatory guide. And just as a little further background, the guide came before the ACRS in February 2020 and again in 2021. And in September 2023, the staff presented an overview of the approach to reviewing information that followed this regulatory guidance.

I would like to take a moment to thank both the staff and TerraPower for their efforts in developing and preparing the materials for this meeting. I'd like to express the staff's appreciation to ACRS for their time previously reviewing the regulatory guide and their time today reviewing the topical report.

We look forward to the conversation today. If there are no other questions, I'll turn things over to TerraPower. Thank you very much.

MR. KELLENBERGER: Good afternoon. My name is Nick Kellenberger. I'm a licensing manager with TerraPower, and with me today are Lindsay Martin, who is our lead on the TerraPower licensing team, and Britt Hill, who is the primary author of our topical report.

I'll turn it over to Britt to walk us through the presentation today.

MR. HILL: Good afternoon. My name is Brittain Hill, and for the past several works I have been working as a consultant for TerraPower on evaluating the potential volcanic hazards of the proposed Natrium site at Kemmerer, Wyoming.

Next slide, please. This afternoon, I'll be presenting some of the key points from TerraPower's topical report on the analysis of potential volcanic hazards. The whole reason for doing this topical report is that, within 100 to 320 kilometers from the proposed Unit 1 site, there are about 575 volcanoes that formed during the last 2.6 million years. Consequently, a volcanic hazard analysis appears warranted for the proposed site using the criteria in NRC Regulatory Guide 4.26.

The goal of this hazard assessment is to quantify volcanic hazards at the proposed site probabilistically so that they can be used in subsequent analyses, if those analyses are needed. The analyses that we're going to talk about today follow the guidance in Reg Guide 4.26.

Slide 3, please. Really simply put, volcanic hazards can be characterized as either materials that flow across the ground surface or airborne particles that fall out from eruption plumes. This overview map, I'm afraid I don't have a pointer, but it shows this part of -- I'll point physically. The proposed site is right here with a 40-kilometer circle around it. The 320-kilometer circle encompasses the region of interest for the volcanic hazard investigation, and the black dots represents volcanoes that are younger than 2.6 million years old in the proposed site or in the region of interest.

One thing to notice is that there are no black dots within about 100 kilometers of the proposed site. This is important because volcanic flow phenomena, things like lava flows, pyroclastic density currents, and debris flows rarely travel more than 100 kilometers from any erupting volcano. The few that do travel a little bit farther than that also are strongly affected by topography, and you'll notice around the proposed site we've got a number of mountain ranges, the Wind River Range to the northeast, along with the Tetons and the Wyoming Range out to the west. So any sort of flow phenomena, say from a large eruption at the Yellowstone volcano, any of those flow phenomena that might go more than 100 kilometers are going to be, effectively, trapped by these topographic areas. They will not be able to overcome them.

So the proposed site is located in an enclosed basin that structurally, topographically, physically isolates it from any potential flow phenomena from a future volcanic eruption. Consequently, we can screen out surface flow phenomena from the hazards analysis and don't have to do anything more about them.

Next slide, please. So the only hazard that was left is tephra fallout. And to analyze the potential hazards from tephra fallout, we took two different approaches. The first one covers most of the volcanoes in the region because we use a similar methodology for those volcanoes. The only exception to this approach is how we treat the Yellowstone super volcano eruption, and super volcano is kind of a loose term but, here, it generally means a huge eruption that involves more than 100 cubic kilometers of molten rock. The reason for the separate approach is the physics, the dynamics, the characteristics, and modeling approaches for this kind of a super volcano eruption are very different from the approaches that we would use for the smaller, more typical volcanoes in the region.

So to analyze most of the hazards from 570-odd volcanoes, we developed this approach where we first have to estimate what were the eruption volumes of tephra from these past eruptions. It's a lot harder than it sounds because most of the tephra deposits have been removed by erosion or buried, so we have to estimate those volumes based on the characteristics of the remnant volcanoes, and we use a strong reliance on analogs to compare similar volcanoes that are well preserved with the volcanoes in the region that are not well preserved. So we come up with a fairly large range of uncertainty about these volumes, but we accommodate that uncertainty in the analysis.

We also have to develop recurrence rates for tephra eruptions from these volcanic fields. Not every volcanic eruption is going to produce tephra, so we have to estimate how many of those past eruptions were likely to produce tephra and then what is the recurrence rate for those tephra-formed eruptions that could be used to estimate probability of a future eruption.

Finally, once we have this and some other critical information together, just detailed, of course, in the topical report, we then analyze a range of tephra thicknesses at the proposed site using an accepted advection-diffusion sedimentation model that is designed for evaluating tephra fallout away from volcanoes.

Next slide, please. The result is that we developed the tephra hazard curves, the probability of exceedance for a certain thickness just on the X axis, even its annual probability of exceedance on the Y axis. So this is a full-probabilistic exceedance curve that accounts for the likelihood of tephra-forming eruption, the likelihood that the wind will be blowing towards the proposed site within a certain sector, as well as the range of potential tephra thicknesses that can occur at the site based on these numerical models.

Now, if you look in the legend, you can see that we have the abbreviations for different volcanic fields followed by an S or an M. M means mafic, very low-silica magma, and S means silicic, a very high-silica magma. We analyze these different scenario classes differently because the volumes, the rates, the heights, the eruption dynamics are different between mafic and silicic volcanoes.

So I think the curve that you're most interested in is the outer black curve which is the cumulative exceedance for all volcanoes at the proposed site. The first thing to notice is that, on the far left-hand side, you can see that the probability of exceedance is less than 10 to the minus 5 per year for any tephra fallout site, and note that the deposit thickness for that likelihood is ten to the minus 6 centimeters, so we're talking about not even discernable.

This is clearly a beyond design basis external event, so everything we're going to talk about falls within that beyond design basis realm for potential event sequences or external event subsequent analysis.

CHAIR ROBERTS: Yes, Britt, just to clarify. The total hazard curve does not include super volcano, right?

MR. HILL: It does not include a super volcano. This is the first part. To jump to the chase, we don't have enough information to probabilistically characterize the super volcano eruption, but we do have enough to gain some statistical insights. I'll come to that in the next slide.

So for most of these volcanoes, the average thickness is about 1 millimeter with a 10 to the minus six probability of exceedance at the proposed site. And more importantly, our 95th percentile thickness which has, coincidentally, a 5 times 10 to the minus 7 probability of exceedance, is about 17 centimeters. So that is one first part of the risk assessment.

Next slide. As I mentioned, the Yellowstone super volcano is a very different dynamic sort of eruption, and we can't use that same model that we used for the other volcanoes to calculate deposit thickness from this really large eruption. We relied on analyses that are published by the U.S.

Geological Survey that did some very detailed numerical simulations using a very advanced super computer type model to look at how a tephra deposit might form throughout the western United States from potential Yellowstone super volcano eruptions.

So the USGS didn't do a fully stochastic assessment of this hazard just because it's very difficult to run that model stochastically. So we're left with a series of scenarios that still give us appropriate insights for these extremely large Yellowstone eruptions, so I would view -- there's a little bit of uncertainty on the precise value that we're talking about for the statistics, but it's pretty darn close and I do not expect, if you did a fully stochastic simulation, that, even at the 95th percentile, you can come up with a significantly different number than what we're talking about.

So from these analyses, we can determine that average deposit thickness would be about 84 centimeters in southwestern Wyoming near our Kemmerer site, and that would also have a 5 times to 10 to the minus 7 annual probability of exceedance. If we come out to the 95th percentile thickness of, roughly, a meter, 113 centimeters, it would have less than a 7 times 10 to the minus 8 probability of exceedance.

I forgot to mention that the likelihood of any super volcano eruption is very difficult to estimate, but the USGS, when pushed into a corner, will say it's less than one in a million per year. So we're using that as our starting point as any kind of eruption from the Yellowstone super volcano, i.e. greater than 100 cubic kilometers, would be less than one in a million.

DR. BLEY: I'm Dennis Bley, and if I just do a little arithmetic in my head that might be wrong, it looks like about half of those 10 to the minus 6 per year super volcano eruptions would get you to this 84 centimeters. So if you get it, you've got a good chance of getting a lot of tephra to come out.

MR. HILL: Yes, that is correct. It's a fairly steep curve. So the probability of exceedance from any super volcano eruption, we don't have that number, but I would say it's probably on the order of 30 or 40-plus centimeters just for any because these are such large eruptions and we're only about 300 kilometers away from the source.

DR. BLEY: That's what I was guessing, so I'm glad you confirmed that.

MR. HILL: So those are the two numbers that we have to work with. Again, we can't fully integrate that into the hazard curve, but this is sufficient for our purposes that, even at the 95th percentile, we're dealing with potentially a meter to maybe a little less than a meter worth of tephra if a this super volcano eruption.

Next slide. So if we have that kind of deposit at the proposed site, there also might be some potential that infrequent floods could remobilize that tephra, bulk up the flood, and, with no suspended solids, and go from a normal dilute flood flow into a much more concentrated and potentially destructive debris flow regime.

So we did some bounding analysis to try to look at what would happen if we had a very infrequent flood within this small basin that encompasses the proposed site, the flood scoured up, incorporated all the tephra instantaneously in the channel, and how much bulking would that do to the flood, how much full suspended solid would we have, compared to a normal flood that has less than 10 percent total suspended solid. Well, the answer is, even for the largest volume eruption scenario we considered, 113 centimeters, conservatively bounding it with essentially a 1-D model, instantaneous bulking of the flow, we find that the channels that currently exist in the upper branch of the north fork of the Little Muddy Creek, those channels are deep enough and wide enough that that bulk flow would stay wholly within the existing channel banks, would not overtop the banks, and would not impact the proposed site. So we can screen localized regional hazards also out from the hazard analysis.

Next slide, please.

DR. BLEY: I'm sorry. Do any of those channels go down near enough the site that they'd be used as a source of cooling water if the site --

MR. HILL: No. They flow maybe once every couple of years, so they're not gauged. We don't know the exact frequency, but they behave like other dry land channels in the region. They only have flow during very large, very infrequent or not very -- infrequently.

DR. BLEY: Yes, I'm familiar with those kind of places.

MR. HILL: There's no water source provided for the surface water.

So I know you've all had a chance to look at the report. I didn't go into all the geology because I know there's so many geologists in the audience that are really dying to know about the advection-diffusion sedimentation models. But to really wrap it up, the takeaway messages are the only potential volcanic hazard at the proposed site is the deposition of tephra fallout from volcano eruptions that occur 100 to 320 kilometers away. Those tephra fallout hazards from all the volcanic sources has a 95th percentile thickness of 130 centimeters, which would have a less than 5.7 times 10 to the minus 7 per year probability of exceedance. Most of that hazard is driven from a potential Yellowstone super volcano event. Finally, the potential debris flows from remobilized tephra deposits should be contained within existing stream channels and would not affect the proposed site.

So with that, I've gone quick, but we're here to present a summary, not the details.

DR. BLEY: My question might belong to somebody else, but I know the staff, in their SE, said they have not reviewed in any way the likelihood of damage or impairment of plant equipment from the tephra, so the implication is that needs to be looked at later. But there's a sentence early on in your report that says enhanced maintenance and inspection procedures for mechanical and electrical systems also appear, that word, capable of mitigating potentially adverse effects of prolonged exposure to volcanic tephra. My question is appear to whom and what's the basis for that? It sounds like you're kind of jumping the gun and saying, even if it's there, it won't do any damage.

MR. HILL: Well, it appeared to me, the author of the report, and that is why we have a chapter in there about considerations for mitigation and considerations for design, if warranted. I know TerraPower has the option of considering all that later on. But, operationally, as I go through, and I think it's Chapter 9 or 10, consider that tephra fallout is not an instantaneous event. It's a slow, evolving hazard that allows plenty of time. Between the onset of an eruption, it will be hours before a tephra plume reaches a proposed site or any site. And then there will be slow accumulation rates of the tephra, so it doesn't all come down in one meter instantaneously. It's not like a massive earthquake or something. So you have time to implement operational measures, closing off air circulation if needed, tephra removal, tephra mitigation efforts. They appear practicable without knowing the details of what they may be. So that's the point that I'm trying to emphasize is that there's a practicability aspect of it that would allow for enhanced maintenance or enhanced operations to mitigate the potentially adverse effects if those adverse effects are found.

DR. BLEY: Okay. I understand what you did and the basis for your judgment. This committee and this letter to the staff had said that was one area that really needed to be looked at closely, and I think the applicant eventually will have to deal with this a little more substantively.

I quickly, before this meeting, went out searching to see if anything had been done in the last few years, and I found a few papers out there that have tracked some of the problems with tephra, especially with electric power plants. And some of the damage that -- this is kind of interesting to me. Systems that have water flow, if this gets in it, it's much more, I'll just say sharp edged. It can do a lot more damage than other things and very elevated rates of damage to equipment, like in a few months you saw damage similar to what you'd see in 15 years or so of normal operations.

So I think it deserves a pretty good look eventually. I know it's not the subject of what we're doing today, but I wanted to get you all thinking about it. And there has been more work. I wish there were more, but there's more than I had seen five years ago or whenever we looked at this, four years ago.

MR. HILL: That's correct. There are a range of potentially deleterious effects on different kinds of structure systems or components that we based on analogous systems and other areas, like some of the hydroelectric things from New Zealand. That's Tom Wilson's group has been instrumental in seeing that.

But I think the only purpose of including that information in this original report was that it's very difficult to collate that sort of information in any one place. There is no sensitivity guide or engineering guide for how do you deal with tephra at nuclear installations. IAEA is working on one but is still well behind the production curve.

So I did assemble some of the most relevant information that I was aware of so that the considerations for things like mechanical abrasion could be thoughtfully looked at, if warranted, to see if any enhanced maintenance or design or operational issues would need to be done. The need for those is completely beyond the scope of this topical report on volcanic hazards.

