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UNITED STATES NUCLEAR REGULATORY COMMISSION'S
ADVISORY COMMITTEE ON NUCLEAR WASTE

AUGUST 28, 2001

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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129TH MEETING

ADVISORY COMMITTEE ON NUCLEAR WASTE

(ACNW)

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TUESDAY,

AUGUST 28, 2001

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ROCKVILLE, MARYLAND

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The Advisory Committee met at the Nuclear Regulatory Commission, Two White Flint North, Room T2B3, 11545 Rockville Pike, at 10:30 a.m., George M. Hornberger, Chairman, presiding.

PRESENT:

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| GEORGE M. HORNBERGER | Chairman |
| RAYMOND G. WYMER | Vice Chairman |
| B. JOHN GARRICK | Member |
| WILLIAM J. HINZE | Consultant |
| MILTON N. LEVENSON | Member |

ACRS/ACNW STAFF PRESENT:

JOHN T. LARKINS ACRS/ACNW Executive Director
SHER BAHADUR
LYNN DEERING
LATIF HAMDAN
CAROL A. HARRIS
HOWARD J. LARSON
RICHARD K. MAJOR
RICHARD P. SAVID
AMARJIT SINGH

# A-G-E-N-D-A

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

10:30 a.m.

CHAIRMAN HORNBERGER: The meeting will come to order. This is the first day of the 129th Meeting of the Advisory Committee on Nuclear Waste. My name is George Hornberger, Chairman of the ACNW. Other members of the Committee present are John Garrick, Milton Levenson, Raymond Wymer. And William Hinze, former member ACNW will be a consultant.

During today's meeting the Committee will discuss the following: Planning and Procedures, Status of Sufficiency Comments, DOE's Supplemental Science and Performance Analysis, Preparation of Reports.

John Larkins is the designated federal official for today's initial session.

This meeting is being conducted in accordance with the provisions of the Federal Advisory Committee Act.

We've received no written comments or requests for time to make oral statements from members of the public regarding today's sessions. Should anyone wish to address the Committee, please make your wishes known to one of the Committee staff.

It is requested that the speakers use one of the microphones, identify themselves and speak with sufficient clarity and volume so that they can be readily heard.

Before proceeding with the first agenda item, I would like to cover some brief items of current interest.

One, the President has forwarded the name of former Commissioner Diaz to the Senate for confirmation.

The NRC Commissioners has approved a solicitation seeking a fifth member for the Advisory Committee on Nuclear Waste, ACNW. This would allow the Committee to cover the projected increase in workload associated with Yucca Mountain review activities and with expertise in health physics, consequence modeling would allow the ANCW to cover technical issues of significance and performance assessment more thoroughly.

The NRC has appointed Stephen L. Rosen to the Advisory Committee on Reactor Safeguards. Rosen has been more than 30 years experience in nuclear power plant industry. Last February he retired from the South Texas Project, where he was Vice President of Nuclear Engineering and Manager of Risk Management. Previously he had held management positions with the

Institute of Nuclear Power Operations, including Vice President of Analysis and Engineering.

The ACRS/ACNW staff will be attending a day and a half retreat September 19th to the 21st at Hunt Valley Maryland. The theme of the retreat is How to Improve Efficiency and Service to the Committees As Well As Each Other.

South Carolina has issued an RFP to conduct an evaluation of the adequacy of the extended care fund for institutional control of the low-level radioactive waste disposal facility in Barnwell County, South Carolina. In particular, the contractor is expected to analyze the target amount of funds needed to conduct extended care activities at the facility and to make recommendations on related issues. Under the terms of the RFP, a final report is due by November 14, 2001 with follow-up presentations scheduled through June 30, 2002.

The Texas legislature adjourned without passing any of the bills which had been introduced relating to the management and disposal of low-level radioactive waste. Absent special circumstances, the new legislature will not be reconvened until January, 2003.

The Nuclear Energy Institute is assisting the U.S. Nuclear Regulatory Commission on developing a list of frequently asked questions and responses related to site decommissioning and license termination. The project is intended to allow licensees to share experiences on issues that commonly arise during decommissioning and license termination.

The Skull Valley Band of Goshute Indians and Private Fuel Storage, Limited Liability Company, a coalition of nuclear utilities seeking to site a spent fuel facility on the Goshute Reservation filed suit against officials of the state of Utah. The action, which was filed in the U.S. District Court for Salt Lake City, complains that six recently enacted state laws erect unfair and unconstitutional barriers to the plaintiff's facility sitting plans. In particular, the suit alleges that the laws unlawfully interfere with interstate commerce and infringe upon exclusive federal authority over the regulation of Indian affairs and nuclear power.

And, finally, the pending site stabilization and closure plan for the U.S. Ecology Washington State LLW disposal facility calls for all trenches to be closed in the year 2056.