DR. BLEY: I like what the staff had to say in this area, and I was just hoping TerraPower wasn't figuring this covered it. We'll eventually see that.

CHAIR ROBERTS: Let me follow up on what Dennis was asking. One of the goals is to get a sense of how useful Reg Guide 4.26 was to you. That reg guide has a seven-step process, and the last couple of steps in that process are basically develop what the plant hazards are and then what mitigations you might do to deal with whatever SSCs are adversely affected by the ash fall.

You did some of that, I wouldn't call it hand waving, but at a very high level. It is the kind of things we could do, and here's kind of one person's look at what the risks might be. But the staff kind of said, well, okay, thank you very much, we don't really think that's going to fit the bill. So I'm just wondering what you plan to do.

MR. HILL: I first just want to make a small correction to your statement that I did not look at the risk. I looked at, to use the John Garret terminology, what might go wrong in the sense of this is the physical demand, the abrasiveness, the hardness, the thermal conductivity that would be the engineering inputs to answer the question of could this or would this not be a potentially deleterious effect on SSC performance. So, again, there is a dearth of information collated from the existing literature, and having that information assembled provides useful guidance to both staff and TerraPower on what would be some considerations if you eventually had to think about these adverse effects, but it was not a risk-informed decision to put Chapters 9 and 10 into the original report.

MR. KELLENBERGER: So this is Nick Kellenberger again. As Britt said at the beginning of the presentation, the initiating event, the eternal hazard, it falls in with a beyond design basis event. So based on the phases of construction permit operating license, the question of what will we do as we go towards operating license as we develop our beyond design basis event response, we'll go through and determine kind of what those responses should be. And then the other thing we'll do is the external hazards PRA scoping, and we have folks that go in more on this, but the external hazards PRA scoping activity is another -- so we've characterized our design basis hazard levels for external events, so those are included in our construction permit. And then the beyond design basis sequences for external hazards is another step in the PRA that will come between construction permit and operating license.

CHAIR ROBERTS: So the intent for this VP is it was sufficient to determine that the hazard was beyond design basis?

MR. KELLENBERGER: That's correct.

CHAIR ROBERTS: Okay.

MEMBER DIMITRIJEVIC: Hi. This is Vesna. There was a little simple question here. You know, you are in the staff, too, here, basically, in the looking and screening or counting hazards. But if you're going to go back and look at the risk insights, then you will need a little more information on the hazard, not on the, you know, even this is beyond design basis events. If you want to, you know, if you want to estimate how efficient prevention or mitigation can be, you know, you sort of need the speed of accumulation of tephra or how long it will take before you get warning of the hazard, you know, things like that.

So is that something, when you were looking and analyzing these hazards to get this type of information, the information which would influence your, you know, analysis of prevention or mitigation?

MR. HILL: This is Brittain Hill. Yes, all that information is in Chapters 9 and 10. We did not apply or develop risk insights --

MEMBER DIMITRIJEVIC: No, no. I understand that you discussed this information, but do you actually have a way to know in what speed, you know, in what speed would, like, tephra accumulate on the roofs or things like that or how long it will take for the warning from eruption to get there. That's what I'm asking. Is there some way that, you know, you say here, I think, you know, it takes an hour or something.

But my question is do you have way from the data which you were looking to estimate those? I mean, to really get some -- this is so much uncertainties in this data, and I'm sure there is no way, you know, to estimate that. But I'm just wondering how would you analyze those preventive actions?

MR. HILL: We use experience from around the world on analogous volcanic eruptions. So we know the mass flow rate, we know the transport rate, we know the duration of those eruptions. In our models, we know what our mass flow rate, transport rates, are, so we can make a very reasonable bound about what accumulation rates would be for these kind of volcanic eruptions, so that's what we used to constrain the range of eruption notification times. We look at the wind speeds that occur out there and say, well, if the volcano is 300 kilometers away and the ash plumes travel at 10 kilometer per hour, we know what the arrival time is going to be and we look at the accumulation rates. All that information was provided just to provide that sort of perspective. It's never meant to be a precise analysis of something that we can't know because we don't know what the future eruption duration would be. Will it be episodic? Will it be continuous? I don't know. Nobody knows. We can't tell that from the past eruptions either, only the ones that have been observed.

So we have this information. If we want to take the analysis further in the Reg Guide 4.26 parlance to go into step five, develop risk insights, but we didn't do that. There was no need to for the scope of this hazard analysis. We're doing the first four steps. We have initial risk insights, our step three, enough to determine that tephra could be a potential hazard to the proposed facility, which relies on air circulation for cooling. Well, tephra could affect. I'm not saying adversely or negative, cause failure, just it reasonably has a potential to affect air circulation systems and air cooling exchange. So there's our risk insight: tephra is potentially significant.

So we're not taking the engineering option in 4.26 to use SSC screening. We went to the next step, step four, to evaluate the eruption potential and hazard potential, which is what the outcome is. We have our exceedance curves, and then we have this additional information that can be used, if needed, to gain those risk insights if that level of effort is warranted.

MEMBER DIMITRIJEVIC: Well, thank you. I mean, you know, I was just curious because you presented some results with even some probability so, you know, accumulation of the, you know, 100, you know, whatever, 13 centimeters, but, you know, no discussion about at what speed is that, you know, occurring and what the possibilities of -- that's why I was sort of curious how much we know when estimating of the mitigation effect in this. Okay. Thanks.

MR. HILL: We have not observed a super volcano eruption. We have very little understanding from the interpretation of past --

MEMBER DIMITRIJEVIC: Absolutely, yes.

MR. HILL: -- what is the duration, the dynamics. Do they open up in a single vent, multiple vents, is it episode, what's the true mass flow rate. There's huge unknowns in doing this for a super volcano eruption, but, fundamentally, you're still dealing with a tephra plume that has limits on its density. There's only so much tephra that can be buoyant in the air given this thermal input. There's only so fast that that tephra plume in the super volcano eruptions will diffuse through the atmosphere because it's not blown by wind, it forms its own kind of lateral flow, and that might be 300 kilometers an hour based on modern analogy with smaller volcanoes. So the rate of accumulation, who the heck knows? It's probably pretty high.

MEMBER DIMITRIJEVIC: I know. I know. I know. Believe me, I understand what type of uncertainties you're dealing with, and super volcano eruptions could be something which, you know, changing the planet climate. But I was just, you know, curious about this data, so thanks.

MR. HILL: You're welcome.

MEMBER MARTIN: So as one of those non-geologists and not yet a student of the reg guide, you focused on existing volcanic fields, but, obviously, their positioned sort of around the site at some distance. Are you able to just discount the possibility of a new eruption in the middle of that?

MR. HILL: Absolutely. That detailed discussion that was part of the tectonomagmatic model is what it was called in the report, but it's looking at what's the characteristics of the deep earth beneath the proposed site compared to the characteristics deep beneath existing volcanic fields. And we know a lot from geophysical investigations and also the chemistry and character of those old volcanic fields. What sort of deep earth conditions formed that volcanic system, and the bottom line is those kind of conditions that form molten rock deep in the earth, they don't exist beneath the proposed site. And for the last 325 million years, there's no evidence that any volcanic eruption has occurred within 40 kilometers of the proposed site. So we have reasonable confidence that a new volcano, if it formed, would form within one of the existing volcanic clusters and that, if a new random volcano formed somewhere, it wouldn't be within 40 kilometers of the proposed site.

CHAIR ROBERTS: So recapping what I think Nick said, so there's a seven-step process. You basically stopped at step four with the remaining three stops you have to be resolved with the external hazards PRA and whatever work comes out of the PLL preparation; is that fair?

MR. HILL: I think that's very fair. It is. They haven't developed the risk insights that would be step five and determined whether any SSC evaluations would be needed or mitigating actions would be needed, given this level of external hazard.

CHAIR ROBERTS: Okay. Thanks. So one of the things in the reg guide is it recommends use of the Senior Seismic Hazards Assessment Committee, SSHAC. I noticed in your report you said you didn't do that. Can you give a little perspective on why not?

MR. HILL: Sure. You know, the SSHAC process is excellent for looking at systems that have large amounts of uncertainty in them with uncertainties that are very difficult to quantify or very intractable given the state of the current literature. When we first scoped this project, we determined that the volcanic centers are well known, that buried volcanoes are not an issue, and that the characteristics of those volcanoes with the exception of Yellowstone were pretty straightforward to estimate based on what's available in the current literature.

So the initial thought was we don't need to do a SSHAC process if the uncertainties are manageable and the literature is sufficient to quantify those uncertainties in a very reasonable, transparent, traceable way. But we reserved the option, if at any stage in the analysis we came to something that was, wow, this is a real huge epistemic uncertainty that is going to need a lot more attention, then we could go and fall back into a SSHAC process. Even a subset of that could be done at a SSHAC, say level two, without having to invoke a fully SSHAC-level multiyear-long process to answer this very basic question.

The other aspect of that is that we took a conservative approach in analyzing the potential for a Yellowstone super volcano eruption. There's a lot of debate in literature about whether Yellowstone is capable of such a huge eruption or not. Rather than falling down that rabbit hole of geologic interest and forming a SSHAC to answer definitively, we took a bounding approach based on conservative analyses by the U.S. Geological Survey that gave us the 113 centimeters at the 95th percentile.

So I'm not arguing that we can screen it from any consideration. It's just probably less than a beyond design basis event, but it's so thick you really would want to have some documentary record of we thought about it and here's why we're not going to have to worry about it based on the current design of risk insights.

CHAIR ROBERTS: Steve Schultz had his hand up. Steve.

DR. SCHULTZ: Yes. Thank you. In evaluating the tephra fallout, you used the ash plume code in order to move forward and perform quite a few analyses and evaluations associated with that. You note in the report that you began with the rev 1 to ash plume, and then you modified the code to develop a revision 2 to the computer code; is that correct?

MR. HILL: That's correct.

DR. SCHULTZ: And you note that, for rev 1, the NRC applied all their QA requirements and some confirmatory testing associated with it. With regard to your modifications, did you perform that under a TerraPower quality assurance program --

MR. HILL: Yes, I did.

DR. SCHULTZ: -- as you went through that? So that was done.

MR. HILL: That's correct.

DR. SCHULTZ: Good. And then also the NRC noted, I wanted to just prepare them for it or they can address it, but they indicated that they also did some confirmatory calculations. I presume you provided them with the computer code and input so that they could do that evaluation?

MR. HILL: Yes, we did.

DR. SCHULTZ: Good. Well, thank you. I just wanted to -- there's a lot of information that was developed throughout the report by using that methodology. It probably could provide more detailed evaluations if the site was closer to the volcanic hazard, but appreciate the work that was done there. I like that it was done under a QA program.

MR. HILL: I'd like to, just to make sure that everybody is aware, the modifications we're talking about are very straightforward. In the original ash plume code, the wind speed and wind direction are hard wired in the code as subroutines because the code was developed for use at Yucca Mountain and only Yucca Mountain. The modifications that I did was locked out those subroutines and put in a stratified wind field, which is basically saying for these 5 kilometers above-ground increments, what is the average and standard deviation wind speed based on NOAA re-analysis data. We then stochastically sampled those wind speeds from the appropriate distributions but always kept the plume directed at the proposed site. So the only modification is, rather than a less than 5-kilometer high wind, I'm using up to 25-kilometer high winds in 5-kilometer increments to just sample based on the top of the plume. And post-processing is accounting for what is the likelihood that the wind will be flowing in that sector directed towards the proposed site from the volcanic source. But it's a conservative assumption because, in this simulation, every analysis center line, the highest concentration of tephra, is always directed at the proposed site. You don't get near hits and near misses in there to dilute your runs.

DR. SCHULTZ: I thought that was quite appropriate for this evaluation. I appreciate that very much. Thank you.

CHAIR ROBERTS: Okay. Any other questions from members or consultants?

MEMBER KIRCHNER: I have one. This is Walt Kirchner. Thank you for your presentation. Just taking it one step further, since we have an expert in volcanism here, have you been looking at effects of the tephra fallout on equipment in places like Iceland where they had recent volcanic eruptions? Obviously, they have to deal with it. Have you been getting any information on component performance under those conditions?

MR. HILL: Yes. For the past several years, I've been part of a working group at the International Atomic Energy Agency that's been assembling information and international experience on just that, what are known or observed effects on different kinds of engineered systems both at nuclear and non-nuclear facilities in respect to tephra fallout hazards.

A consideration in Iceland is it usually has a very high amount of adhered ions on the tephra, so leaching of acidic fluids or acid is a longer-term problem from Icelandic tephra that has come from time to time up in the literature but not quite on nuclear systems.

So there is some experience internationally. It has not been assembled into a unified or even curated collection of documents. We can answer some very fundamental questions, like how little matters, what's the minimum thickness to where you say, oh, this is a nuisance level.

If you're talking about earthquakes, we all have a minimum design standard that we're very comfortable with and say, oh, below this, we don't really care. We don't have anything like that. We're just sort of starting out on tephra. Engineers for earthquakes, they've got 40 - 50 years of experience, so it's not fair.

MEMBER KIRCHNER: Thank you.

MEMBER MARTIN: Bob Martin here. When I think of the most likely hazard, it would relate to its impact less on equipment but on maybe the most important piece of equipment and that is the people. You know, of course, you highlight the need for respirators, goggles, and such, you know. At the least, those are inconveniences, but, at the most, it really creates, you know, contribute to just the chaos because, of course, this would be a situation that we're definitely unfamiliar with. I would expect that the likelihood of other hazards related to the operator would be heightened. Is there a connection from a document like this to feed into a PRA, you know, type model, which would ultimately elevate the likelihood of these kind of human errors associated with that? I mean, it comes down to data, but I think, you know, we all were alive during Mount St. Helens and remember pictures of other places, and, you know, it was worse than a fog, right. You really couldn't see. Large lights couldn't really help, you know, help the people get through traffic and things like that, and it was a mess, to say the least. But I want to see how you go from a document like this into state the analysis. That would be the most likely thing I would focus on the most.

MR. HILL: There isn't a direct link in the literature on human factors in the way that we mean that in nuclear facilities and volcanic eruptions. We do now have some very good experience with what happened at Hanford during the Mount St. Helens eruption because there were a number of nuclear facilities that were operating. Even though Hanford only received less than a centimeter of tephra, it was south of the main plume from St. Helens, there were impacts from all of that, especially in vehicle operations. That's why part of that is discussed.

And remembering with a grain of salt, you remember cars in 1980 versus cars today. How do the electronics do? They may be better, they may be more susceptible to ash ingress; I don't know. Nobody has looked at it since really Mount St. Helens.

Getting people through the site, people adapted very quickly both for the transportation network, the busses. They started putting on external air filters and increased the oil change. Washington state did the same thing. They just really amped up their maintenance cycle without any formal guidance. It was just, well, we've got to clean out the air filter and put a primary filter on top of that in order to keep the cop cars running.

But I think from what I know from St. Helens, it wasn't really chaotic. It was difficult for about eight hours when the peak air fall fell beneath the plume itself, but you weren't getting blackout conditions at the Hanford facility. You got a really smudgy day with the tephra falling out and a lot of dust kicked up on the road.

So it's an inert particulate. It's a nuisance particulate, and I have been in a number of countries where people just put the umbrella up and walk through the tephra falling out tens of kilometers away. They're very non-plussed by it all.

So it's not a very thick fallout, except during the peak. If you put your umbrella up, you'll probably be okay from all of that. There are considerations, of course. I'm not trying to pooh-pooh the idea.

MEMBER MARTIN: Right.

MR. HILL: It's just it is not an immediate threat to human health and safety. It needs to be managed, and that was part of the whole point of the operational considerations is this is manageable. It's not a huge flood coming out of nowhere. It's relatively easy and straightforward to manage this.

MEMBER MARTIN: But does it set requirements for having, you know, respirators and goggles on-site for the staff? And where is the traceability of the requirement?

MR. HILL: That would depend on the operational significance of this external event and probability level. All I can say is it appears practicable. If it's warranted, that's a risk insight.

DR. BLEY: This is Dennis Bley again. Maybe to be a little argumentative, that plume lofted over Hanford. But if you talk to people on the eastern side of Washington near the border, they got a couple of feet of ash on their roofs. It really came down hard over there, so it depends on where you are.

MR. HILL: Oh, yes. If you were in Yakima, that's really different, though, a different experience than if you were down at the Hanford reservation. I think Hanford is, like, 50 to 60 kilometers south of the --

DR. BLEY: Yes.

MR. HILL: -- so it wasn't like -- St. Helens was a relatively small eruption in the scale of volcanoes, but it still was a fairly narrow wind-driven plume and, if you were unlucky enough to be right in the center line of the plume like Yakima, yes, you were having tens of centimeters of tephra falling out, and that was the day turned into night and you couldn't even see the streetlights and you had to hunker down for about 12 hours. And afterwards, the tephra removal, the ash removal, was a lot worse than snow because, if you get ash wet, it weighs about a ton per cubic yard. That's heavy stuff.

DR. BLEY: I've heard it can almost turn into concrete, too, after --

MR. HILL: Well, if you really get it wet, it does indurate pretty successfully, yes.

CHAIR ROBERTS: Okay. If there's no more questions -- looking around I don't see any hands up, so, TerraPower, thank you very much for your presentation. We'll now switch to the NRC staff.

All right. Stephanie, when you're ready.

MS. DEVLIN-GILL: Okay. Ready. Hello, everyone. My name is Stephanie Devlin-Gill. I am a senior licensing project manager at the NRC assigned to the TerraPower Natrium project. I'm the lead project manager on this topical report. Sitting next to me today is the lead technical reviewer, Jenise Thompson. She's an experienced NRC geologist and the lead technical reviewer on this topical report.

This slide describes the agenda of the NRC's presentation today. We will be reviewing the chronology of the review, the purpose of the staff's review, and the staff's review strategy of the topical report, and then provide an overview of the contents of the staff's safety evaluation report, and then, finally, summarize the staff's conclusions regarding TerraPower's topical report.

Regarding the time line, we started off with a pre-application public meeting in July 2022. TerraPower submitted the topical report in April 2023. In June 2023, the NRC accepted the topical report for review, and then in September and October the NRC conducted an audit. In February 2024, the draft safety evaluation was issued.

This slide shows the NRC staff and their review team. The TerraPower project management team has a few names on it: Mallecia Sutton, the lead, TerraPower project manager, she started off this review; Role Brusselmans led the audit; and I'm here to finalize the review.

And now I will turn over the presentation to Jenise Thompson, and she'll start off by describing the technical staff participation in this review.

MS. THOMPSON: Thanks, Stephanie. So in addition to myself as the geologist and lead reviewer, we brought in some additional support staff on the hazards site. Jason White, a meteorologist. As you heard, there was some meteorological data that was important to the modeling, so we brought in one of our experienced meteorologists to support that review. We also had Scott Stovall, a seismologist and geophysicist. Typically, he's in the Office of Research. He was on detail to NRR, which was great for us because he was able to perform the independent confirmatory calculations of the model that was used. And then we also had Hanh Phan, who is a senior reliability and risk analyst, and he's here today, as well, because we did recognize that the hazard component was the end of this topical report and there is still an important interface between the hazard that was determined in the topical report and what comes next if there's a subsequent engineering analysis, so we wanted to make sure that we were already having discussions with the team that was going to take over looking at the impact on the overall facility risk from that particular hazard. So that was our review team.

We'll go to the next slide, please. As Stephanie said, we received the topical report, conducted an audit, issued our audit summary. I'm not going to spend a lot of time on this because I think she covered it here.

Something I do want to emphasize is that, because they kind of bifurcated the process in Reg Guide 4.26, the scope of the topical report is primarily focused on the hazard determination and we didn't go into the effects on overall plant risk, any necessary mitigating actions or enhancements to any of their SSCs that may be impacted by these volcanic hazards because that information was not provided within the scope of the topical report. So we weren't provided with the overall plant PRA, we weren't provided with overall detailed design information of potentially affected SSCs, so we focused our review on the hazard determination only.

Moving on to the next slide, we're on slide six, the regulatory requirements. For those members who were part of the reg guide briefings that we've given over the years, you're probably familiar with the regulatory requirements entitled 10 GDC 2 and then you may recall 100.23 is the specific regulation that calls out volcanic activity as something that needs to be considered in the context of licensing a reactor.

Go to the next slide, please. The applicable guidance here is Reg Guide 4.26. I know there's been some discussion on the content of that already. We were here in ACRS in February of 2020 and then April of 2021. We issued rev 0, and then just last summer we processed an administrative change. I think you all were aware of that. And then last September I came and presented an overview of how the staff was planning to approach the review of any topical report or application that was using Reg Guide 4.26 to perform their volcanic hazards assessment.

We've already talked a little bit about the incorporation or endorsement of the SSHAC process within Reg Guide 4.26. I want to emphasize that it's not a requirement in 4.26. It's just a suggestion. If you think it may be necessary for your particular site and the hazards, particularly volcanic hazards, that may need to be considered, and so this is something that we are tracking as a potential clarification in a future revision to the reg guide that SSHAC is one method that can be used for expert elicitation but is not necessarily a please do this for your volcanic hazards assessment to be considered acceptable. So we are tracking that with the reg guide project manager who was responsible for Reg Guide 4.26.

And within 4.26, we have identified that flow chart -- we'll go to the flow chart in the next slide here, but there is an option to pursue what's called an engineering analysis where you perform a basic hazard assessment and then start to look at what the impact would be on the SSCs in your particular reactor design and what the impact would be of those hazards on those SSCs. And that engineering analysis would move forward considering a maximum magnitude volcanic hazards. So what is that? Screened-in volcanic hazards, remembering there are many different types of volcanic hazards that may impact a facility and then determining what would be that magnitude to consider in any subsequent engineering or risk analysis for that site.

Next slide, please. Most people are familiar with this flow chart outlining the methodology in Reg Guide 4.26. Again, we're looking here for a maximum magnitude hazard for those screened-in volcanic phenomena, recognizing that not all phenomena are going to impact a particular site. And just as a brief overview, we start with available information, so we start with the geologic information, geologic history, and site characterization information looking particularly at are there quaternary volcanoes in the site region, which is a 200-mile or 320-kilometer radius around the site, and are there quaternary volcanic deposits in the site vicinity, so within a 25-mile or 40 kilometer radius of the site, and the quaternary being the last 2.6 million years of geologic time.

And from that, an applicant would move into step two to screen volcanic hazards and then develop the initial risk insight. What we note in the topical report here submitted by TerraPower is that the subsequent evaluations of SSC performance or the impact on a probabilistic risk assessment for the facility is going to be deferred to the construction permit review stage because we weren't provided that information within the context of the topical report. So these bottom steps five, six, and seven, those are going to be deferred to later.

And I recognize, going back into Reg Guide 4.26, we did not state that that would be an acceptable approach to essentially bifurcate the hazard steps from the engineering analysis steps, and so that's another area where we have already started talking with our regulatory guide PM. His name is Ed O'Donnell, and he's amazing. So we've already had conversations with Ed about what does this look like going forward for a potential revision to this guide now that we have some experience with an applicant using it because it's difficult, I would say challenging, to know where you need to provide additional clarification until you've gone through the process of using the methodology, and then you have a much greater ability to identify areas to focus on for clarification in the future. So that is something that we are looking at in the future for --

DR. BLEY: Dennis Bley. You really intend that they complete the evaluation of SSC performance, especially under tephra, for the CP? I would expect they'll be able to put it off until the operating license if they want to.

MS. THOMPSON: Yes. That's another option. Either would work, the CP or the OL. It's also possible that, once they have the detailed design information, that they will be able to end the assessment and document the results for why they don't need to perform an additional evaluation of SSC performance or implement mitigating actions. So within the flow chart here, the methodology in 4.26, any of those would be acceptable in the future. We just don't have that information yet. An early end of the assessment is, you know, well within the methodology we outlined in 4.26.

DR. BLEY: And that would be great.

CHAIR ROBERTS: You used the term screened-in volcanic hazards. The applicant just made a distinction between screened-in but beyond design and screened-in within design basis. Did I understand that right? Are there two ways that you could be still screened in but lead to a different level of assessment of the risk?

MS. THOMPSON: Yes. There's a wide range of volcanic phenomena that may pose a hazard to a site. And in TerraPower's presentation, they talked about flow hazards versus the suspended hazards. Not every volcanic phenomena is going to pose a potential risk to the facility. They talked about topography and distance, and that's something that in this initial screening here you would be able to say we're over 100 miles over several mountain ranges from the volcanic source to the proposed site; therefore, we don't need to consider lava flow phenomena as a potential hazard at the site. And that's what this initial screening volcanic hazards stuff would include.

The decision or the determination of what's a design basis hazard versus a beyond design basis hazard would be subsequent to that initial screening of which phenomena need to be considered for a particular site.

CHAIR ROBERTS: Okay. Thanks. So when and how much you do in steps five through seven may be informed by, it's screened in but beyond design basis versus design basis?

MS. THOMPSON: Exactly.

CHAIR ROBERTS: Okay. Thanks.

MS. THOMPSON: Okay. So we can go to our next slide, slide 9. The review approach, this is the approach that we took as a staff is exactly what we briefed to the committee back in September of 2023. The goal of the reg guide is to start with the available geologic information, so the geologic history, site characterization information. TerraPower touched briefly on the tectonomagmatic model. That's a very important consideration for us in determining what volcanic sources could have the potential to induce a volcanic hazard that would need to be considered for that site and whether there's the potential for a new vent to open in a place where there isn't currently a volcanic source.

We also recognized that Reg Guide 4.26 and the applicants are using numerical modeling to consider their screened-in volcanic phenomena, and so we'll talk about that a little bit later in this presentation. And then, again, emphasizing that, here, we're looking at what is the magnitude of the volcanic hazards that would or could be used if an evaluation of SSC performance or mitigating actions needs to be made at the CP or OL stage.

DR. BLEY: Can I ask you how -- have you run into any difficulties reviewing the tectonomagma -- I can't say it.

MS. THOMPSON: Tectonomagmatic model?

DR. BLEY: Thank you.

MS. THOMPSON: It's a bit of a tongue twister. It is.

DR. BLEY: That's a fairly complicated model. How do you review that?

MS. THOMPSON: So we're looking specifically at the drivers of the volcanic system. I wouldn't say that it's complicated if you're a geologist. That's how I'd preface it. But you're looking at the geophysical drivers of the current state of the volcanic systems. Volcanic systems are highly dynamic, so what conditions existed in the past that resulted in an eruption may not exist presently or have the potential to exist in the future.

A great example, think about a hotspot track. So if you are, I don't know if you're familiar with Hawaii, the big island there, that is where the current hotspot is. That is where the volcanic events are occurring. You want to go on vacation and not worry about a volcano, go to Kauai at the far other end of the archipelago where there have not been eruptions there. So in looking at the tectonomagmatic model for Kauai, it would be very difficult than the island of Hawaii because of the change in the hotspot tracking. We wouldn't expect that Hawaiian hotspot would reverse and go back to one of the older islands in that volcanic chain. Does that kind of address your question?

DR. BLEY: Kind of.

MS. THOMPSON: Okay. All right. We'll go to our next slide. We're on slide 10. We start with the site geology and regional geologic history, and this is where the basis of developing that tectonomagmatic model comes into play because we do want to have a clear understanding of what are the geologic processes that have driven things, like volcanism, seismicity, just general rock-forming or mountain-forming events, and how did the rocks that are there now get to be there. So that overall geologic history becomes an important component to understanding the tectonomagmatic model.