What we're going to do now in proceed directly to the status of the sufficiency review.

Jeff Ciocco is going to do the presentation.

Jeff, I will apologize in advance. We had a meeting scheduled with Commissioner Merrifield and John Garrick and I are going to stand up and leave during your presentation. My apologies. It's not because we're not interested, but an unavoidable conflict in scheduling.

DR. GARRICK: You know how interested we are in the sufficiency.

MR. CIOCCO: Yes, sir. All right.

Thank you, Dr. Hornberger. My name is Jeff Ciocco. I'm the project manager responsible for the process for developing the potential preliminary comments from the NRC on the sufficiency of the Department of Energy's information.

The objective of this presentation is to provide an understanding of the process used in preparing the NRC's preliminary comments and where we are today. And I use the word "potential comments," because these are still draft comments. The staff has not finalized our comments. We're still reviewing one of the primary documents that could be used in the site recommendation, and that's the supplement science and performance analysis report. So you will see me use potential in draft throughout the presentation today.

The outline of the presentation: I'm going to present to you the completion schedule for the comments; describe what the NRC is required to do; how the NRC is preparing our comments; what the basis for our potential comments are; the path forward to produce our comments; give you a brief comparison between what the NRC commented on in its Viability Assessment comments back in June of 1999 to what the current status is through the issue resolution process.

The completion schedule for our preliminary comments are August 28th presenting today to the ACNW.

We have an important Igneous Activity Technical Exchange in Las Vegas on September 5th. And this is really the fourth, if you will, fourth technical exchange within a year for igneous activity. They met in August of 2000 for technical exchange, they had one in May of this year, which was on Appendix VII, in August this year they had another technical exchange and they're meeting again on September 5th.

September 6th and 7th we have a Quality Assurance Management Meeting in Las Vegas.

September 13th and 14th in Las Vegas we have a Range of Thermal Operating Modes Technical Exchange. And this is really the second for this particular topic. We had a technical exchange on August 2nd, which was more or less an information exchange where DOE presented to us their supplemental science and performance analysis report, which is the main subject of this exchange.

September 14th is when the actual Concurrence Process for our preliminary comments will begin.

And our comments are due to the Department of Energy on November 1st at the request of DOE.

What we are required to do. First, in order to determine on how we're going to write our comments, we had to read the Act and we had to read the Nuclear Waste Policy Act, Section 114, which is site approval and construction authorization, which says "Together with any recommendation of a site under this paragraph, the Secretary shall make available to the public, and submit to the President, a comprehensive statement of the basis of such recommendation, including the following."

This particular statement is one of eight pieces of information that the Secretary would have to include if he does a site recommendation. This is E, and I believe there's A through H in the Act. "The NRC is required to provide preliminary comments of the Commission concerning the extent to which the at-depth site characterization...and the waste form proposals for such site seem to be sufficient for inclusion in any application to be submitted by the Secretary for licensing of such site as a repository."

So this 50 word independent clause is the scope that we had to interpret to write our sufficiency comments. And these areas that are underlined are very significant that I'm going to explain in a little more detail as we interpreted the Act.

What does preliminary comments mean? It's important -- it's very important to understand that preliminary comments, it does contrast that preliminary comments from a potential final decision made on the adequacy of DOE's information in a possible license application if there is one. It means there's no prejudgment of any matters which can only be decided in a construction authorization decision. This is not a licensing review. This is just a preliminary review of data. It means that the preliminary comments do not become final. These aren't final at any point along the line, even though they're called preliminary.

Interpretation of at-depth site characterization analysis. It means evaluating the futures events and processes below the ground surface. This is really characterization of the geosphere. It's the activities involved in that characterization that could be below ground, at the ground surface or even up in the air, some kind of geophysical survey.

Continuing on with the interpretation of the Act, as far as waste form proposal goes, it means the design, selection and evaluation of the components of the engineered barrier system. These are the components include the waste form, the waste package, cladding, drip shield and the drifts.

How do we interpret seems to be sufficient for inclusion in any license application? It means that the data and the approach are appropriate. It means we accept that there are DOE plans and schedules to collect added information. It means there will be enough acceptable information for inclusion in a potential license application if there was one. It means we could conduct a safety evaluation of the potential application with this information, with sufficient information for their review.

It also includes DOE's consideration of a quality assurance program because we need to look at the implementation of the quality assurance program and is the quality of the information sufficient for license application.

Okay. How we're preparing our comments. We're using the high-level waste safety evaluation process. I think you probably heard before, it's the issue resolution process is the key tenet of our high-level waste process. This process utilizes:

Performance assessment analyses, both ours and the Department of Energy's.