So for this particular site, we looked at all the information that was provided. The site under consideration in this topical report is in the middle Rocky Mountain physiographic province. It's that green dot in the very center of this figure. The site vicinity is the green line around it, and then the red line, and I apologize to anyone who has trouble seeing colors, but the far red line is the site region. So we're looking at volcanic deposits within the site vicinity or volcanic sources within the site region. As you can see, there are several volcanic sources here, and we'll get to the figure that was shared by TerraPower, which is a little bit easier to see where the volcanic sources are.

But in the site vicinity and particularly underlying the Kemmerer site is a series of Paleozoic and Mesozoic sedimentary rock, so we're not sitting on any type of igneous rock, we're not sitting on volcanic rock or volcanic deposits. Also, Paleozoic and Mesozoic are very old geologically, so we're not looking at young rocks by any stretch. And within that, we also see that these sedimentary rocks have been folded and deformed as part of a mountain-building event, which was the last 50 to 150 million years. So we're sitting on old rocks that were deformed and faulted a relatively long time ago geologically. We don't see young volcanic within the site vicinity. We don't see any of the, in any of the features that we would expect for a potential volcanic event within that site vicinity, and we don't have any evidence geologically of volcanic eruptions in the site vicinity for at least the last 150 million years. So we have geologically from a regional geologic history perspective a long history of no volcanism at this particular site.

Next slide, please.

MEMBER HARRINGTON: Just one quick question. This is Craig Harrington. The tectonomagmatic model, is that more of a qualitative model or a quantitative mathematical?

MS. THOMPSON: I would say that it's more qualitative. It pulls together the information that's available for the geologic history on that particular site, so it's looking at the available geologic information for the history of the region. So we're not pulling out a numerical model that's telling us something about it. We're looking at all of the available data and information that we have for that region to determine what could realistically occur, given the current state of that volcanic system. And I actually have a slide coming up, I think it's slide 12, where I talk about their tectonomagmatic model. So I'll go into in a little bit more detail.

All right. So we can go to slide 11. There we go. We also looked at site characterization information. The topical report focused primarily on all of the volcanic information, so we weren't looking across the board at the entire geologic history but focused on the volcanic sources in the site. And there were seven regional volcanic sources within the 320-kilometer or 200-mile radius. Those are all listed here. As you can see, most of them are towards the periphery of the site region. They're not just outside the site vicinity. Most are sitting greater than 100 or more kilometers from the site. The closest volcanic source to the site is the Leucite Hills volcanic field, which is almost directly to the east of the site, and then you can see the other volcanic sources within the site region here.

At the far southwestern edge of the site region is the North Black Rock Desert Volcanic Field, and that was something that the applicant determined would screen out based on distance and other considerations. It's past the Wasatch Range, which, if you've been to Salt Lake City, there's a large mountain range there, and it's easy to imagine that it would take a lot for a lava flow to summit that mountain and come back the other side into Wyoming.

So getting to Member Harrington's question on the next slide, 12, we will discuss the tectonomagmatic model that was presented by the applicant. There are two main drivers of volcanism in the site region, and those are volcanic sources that are associated with the Yellowstone hotspot track, and those sources are the Eastern Snake River Plain, which is that sequence of black and blues in the northwestern part of the site region; the Yellowstone volcanic source, which is the red dots almost directly to the north of the site; and then, finally, the Upper Wind River Basin, which is just to the southeast of the Yellowstone field. And all of those sources are associated with the Yellowstone hotspot track, and, as you can see from the map, the site is not located near the track of that hotspot. So from a tectonomagmatic model, we know that the Yellowstone hotspot is driving volcanism in those particular sources within the site region, but the site itself is not within the track of that hotspot, so we wouldn't expect the site to be subject to volcanic events originating from that hotspot activity.

We also recognize that there are volcanic sources in the basin range physiographic province, and those are all caused by extensions, so the pulling apart, the thinning of the earth's crust. And those sources are the Black Foot Reservoir, the Leucite Hills, Curlew Valley, and the North Black Rock Desert. But if you go back to the first slide on geologic history, this site is not located in the basin range physiographic province. It's located in the middle Rocky Mountains, so it's characterized by different drivers of geology, different geomorphology, different structural components that make it part of that Rocky Mountain physiographic province, not the basin range physiographic province. And so because it's located within the Sevier overthrust within that middle Rocky Mountains physiographic province, we would not expect this site to be subject to volcanism from basin range extension because we have the extension in the basin range and we have compression at the site within their physiographic province.

So from a tectonomagmatic model perspective, we looked at the information provided in the available literature and were able to reach that conclusion that neither the Yellowstone hotspot track or basin range extension would result in volcanism at the site.

Were there any questions on the tectonomagmatic model? Okay.

So with all of that background information, we then move into -- we're on slide 13, thank you -- that screening question. So step two, what hazards or volcanic phenomena could screen out from further consideration, and the applicant determined that three volcanic phenomena, those being proximal hazards, lava flows, and pyroclastic density flows, could be screened out based on the distance from the volcanic source to the proposed site and the topography in between. So we're in a mountainous area. It's unrealistic to imagine that a lava flow is going to summit mountains and come back to this particular site.

So, in this case, topography and the

distance is an important driver of whether a hazard needs to be considered for the site or can be screened out. In this case, these hazards can realistically be screened out.

We also looked at whether there was a need to consider sources of tephra beyond the site region, and the cutoff point for that is are there quaternary volcanic deposits within the site vicinity. And if there are, then you may need to consider tephra sources beyond the site region. In this case, there are no tephra deposits within the site vicinity, so there's no need to consider tephra from sources outside of the site region, so that could also be reasonably screened out based on the geology at the site.

We'll go on to slide 14. The applicant did consider the potential for a new vent opening at the nearest volcanic field as part of their screening, and that, again, is the Leucite Hills Volcanic Field almost directly to the east of the site. It's still greater than 100 kilometers from the site. I think the closest point is about 117 kilometers from the site. They used a code that was developed for the Yucca Mountain project that went through an NRC QA program, and that was PVHA_YM, and, essentially, transposed the geographic co-ordinates from Yucca Mountain to the Leucite Hills Field and determined that there wasn't going to be potential for a new vent opening in Leucite Hills that would impact the facility. So you could screen out lava flow or new vent opening from that Leucite Hills source based on that modeling.

DR. BLEY: Jenise, Dennis Bley again. On your previous slide, is there any guidance or requirements on how deep and how near or far away from the site one has to be to say that there have been no tephra deposits there?

MS. THOMPSON: We don't have any specific requirements for depth or distance -- or for depth. We don't have specific requirements for depth at the site. But I think it's safe to say that if you're sitting on -- the youngest rocks are Mesozoic, and what we're seeing within the stratigraphy that's visible as you cross this section across the surface of the site, that those rocks continue to get older and we're not seeing tephra there, that it's reasonable to assume that there isn't going to be tephra in the subsurface or, if there is, it's going to be older than what's exposed at the surface.

Now, if this were a different location

with younger rocks at the surface, then that would be a different question to consider. And, in that case, maybe it would be more appropriate to consider is there tephra in the subsurface that's younger than 2.6 million years. But for this site, we're sitting on very old rocks, and we wouldn't expect to see tephra, we wouldn't expect to see younger tephra under older rocks. Geologically, that's not something that we would see. That would be somewhat alarming.

Okay. So the applicant performed a screening and screened out lava flow and potential new vent opening from further analysis.

So with that, I'll go to slide 15, and there are hazards that screened in. So we've already heard from the applicant that tephra was a source of volcanic hazard within the site region. The applicant moved forward with an analysis of both the silicic and mafic sources, and the applicant, as you heard, also considered debris flow from remobilized tephra on the north fork of Little Muddy Creek and ultimately determined that was not going to result in a hazard to the site. So tephra from the regional sources was the primary hazard considered here for additional analysis.

We're now on slide 16. I'm going to go

back to this figure so that everyone can have a good picture of what was considered in the tephra analysis. So as we talked about, the applicant considered both silicic sources and mafic sources, and the different volcanic systems here are producing silicic or mafic and, in some cases, both.

So the silicic sources that were considered were the Black Foot Reservoir Volcanic Field, the Eastern Snake River Plain, Curlew Valley, and the Yellowstone Volcanic Field; and mafic sources were the Upper Wind River Basin, Leucite Hills, Black Foot Reservoir, and the Eastern Snake River Plain.

We'll go to the next slide. We're on slide 17. The applicant used the Ash Plume 2 model as part of their, for their numerical modeling of tephra hazards, and they used this to analyze both the silicic and mafic tephra hazards for all but the Yellowstone super volcano eruption, and you'll see that in a subsequent slide. As they used Ash Plume 2, they used run intervals that were designed to maximize the number of realizations in order to adequately capture a range of uncertainty. And as I mentioned before, we were greatly appreciative of Scott Stovall who performed the confirmatory calculations using the input files provided by the applicant, and we confirmed the applicant's results in using the Ash Plume 2 model.

So we're on slide 18 now. This is essentially a summary of the hazards for potential use in future analysis. You can see it's a combined mafic and silicic sources here, and, as was touched on by the applicant, all but the very last line here of the Yellowstone volcanic field, VEI8 silicic eruption were performed using the Ash Plume 2 code and confirmed by the NRC staff. The Yellowstone volcanic field VEI8 was from a USGS code, Ash3d. We did not perform confirmatory calculations for Ash3d, but we believed that the incorporation of the USGS code is acceptable and that's something that is considered kind of the seminal approach for the Yellowstone volcanic field, and we considered it acceptable for use here.

With that, we'll go to the limitations and conditions. We've touched on this a couple of times in the presentation. The conclusions here do not adjust the content provided in Section 10, so an applicant or licensee in the future referencing this topical report will need to evaluate the specific design mitigation or monitoring actions that may be required to mitigate the effects of volcanic hazards if necessary. It is also possible, as we saw in the flow chart for Reg Guide 4.26 that, as you apply the additional risk insights, that it may not be necessary to perform an additional evaluation of SSC performance or implement mitigating actions, but we didn't have that detailed design information or risk information provided with the topical report, so that is not part of our conclusions here.

And the limitations and conditions are something where we worked very closely with the risk analyst folks to ensure that we were not seeing anything in our topical report conclusions that was going to hinder their future review if it's necessary based on the impact of these volcanic hazards on the engineered systems for the proposed facility.

And then, finally, we weren't provided with the overall plant risk, so the conclusions in this SE do not address the impacts of those calculated probabilities on the accumulative plant risk. That's something that will be deferred to such time as the overall plant risk is provided for the NRC staff review.

And with that, I believe we're at the end. Our conclusions are that the characteristics of the volcanic hazards to the tephra hazard that was determined for the Kemmerer site are appropriate for use as inputs to the evaluation of SSCs or the efficacy of mitigating actions, if necessary. And with that, I will take any questions that you may have.

MEMBER KIRCHNER: Jenise, I have a question. If necessary. The if necessary is going to depend on some assessment of that bottom line, 5 times 10 to the minus 7th cutoff. Just could you lead us to the next step forward? Even if you had a complete risk profile for the planned plant, where would you stop your analysis? You've got an input to consider, but when do you actually consider it?

MS. THOMPSON: So, Stephanie, if we could go back to slide 8.

MEMBER KIRCHNER: This is the problem of cliff-edge effects. We've been dealing with other applications that were seismic related, so I just want to try to understand what the logic is to take it the next step and then say, no, you don't have to consider this for the plant in Kemmerer or you do. How do you come to that decision?

MS. THOMPSON: So I'm going to refer back to the flow chart here. So we've essentially stopped the analysis at step four with the characterization of the hazard information. We don't have the additional risk insights that we would see in step five, and that's something that we would expect the applicant to provide either in a CP or OL referencing this topical report. And they would be able to make the case for why or why not this level of tephra hazard is or is not consequential to their site. So it maybe, and I'm just going to speak in hypotheticals, not about the CP or any potential OL, but there's the potential if you have, let's say, a closed system where you don't have any air intake that tephra would come into and potentially damage or hinder the performance of that SSC. At this stage in step five, you would be able to say we don't have any systems that tephra could get into and potentially impact their ability to perform their safety function. And that risk insight could be used to document the results and end the assessment at that point.

If you did have a system or determined at stage five or step five in the methodology here that there is a concern that the hazard might impact a certain system or need to consider a mitigating action to ensure continued performance of that SSC, then they would come down to step six or seven and provide that justification, which we would review at that time.

This isn't a staff decision of you need to move forward or you need to not. The goal of Reg Guide 4.26 is that the applicant can make the safety case for why it does or does not matter, and we will review that for its adequacy. So I would expect that, as this move forwards, we will see consideration of these tephra hazards in the plant risk and in the performance of SSCs that may be potentially be impacted and we'll review that when that information is provided to the staff. Does that kind of address the question?

MEMBER KIRCHNER: Yes. Thank you.

MS. THOMPSON: Thank you.

CHAIR ROBERTS: If I were to summarize that is the developed risk insights needs to include more than numbers, and the key here is if you've got numbers you think are favorable but the consequence is really bad and the numbers don't mean as much in terms of screening out, hopefully that's what you then can do. Risk insights don't mean calculate a number and stop. But, anyway, I just wanted to throw that out there.

Any other questions from --

MEMBER MARTIN: Sure. I know you weren't thinking along the lines of, you know, this is the first advocation of the reg guide, and I'm wondering, you know, in using this and maybe other -- there's not necessarily enough hazard analysis guidelines out there, as far as I'm concerned, but now that there's one and, of course, the temptation would obviously be to use this in a risk evaluation, I'm wondering about collateral hazard. In the case of the volcanic hazard, obviously, the direct hazards are what's been discussed today. But like wildfire, I would think wildfire would be highly probable collateral hazard created by a volcano.

Who would be responsible for capturing that hazard and propagating it into a natural phenomena hazards analysis? You know, should the folks working on this particular volcanic hazard be evaluating and recognizing it? Is it someone that is focused on the wildfire? Where do these two worlds meet, and how do we know for sure it's going to be addressed?

MS. THOMPSON: So I want to ask a clarification question. Are you talking about a wildfire resulting from a volcanic event --

MEMBER MARTIN: Sure, sure.

MS. THOMPSON: -- or just a wildfire that occurs naturally?

MEMBER MARTIN: No. In this particular

case, it is a particular, it's occurred coincident with this, so we're dealing with hot stuff. You know, you look at -- of course I'm googling a little bit -- 600 square kilometers were affected from Mount St. Helen. That's a lot of area and a lot of it was burnt.

MS. THOMPSON: So in the context of --

MEMBER MARTIN: That might be a bigger issue than some of the other things we consider. But, again, it's not the direct hazard that's under consideration with this reg guide, but it may be an important hazard to capture. So who's responsible for at least identifying the hazard and considering its risk in natural phenomena hazard?

MS. THOMPSON: So we have an entire branch here in NRR, which is the External Hazards Branch. We have a team of geologists, seismologists, meteorologists, and hydrologists who all cover the external hazards that fall into our varying aspects. We also have staff in the Division of Engineering and Eternal Hazards that perform the human-induced external events hazard analysis. They also look at hazards from nearby facilities, and we also have our geotechnical engineers who consider the geotechnical engineering considerations.

I don't know exactly off the top of my head who would consider wildfires, but I can take that back and get you an answer --

MEMBER MARTIN: No, I'm not just asking about wildfires. I'm asking about wildfire --

MEMBER HALNON: Bob, GDC 2 requires appropriate combinations of effects. The licensee has to do that as part of their effect. Now, you can question it and they can say there's a fence that goes around it and there's no a way a fire can come from the outside in, which is typically, but the power lines are an issue. That's been looked at --

MEMBER MARTIN: So the gap I'm trying to point out is should there be some discussion in a TR related to collateral hazards? And then, of course, when you integrate it into a broader hazard discussion and consideration in a natural phenomena --

MEMBER KIRCHNER: Debris flow is what would fall into your collateral hazard example. The debris -- so what was discussed was you get the tephra fall, and then you get a flood or you get water. So they did examine collateral damage --

MEMBER MARTIN: Well, the combination --

MEMBER KIRCHNER: -- to demonstrate that the channels would divert any of that from the site.

(Simultaneous speaking.)

MEMBER KIRCHNER: A flooding event carrying ash into -- that would fall in Chapter 2 type analyses.

MS. THOMPSON: And I'll just add that, if we're talking in the context of a volcano erupting at one of the sources in the site region resulting in a wildfire at that source, we are talking about significant distances from the volcanic sources to these site. So even if there is, let's say, an eruption at Leucite Hills Volcanic Field that produces a wildfire, there's over 117 kilometers of distance between the site to that potential wildfire source, and then we would also need to look at what are the atmospheric wind conditions, are conditions right for things to blow towards the site. And I also see that Hanh has his hand up.

MEMBER MARTIN: Our assumptions are different on that one because I'm thinking that ash could still be hot and travel 50 - 60 miles and contribute to, you know, be a source of ignition.

MS. THOMPSON: We wouldn't expect transported ash to have a significant temperature to it that would result in a fire. If it was in the immediate vicinity, much like your campfire, an ember just flies out and hits your toe, that's probably going to burn you. If a little piece of ash floats away a few miles down and lands on somebody's car, it just looks like a burnt leaf.

MEMBER MARTIN: It's pretty dry out west. You know, having lived out in Hanford and Idaho, fires can get out of control pretty fast and be a mess.

MR. PHAN: Good afternoon, everyone. My name is Hanh Phan, the senior PRA analyst in NRR, Division of Advanced Reactors. So I have more than 37 years in reliability and PRA, 18 of those, almost 18 of those with the NRC. So according to records, 1.253, applicants who implement LMP, they don't have to address a volcano PRA, not until the OL stage. The staff expect that in the future at the OL stage. The PRA will address everything, including volcanic hazard-induced fire, induced vibration or movements, or any impact by volcano later at the OL stage, and the PRA should address those. And if not, the applicants should explain or revise the basis why those not impact the plant. But at this stage, not available yet based on the staff guidance. So those will be addressed later.

MEMBER MARTIN: Okay. So it's just not really something that you would expect here. I'm just thinking, from a completeness standpoint, you would expect to have some at least acknowledgment in a document like this, but I can certainly understand where you're coming from.

MR. PHAN: Yes.

CHAIR ROBERTS: So I guess what you're saying is the Regulatory Guide 1.253 acknowledges there's a risk that the volcanic hazard might end up being significant at the site and the construction permit would then still be granted, and they could be building the site and then not get it licensed; is that right? It seems there's a judgment being made, and maybe it as made just generically, that you can always find a way to mitigate the volcanic risk or hazard. Otherwise, you'd think you'd want to have a little bit more at the CP stage to at least mitigate that risk that the site might be found unacceptable.

MR. PHAN: Appendix A of Reg Guide 1.253. In there, we endorse and encourage the PRA standard, the advanced PRA standard. There are 1,233 supporting requirements associated with the PRA in that standard, many of those related to the external hazard, including volcano. So in there, you will find that, you know, not how to address volcano but what to address, including the impact from the volcano. And that we expect applicant to follow up, you know, conform to that standard and address all the hazard impact from the volcano.

CHAIR ROBERTS: Okay. Thank you. Any other questions here on the floor from members or consultants online?

DR. BLEY: Yes. Dennis Bley. I've been thinking about Bob's statement, and this has been a problem over the years, you know, who's responsible. First, the applicant is. Second, reviewers are. But the standard Hanh is referring not now requires them to essentially, in the language of the committee, start with a blank sheet of paper to think of all the things.

When they look at the hazards, they need to identify knock-off hazards or whatever you want to call them, like you were talking about, and it would seem appropriate to me that, in a document like this topical, the idea that the seismic, I'm sorry, the volcanic event could lead to a fire. You know, seismic events can also lead to fires. Those hazards should be enumerated and then examined more thoroughly later on. But if it's not here, in the end, the committee has a backup to say nobody looked at this. But we know, because you're using that standard, that, by the time we get an OL coming in here, that issue will be spelled out. So that's great.

MEMBER HALNON: Part of the problem is there will be a fire if there's lava flow. The distance and everything else you have to consider. But you don't really know what it is until you get the design of the plant to a point where you know if you're, you know, where the meteorological portions of the plant have to be figured out. So it's all in this Chapter 2 evaluation and assessment in order to comply with GDC 2.

So it's a little bit of cart before the horse to say and you have to go look at fire. Well, maybe there's other things you need to look at for sure. So you don't want to pre-condition somebody to not look at something. You're not really starting with a blank of sheet of paper if this early in the process you say here's some problems. I mean, there will be a fire. It's just a matter of -- and there will probably be some other consequences. The consequential failure could dam failures. You'd have to look at flooding, you have to look at other things that are consequential to this.

So I don't want to pre-condition all that LMP stuff in the license event blank sheet of paper saying that this has to be totally all-inclusive because then you'll pre-condition that thinking, in my mind. That's the way I'm --

DR. BLEY: Yes. I kind of think differently. I understand that point. I think all of this you can accumulate that people have built up. When you do your own look from a blank sheet of paper, you ought to then play it against everything else that was there. You shouldn't start with a list that says fire coming from volcanic. You ought to start by looking at the source and working out from there.

Then when you're done, you ought to go back and check all the other lists. And it's true that if you bias it ahead of time, somebody might not. In light water reactor PRAs, people think they've identified everything, so they don't look anymore than they need to.

CHAIR ROBERTS: Okay. I think we're out of questions. So just before I thank everybody, I'll go out for public comments, this is an opportunity for anything who has been listening here in the room or out on Teams or the phone line, any member of the public has a comment they'd like to make? Go ahead and unmute yourself, state your name and affiliation if appropriate, and your comment.

Okay. Hearing none, I'll speak for myself. I thought these presentations were excellent both from the applicant and from the staff, in terms of informing things. And this next step is to have a committee discussion. I wanted to observe the one thing that diehard is that there is definitely work underway to look at the Reg Guide 4.26 to factor in the experience from the TerraPower work and to reflect what seems to be a preferred approach, maybe not in all cases but a preferred approach to define a hazard first and then, at some point after that, other than maybe a little bit of qualitative work just to try to bound the problem, so to speak, at the beginning, then sometime, maybe years later, do the actual risk assessment and mitigations. And so that's something I know you're looking at in the reg guide, and maybe that's something that would be split out. And I'm sure we'll have that discussion in the next couple of years with the finalization of the Natrium CP just to see how it is you've dealt with the topical report, is it incorporated by reference, but you thought that was sufficient. And I'm sure we'll talk again as we get a little further along the Natrium process.

And so with that, my view is that there's really no reason for us to write an ACRS letter on this subject. I think a summary report would be just fine, a paragraph in the meeting minutes. I think what we heard is that the reg guide essentially works in a bifurcated way. There was no real technical issue with the hazard elicitation part of the reg guide and that a respite is still yet to be exercised. I kind of came in with that view, and I heard nothing that would change that view. I don't think there's any divergence on that view between us and the staff, and so I don't think a letter would do a whole lot of use, but I'm considering other comments.

Okay. Hearing none, it sounds like that's the path we'll take on this one.

MS. DEVLIN-GILL: This is Stephanie Devlin-Gill. Can I ask a clarifying question? Does that have implications on a full committee presentation or not?

CHAIR ROBERTS: Yes. The intent is I'll try to write something up tonight, and we can review it on Thursday.

MEMBER HALNON: There won't be a full committee presentation on it.

MS. DEVLIN-GILL: That's what I was asking. Thank you very much.

CHAIR ROBERTS: So, actually, a lot of the committee is here right now, but this subcommittee can't make that decision. We'll make a recommendation to the full committee that we not write a letter, that we put out a summary report and we put that in part of the monthly meeting. So we'll see how that goes with the full committee, but most of the full committee is here; it's probably a pretty good bet.

Any other comments, discussion? Very good. Once again, I want to thank the folks from TerraPower who traveled here. Someone made a comment this morning at least this discussion worked much better in person. We got to hear from experts.

I wanted to just acknowledge for the record, we ought to note that I didn't announce that Dennis Bley was here at the outset of the meeting, so I'll just get that on the record that Dennis has been here. And with that, we are adjourned.

(Whereupon, the above-entitled matter went off the record at 2:45 p.m.)

NRC Staff Review of the Topical Report "An Analysis of Potential Volcanic Hazards at the Proposed Natrium Site near Kemmerer, Wyoming," Revision 0A

July 9, 2024

Presentation to the ACRS Subcommittee

Jenise Thompson, Geologist

Stephanie Devlin-Gill, Senior Project Manager

Office of Nuclear Reactor Regulation

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

Agenda

- Review Chronology
- Topical Report (TR) Overview
- TR Review Strategy
- Safety Evaluation (SE) Overview
- Conclusions

Review Chronology

- July 12, 2022: Pre-Application Public Meeting (ML23030B893)
- April 25, 2023: Submittal of the TR "An Analysis of Potential Volcanic Hazards at the Proposed Natrium Site near Kemmerer, Wyoming" (ML23115A387)
- June 28, 2023: TR accepted for review by the NRC staff (ML23167B211)
- September - October 2023: Audit conducted (ML23338A047)
- February 28, 2024: Draft SE issued (ML24059A056)

NRC Staff Team

- Jenise Thompson, Geologist
- Jason White, Meteorologist
- Scott Stovall, Seismologist/Geophysicist
- Hanh Phan, Senior Reliability and Risk Analyst
- TerraPower Project Management Team
  - Roel Brusselmans, Project Manager
  - Stephanie Devlin-Gill, Senior Project Manager
  - Mallecia Sutton, Senior Project Manager

TR Overview

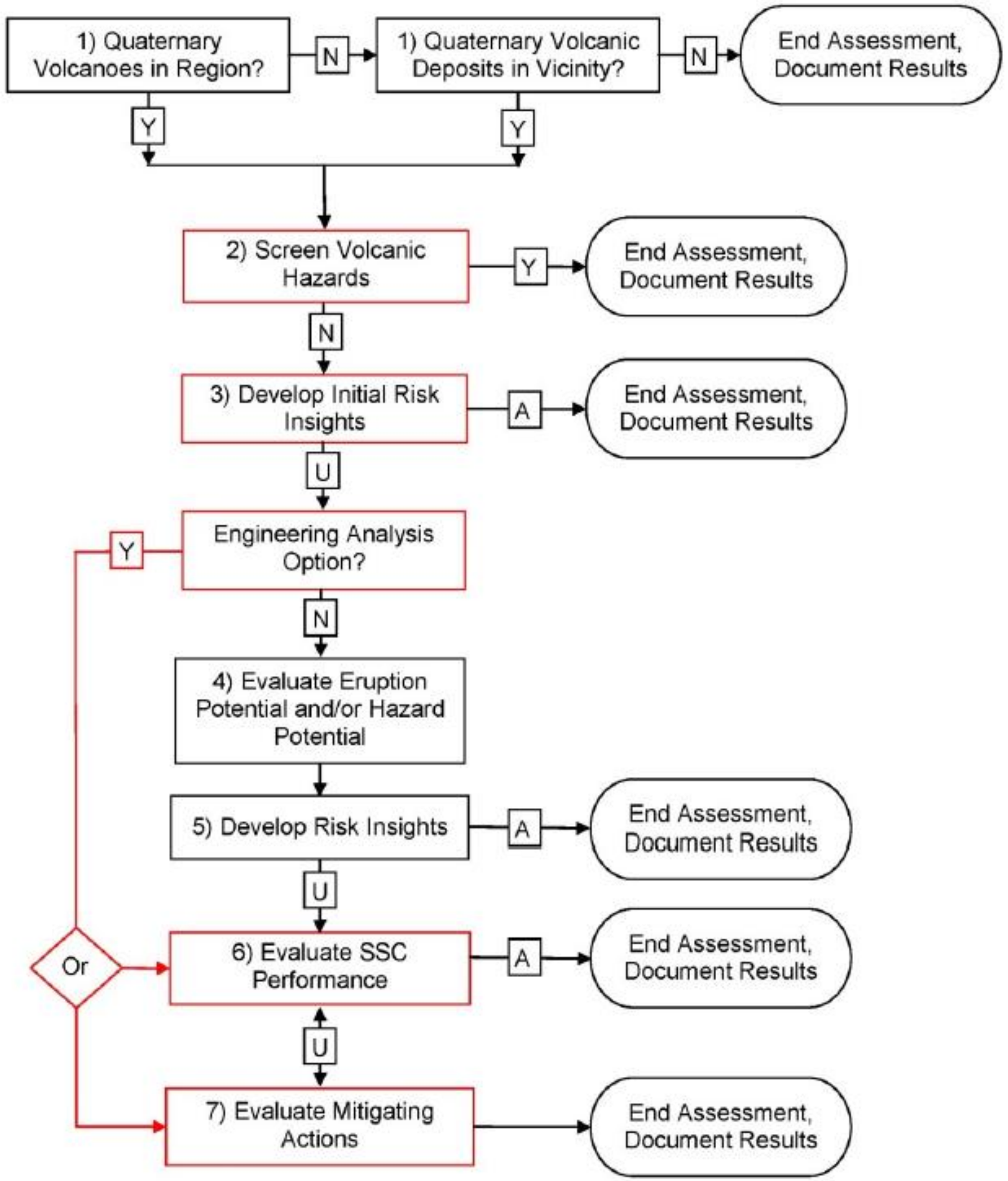
- An Analysis of Potential Volcanic Hazards at the Proposed Natrium Site near Kemmerer, Wyoming submitted in April 2023 followed the guidance in Regulatory Guide (RG) 4.26 in performing the assessment of potential volcanic hazards at the proposed site.
- Audit conducted from September 11 to October 19, 2023
  - Audit summary report issued on December 4, 2023.