Preclosure safety analyses, which is really in the early states of issue resolution, we had our first technical exchange this summer. It uses the issue resolution status report, which have been updated which have evolved into a more risk informed performance based documents.

We have independent investigations here and at the center in San Antonio which look to confirm DOE analysis.

And we have public technical exchanges with the DOE. And this is very important, was the public technical exchanges, which is really our main principle of good regulation. It's very open.

Everybody is aware of the process.

The issue resolution process was the basis in June of 1999 for our viability assessment comments as well as these preliminary comments.

What is the subject matter of our potential preliminary comments? First off, I want to say what our comments aren't. We're not evaluating the performance of the site. So, this is a subset of everything that could be included in the potential application based on the proposed Part 63.21 what would be included the license application.

We're constricted to what is in the scope of the NWPA, which I showed earlier.

And in the area of preclosure, which is the repository safety before permanent closure, we evaluated the waste form characterization. For example, burn-up levels of fuel. We looked at the waste package design; thermal design, welding flaws and design drop height. We looked at subsurface design and design analyses. We did not look at surficial designs. We did not look at event sequences and consequences; that's not part of the scope. We did look at the natural and physical processes which would help identify the hazards and the initiating events. And really these helped form your design basis for the project.

And postclosure, we looked at areas of the multiple barriers, the identification and description of barriers. We looked at scenario analysis; is there a sufficient range of features, events and processes. We looked at 10 of the 14 model abstractions to see if there was sufficient data and analysis or plans.

When I say 10 of the 14, there's four that are not within the scope of what the Act requires. For instance, climate and infiltration was not a below ground condition. We didn't look at the biosphere in the critical group. We didn't look at distribution of radio nuclides in the soil at the receptor location. That wasn't part of what we considered within the scope of the Act. And we didn't look at the overall performance or compliance with the public health and environmental standards.

We did look at quality assurance. How the DOE is implementing it QA program and what is the quality of the data. And we looked at expert elicitation because occasionally DOE uses expert judgment in place of unavailable information. So we thought this was important to look at at that data which essentially becomes data in the models. And I'll also point under the model abstractions, we're not looking at the output of the models. We're looking at the input into the models, not the consequences and not the overall system.

Now this is slide 10 in your viewgraphs. I've split this up into slide 10 and 11 to make it a little more visible here. So these are the top three bullets on your slide 10.

This is how we are preparing our potential comments. We're applying the prelicensing issue resolution result to our comments. So, there's no surprises in what's going to come out in our sufficiency comments, because they follow closely to what's in the issue resolution process. Our potential comments build on the continuing prelicensing activities.

The issue resolution technical exchange agreements, close to 300 now, are the basis for the preclosure and postclosure draft comments.

The issue resolution status corresponds to the defined comments, draft comments.

This is what you have on the bottom of page 10. This is how we're preparing our potential sufficiency comments. And this is the correlation between what you see in issue resolution and what we're proposing for our preliminary comments.

On the left side, closed, no additional information needed. Close-pending, which correlates over here in our potential preliminary comments to areas that appear to have sufficient information and areas for which DOE has agreed to obtain additional needed information. And there's a line draw across from the upper half and the lower five.

Then we have the open areas where the DOE has not addressed questions or agreed to provide information for licensing decision. That would correlate to an area that appears to need more information in a preliminary comment.

So now the basis for our comments is the issue resolution process. So I'm going to use this as the context for our preliminary comments.

The goal of the issue resolution process is to resolve the postclosure and preclosure performance issues prior to any possible submission of a license application.

The issue resolution at the staff level is reached when: DOE's approach and available information adequately addresses the staff questions, and; no information beyond what is currently available will likely be required for regulatory decision making at the time of any future license application if there is one. Once again, this is the basis for the preliminary comments.

The approach to risk-informing the issue resolution process. Before we go into these technical exchanges, we have all the key technical issues that are reviewing the AMRs and the PMRs, the DOE, the total system performance assessment for site recommendation.

There was risk insights gained from the performance assessment, that DOE and the NRC's. There's repository safety strategy that provide the basis for the areas discussed at the issue resolution technical exchanges.

The agreements reached during the technical exchanges form the basis for the path forward and represent those items determined by both the DOE and the staff analyses as important to repository performance, safety and waste isolation.

One example here is scenario analysis of risk-informing. And this is also a condition in the proposed rule where scenario analysis is designed to focus on those features, events and processes most important to performance where we're screening on the grounds of either low probability risk or low consequence as a way to risk-inform the process.

I mean, there is some caution here in risk-informing the process in that, you know, as my systems analysts point out that you have to be careful in what level you capture the risk insights. Because at a lower -- if you don't look at the synergism of the entire system, you may eliminate something at a lower level where it may be more important at an upper level. So, we really integrate with our performance assessment folks with our system analysts to see what is really important.