Review Strategy – Regulatory Requirements

- Title 10 of the Code of Federal Regulations (10 CFR) Part 50, Appendix A, "General Design Criteria for Nuclear Power Plants," General Design Criterion (GDC) 2
- 10 CFR 100.23, "Reactor Site Criteria"

Review Strategy – Applicable NRC Guidance

- RG 4.26 Volcanic Hazards Assessment for New Nuclear Power Reactor Sites
  - Briefed to ACRS February 2020 and April 2021
  - Revision 0 issued June 2021 (ML20272A168)
  - Revision 1 administrative change August 2023 (ML23167A078)
- Endorses Senior Seismic Hazard Analysis Committee (SSHAC) process for expert elicitation, when warranted.
- Options to assess volcanic hazard or pursue engineering analysis based on maximum screened-in hazard



RG 4.26, Figure 3

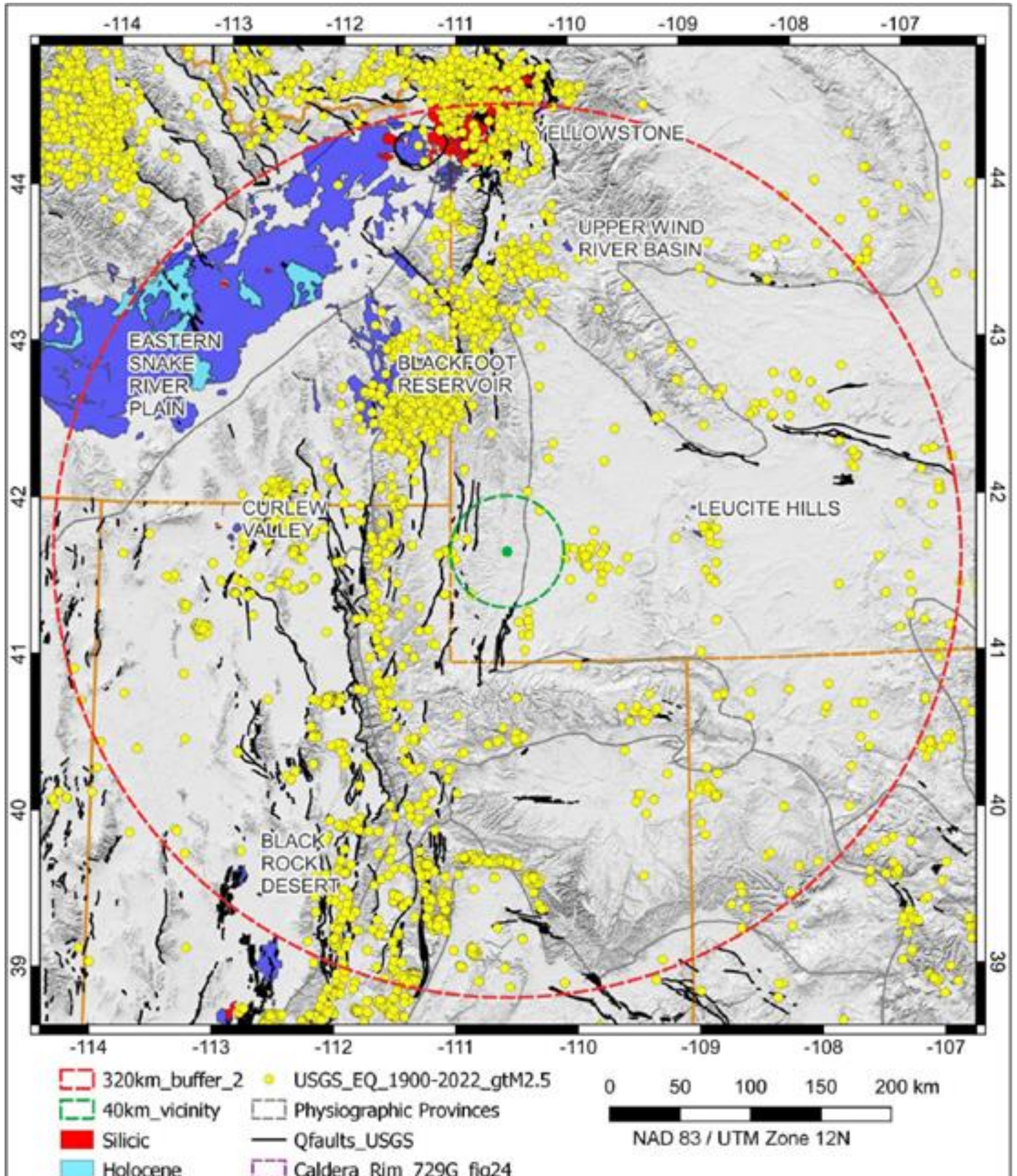
RG 4.26 Methodology in Topical Report

- Determine maximum magnitude for screened in volcanic hazards
- To be completed as part of Construction Permit (CP) review
  - Evaluate SSC performance and mitigating actions
  - Evaluate impact on probabilistic risk assessment (PRA)

Review Approach

As described in September 2023 ACRS presentation

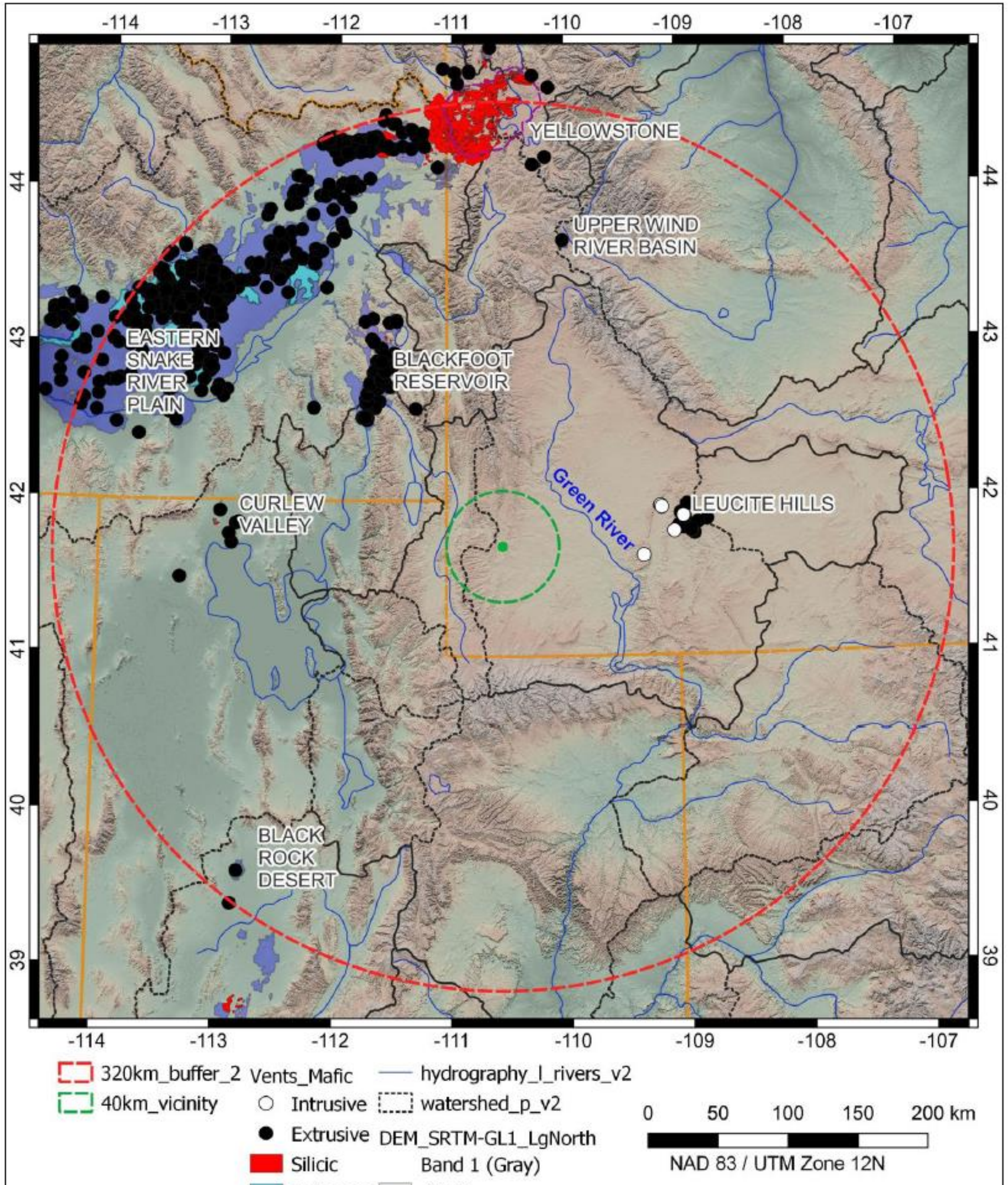
- Geologic History
- Site Characterization
- Tectonomagmatic model
- Numerical Modeling
- Outcome is acceptable maximum magnitude volcanic hazards for use in engineering analysis of SSC performance or mitigating actions review of the CP application.



Topical Report Figure 14

Site Geology and Regional Geologic History

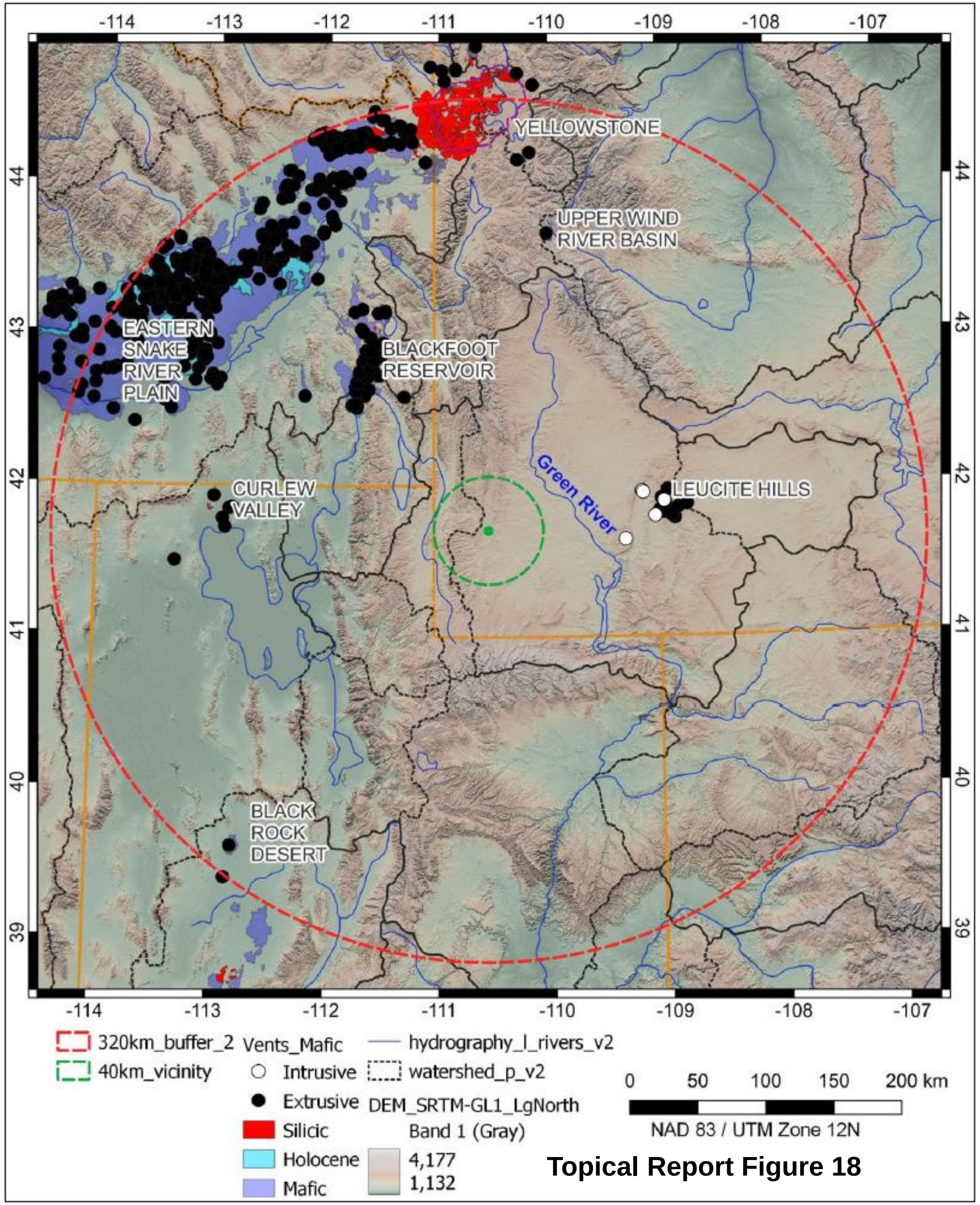
- Middle Rocky Mountain Physiographic Province
- Paleozoic and Mesozoic sedimentary rocks
  - Faulted and deformed by compression during Sevier Orogeny (50-150 Ma)
- No evidence of volcanic eruptions in the site vicinity in the last 150 Ma



Topical Report Figure 18

Site Characterization – Volcanic Sources

- Regional sources include:
  - Yellowstone Volcanic Field (YVF)
  - Upper Wind River Basin (UWRB) Volcanic Field
  - Eastern Snake River Plain (ESRP) Volcanic Field
  - Leucite Hills Volcanic Field (LHVF)
  - Curlew Valley Volcanic Field (CVVF)
  - Blackfoot Reservoir Volcanic Field (BRVF)
  - Northern Black Rock Desert Volcanic Field (screened out based on distance from site)



Topical Report Figure 18

Tectonomagmatic Model

- Volcanic sources from Yellowstone Hotspot track – Eastern Snake River Plain, Yellowstone, Upper Wind River Basin
  - Site is not located near the track of the hotspot
- Volcanic sources from Basin and Range Physiographic Province extension – Blackfoot Reservoir, Leucite Hills, Curlew Valley and North Black Rock Desert
  - Site is located within the Sevier Overthrust, characterized by compression, not extension.

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Hazards Screened Out

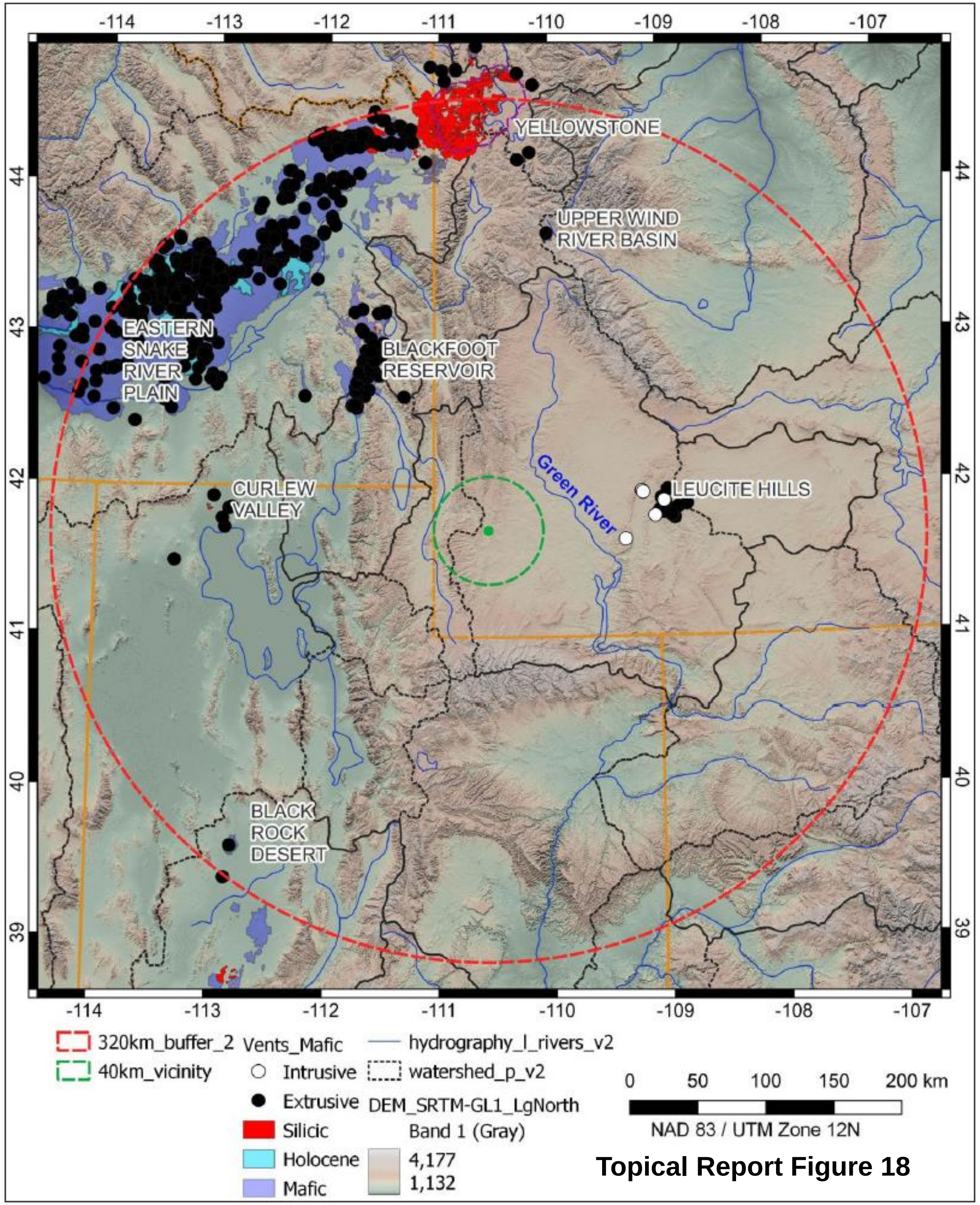
- Screened out based on distance to volcanic source and topography between the source and proposed site
  - Proximal hazards
  - Lava flows
  - Pyroclastic Density Flows
- Screened out based on absence of tephra deposits in the site vicinity (25 mi/40 km radius)
  - Tephra from sources outside the site region (200 mi/320 km radius)

Screening of Potential New Vent Opening

- New vent opening considered for the Leucite Hills Volcanic Field (greater than 100 km from site)
- The PVHA_YM code uses kernel density function to calculate vent density for points on a grid
  - Developed for Yucca Mountain, geographic coordinates transposed for use at Leucite Hills
- Screened out lava flow from potential new vent opening from further analysis

Hazards Screened In

- Tephra from sources within the site region
  - Analyzed both silicic and mafic sources separately
- Debris flow from remobilized tephra deposits on the North Fork of Little Muddy Creek.



Topical Report Figure 18

Sources of Tephra

- Silicic
  - Blackfoot Reservoir Volcanic Field, Eastern Snake River Plain, Curlew Valley Volcanic Field and the Yellowstone Volcanic Field
- Mafic
  - Upper Wind River Basin, Leucite Hills Volcanic Field, Blackfoot Reservoir Volcanic Field, and the Eastern Snake River Plain

Numerical Modeling of Tephra Hazards

- Applicant used the ASHPLUME2 code to analyze silicic and mafic tephra hazards
- Run intervals maximize realizations and adequately capture range of uncertainty
- Staff confirmed applicant results

Hazards for use in Engineering Analysis

Table 54. Combined mafic (Table 26) and silicic (Table 51) tephra-fall hazards from all potential volcanic sources in the proposed site region.

VolcanicField	Avg. Deposit (cm)	Avg. Prob. (/yr)	95%ile deposit (cm)	95%ile Prob. (/yr)	$5x10^{-7}$/yr deposit (cm)
LHVF - mafic	0.001	8.3E-09	0.063	9.10E-10	0.0
UWRB - mafic	0.010	9.0E-07	0.172	7.90E-08	0.038
BRVF - mafic	0.006	5.9E-07	2.106	6.00E-08	0.022
ESRP - mafic	0.019	2.1E-06	0.324	1.90E-07	0.210
BRVF - silicic	0.034	1.7E-07	0.94	1.6E-08	0.0
CVVF - silicic	0.019	1.5E-07	0.59	1.5E-08	0.0
ESRP - silicic	0.001	3.4E-07	0.21	3.2E-08	0.001
YVF VEI3-4 - silicic	0.005	1.1E-06	0.26	8.9E-08	0.06
YVF VEI4-5 - silicic	0.02	2.1E-07	11.9	1.7E-08	0.0
YVF VEI8 - silicic	84	<5.0E-07	113	<7.0E-08	84
Total	**84.12**	**<6.1E-06**	**129.6**	**<5.7E-07**	**84.3**

Limitations and Conditions

- The conclusions reached in this SE do not address the content provided in Section 10 of the TR. Thus, any licensee or applicant referencing this TR must, evaluate specific design, mitigation or monitoring actions required to mitigate the effects of volcanic hazards at the site, including any monitoring requirements for notification of impending volcanic events.
- The conclusions reached in this SE do not address the impacts of the calculated probabilities of volcanic hazard events on the cumulative plant risk. Thus, any licensee or applicant referencing this TR should evaluate the effect of volcanic hazards on the overall plant risk.

Conclusion

- The characteristics of volcanic hazards as described in the TR are appropriate to use as inputs to further engineering analysis of the potentially affected SSCs in the Natrium reactor design and for consideration in assessing the potential need for mitigating actions in the event of an impending volcanic hazard arriving at the proposed site.

Abbreviations

ACRS – Advisory Committee on Reactor Safeguards

BRVF – Blackfoot Reservoir Volcanic Field

CFR – *Code of Federal Regulations*

CP – Construction Permit

CVVF – Curlew Valley Volcanic Field

ESRP – Eastern Snake River Plain

GDC – General Design Criteria

km – Kilometers

LHVF – Leucite Hills Volcanic Field

L&C – Limitation and Condition

mi – Mile

Ma – Millions of years old

NRC – Nuclear Regulatory Commission

PRA – Probabilistic Risk Assessment

RG – Regulatory Guide

SSC – Structure, System, or Component

SE – Safety Evaluation

TR – Topical Report

UWRB – Upper Wind River Basin

VEI – Volcanic Explosivity Index

YVF – Yellowstone Volcanic Field

Volcanic Hazards Analysis

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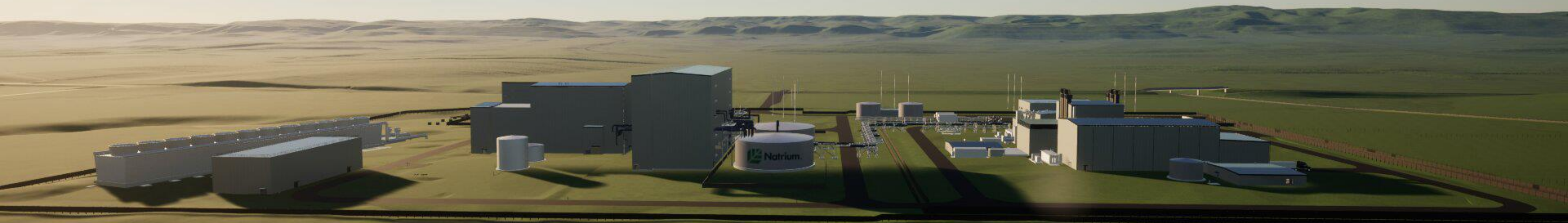


ACRS Subcommittee Meeting

July 2024

TerraPower

Natrium™

SUBJECT TO DOE COOPERATIVE AGREEMENT NO. DE-NE0009054

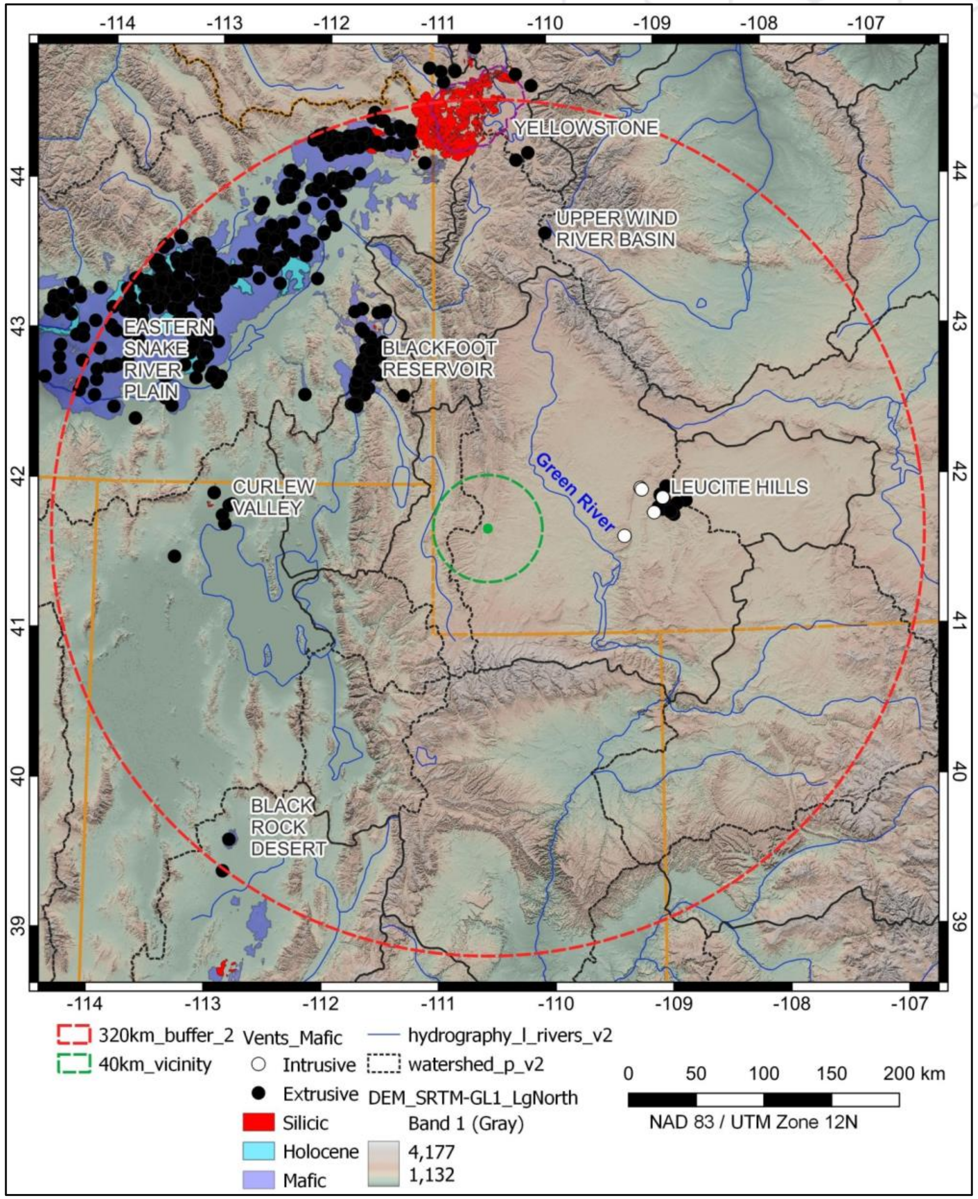
TP-LIC-PRSNT-0027

Objective

- Topical Report titled, “An Analysis of Potential Volcanic Hazards at the Proposed Natrium™ Site near Kemmerer, Wyoming” (ML23115A387)
- Approximately 575 volcanoes less than 2.6 million years old are located 100–320 km from the proposed Kemmerer Unit 1 site.
- A volcanic hazards assessment appears warranted for this proposed site using criteria in Regulatory Guide 4.26, “Volcanic Hazards Assessment for Proposed Nuclear Power Reactor Sites.”
- Goal is to quantify volcanic hazards probabilistically for potential use in subsequent analyses, as needed.
- Analyses follow guidance in RG 4.26.

VHA: Flow Hazards

- Distance (greater than 100 km) and topography isolate the site from potential flows from seven different volcanic fields in the site region.
  - Lava flows
  - Pyroclastic density currents
  - Debris flows
- Flow phenomena from greater than 100 km are screened from the volcanic hazards analysis.



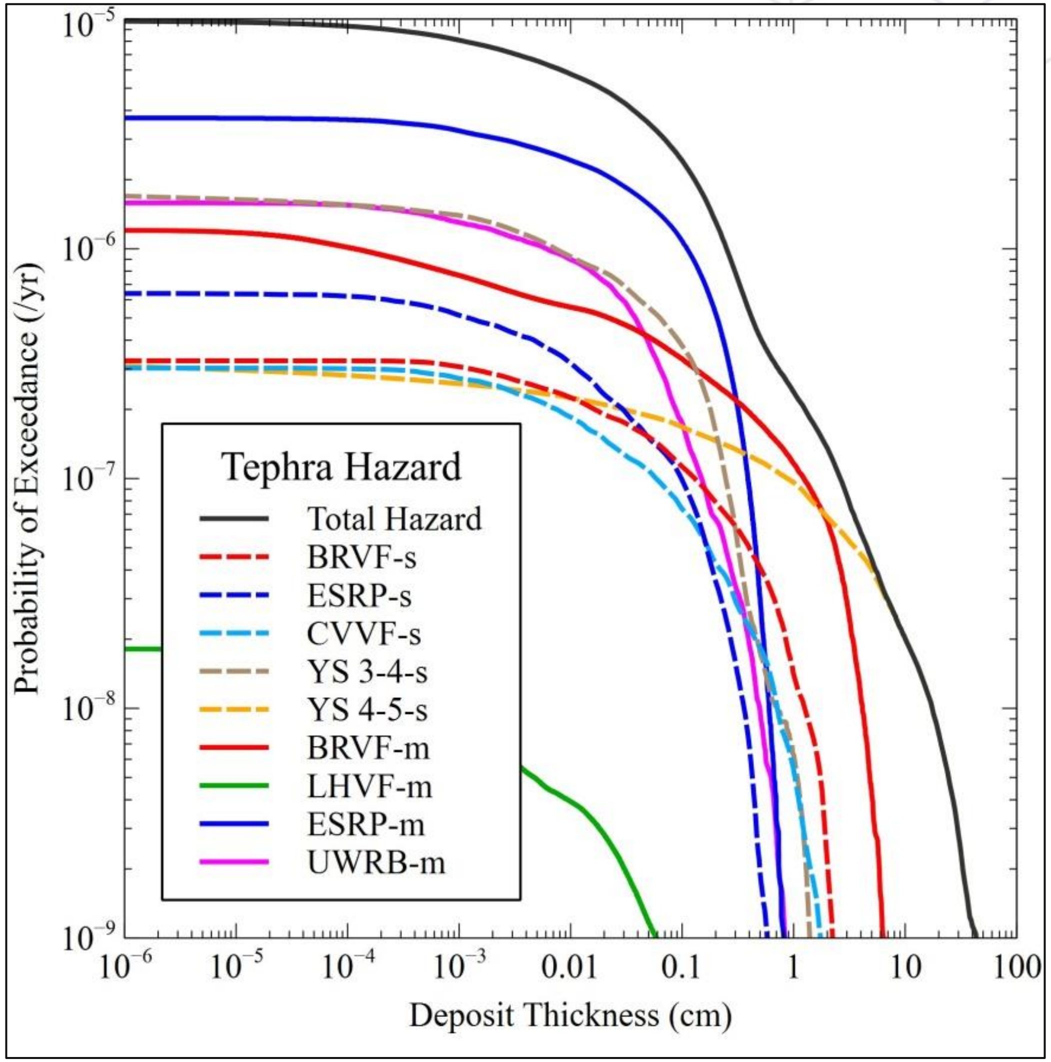
ML23115A387, Fig. 18

VHA: Tephra Fallout 1

- Evaluation approach for all eruptions except the Yellowstone “Supervolcano” eruption (greater than 100 km^3):
  - Develop eruption volumes for past eruptions in the seven different volcanic fields.
  - Evaluate recurrence rates of past eruptions for the seven volcanic fields.
  - Analyze ranges of tephra thicknesses at proposed site using an accepted advection-diffusion-sedimentation model.

VHA: Tephra Fallout 1

- Tephra fallout hazard curves at the proposed site from potential mafic (m) and silicic (s) eruptions.
- Tephra fallout is a less than 10^{-5}/year event.
- Average thickness of approximately 0.1 cm with a 6×10^{-6}/year probability of exceedance.
- 95th percentile thickness of approximately 17 cm with a 5×10^{-7}/year probability of exceedance.



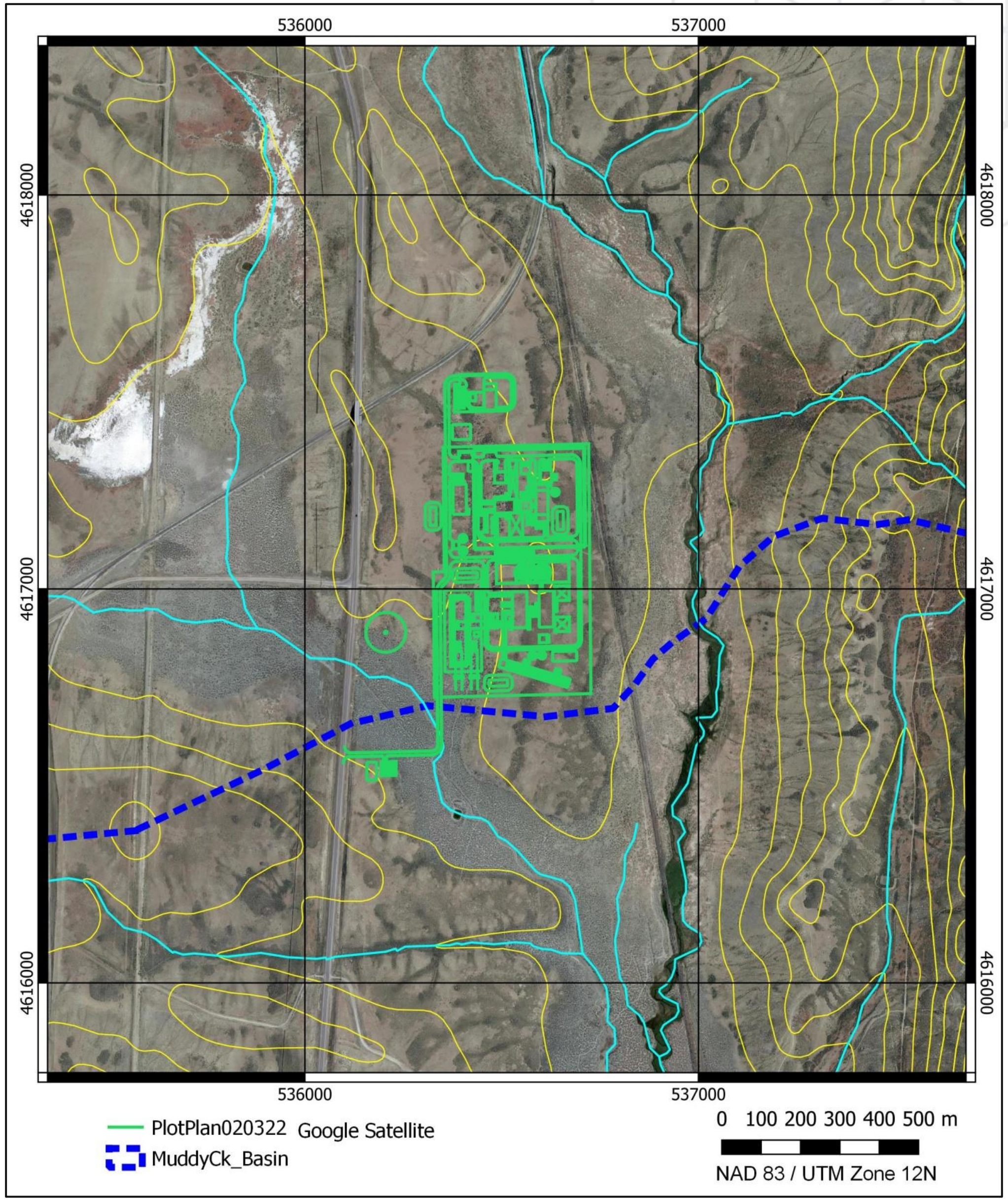
ML23115A387, Fig. 45

VHA: Tephra Fallout 2

- USGS estimated a less than 10^{-6}/year likelihood of a large volume (greater than 100 km^3) eruption from the Yellowstone "Supervolcano."
- USGS evaluated tephra fallout from Yellowstone "Supervolcano" eruptions using a complex tephra dispersal and sedimentation model.
  - Multiple eruption scenarios analyzed.
- Estimated average deposit thickness of approximately 84 cm with a less than 5×10^{-7}/year probability of exceedance.
- 95th percentile thickness of approximately 113 cm at less than 7×10^{-8}/year probability of exceedance.

VHA: Debris Flows

- Determine whether infrequent (0.5/year) floods could mobilize tephra and form debris flows that overtop channel banks in the North Fork of the Little Muddy Creek.
- Scour during peak discharge events can lead to small-volume debris flows.
- Existing channels can contain these potential debris flows.
  - Debris-flow hazard screened out.



ML23115A387, Fig. 44

Conclusions

- The only potential volcanic hazard at the proposed site is the deposition of tephra fallout from volcanic eruptions 100–320 km away.
- Tephra-fallout hazard from all volcanic sources has a 95th percentile thickness of 130 cm, which has a less than 5.7×10^{-7}/year probability of exceedance.
  - Most (85%) of this hazard is from a potential Yellowstone “Supervolcano” eruption.
- Potential debris flows from remobilized tephra deposits would be contained within existing stream channels and would not affect the proposed site.


Questions?

ACRS Interactions

- Meetings to Date
  - Design Overview Presentation
  - Regulatory Management of Natrium Nuclear Island and Energy Island Design Interfaces Topical Report
  - Principal Design Criteria for the Natrium Advanced Reactor Topical Report
  - TerraPower's Fuel and Control Assembly Qualification Topical Report
- Today – Volcanic Hazards Assessment Topical Report
- Topical Reports under NRC Review
  - TerraPower Natrium Plume Exposure Pathway Emergency Planning Zone Sizing Methodology Topical Report
  - Natrium HFE Program Plan and Methodologies Topical Report
  - Radiological Source Term Methodology Topical Report
  - DBA Methodology for In-Vessel Events without Radiological Release Topical Report
  - Radiological Release Consequences Methodology Topical Report
  - Natrium Stability Methodology Topical Report
  - Reactor Seismic Isolation System Qualification Topical Report
  - I&C Architecture and Design Basis Topical Report
  - DBA Methodology for Events with Radiological Release Topical Report
  - Partial Flow Blockage Methodology Topical Report
- Construction Permit Application submitted on March 28, 2024 and accepted May 21, 2024
  - ACRS interactions planned to begin November 2025 (ML24162A063)

Acronym List

ACRS – Advisory Committee on Reactor Safeguards
BRVF – Blackfoot Reservoir Volcanic Field
cm – centimeters
CVVF – Curlew Valley Volcanic Field
ESRP – Eastern Snake River Plain (volcanic field)
km – kilometers
LHVF – Leucite Hills Volcanic Field
m – mafic
RG – Regulatory Guide
s – silicic
UWRB – Upper Wind River Basin (volcanic field)
VHA – volcanic hazards analysis
YS – Yellowstone (volcanic field)