Here's the results of the issue resolution, which are the basis for our comments. Staff and DOE conducted several public meetings over the past year and even prior year, perhaps, on issue resolution. As of August this year, the consequence of Igneous Activity is currently open. there's a technical exchange on September 5th.

The implementation of the DOE's Quality Assurance Program is undergoing enhanced review and evaluation.

And finally, the NRC is currently reviewing the Supplemental Science and Performance Analyses report to determine if there are any impacts to issue resolution.

Additional meetings are scheduled in

September to discuss Igneous Activity September 5th, the Range of Thermal Operating Modes September 13th and 14th, and Quality Assurance there's a meeting on September 6th and 7th to address those issues. So this is really the basis for our draft comments at this time.

I'll get into a little bit more detail for two of the areas, for the Igneous Activity as well as Quality Assurance, which this is an open area.

Probability of the Igneous Activity -- Igneous Activity is broken into the consequence and the probability. For probability, which is closed-pending, DOE agrees to provide a single point sensitivity analysis using a probability value of $10^{-7}$ per year.

Doe agrees to perform an analysis of the new aeromagnetic data to decide the presence of more buried or possibly buried igneous bodies within the site area.

Now, the consequence of Igneous Activity, it is what is current open. NRC expects DOE to provide plans to address the consequence of these activities of the Igneous Activity at the September 5th technical exchange. This is what DOE needs to do.

DOE needs more information to support

assumptions for their magma interactions with the repository, with the waste package and with the waste form.

Currently DOE only evaluates a limited set of physical processes that occur during the basaltic igneous events. DOE needs to consider more directly the physical processes for the interaction between the magma and the repository drifts, the engineered barriers, and the waste forms. Specifically, the number of drifts that would be affected by the magma and the waste packages and the waste forms affected by the magma. So that's where we are currently with the Igneous Activity.

Now we'll get into the area of Quality Assurance. DOE is preparing a corrective actions plan to address the quality assurance problems identified below, which I'll explain. NRC will evaluate the acceptability of DOE's approach for its corrective actions plan at the meeting scheduled on September 6th.

These are problem areas that have been newly identified in this calendar year. The first area, and there's three of them, the first is model validation. DOE found inadequate model validation supporting reports, such as the performance assessment. Prior corrective actions have not been effective and DOE issued a corrective actions report for failure to follow the applicable procedures.

The second area is technical inconsistencies. NRC identified inconsistencies between the performance assessment for site recommendation and model reports, computer codes and hand calculations as we were doing our review of those documents.

And a third area of concern this calendar year are software controls where DOE issues a corrective actions report for the software controls in June of this year. There's currently follow-up actions underway by the DOE.

And there's also issues that the status issues prior to 2001, which from 1998, 1999 quality assurance. In those areas, which are in the areas of data and software qualification, DOE has completed all corrective actions except for confirming the adequacy of data and software qualifications. And I think they're in the 80 to 90 percent area of qualifying all of their data and software needed to support a possible site recommendation.

And those are the follow-up actions underway in this area where DOE is going through and qualifying this data.

Now, this is a comparison of the viability assessment comments, which were issued in June of 1999 to the current issue resolution status.

The viability assessment comments of June of 1999 identified the following area which needed more information for inclusion in the potential high quality license application. So back then we had repository design, waste package corrosion, quantity and chemistry of water contacting the waste packages, saturated zone flow and transport, volcanic disruption of waste packages, and quality assurance.

So jump ahead currently in the year 2001, like you saw on a prior slide, these are areas that remain open: The consequences of the Igneous Activity, we have some issues with the implementation of the DOE quality assurance program which is currently enhanced review and evaluation, and the ongoing NRC review of the Supplemental Science and Performance Analyses report. So we don't have the results yet of this, which could impact issue resolution.

And what you don't see in this column, which should probably be here, is we now have agreements in place to address a lot of these areas.

Like, for example, I believe this was considered needing more information because there wasn't any characterization of the site at 20 kilometers at that time, and we felt that there was not enough information along the potential flow path. Well, now we have agreements in those areas.

So this is just a quick kind of show between the two.

What's the path forward. We need to finish reviewing the Supplemental Science and Performance Analyses Report. We've been sending DOE comments over the past couple of days on this report in preparation for the September 13th technical exchange.

We're going to conduct a limited review of the preliminary site suitability evaluation. As you may know, this is DOE's evaluation of the performance of the site against the site suitability guidelines. That's not within the scope of the NRC's review according to the Act. However, we will examine this document to see if there's any new information, any data presented which would fall within our scope.

We're going to conduct the Igneous Activity and the Range of Thermal Operating Modes technical exchanges and the Quality Assurance management meeting.

We need to finalize our draft preliminary comments and deliver those comments to the DOE by November 1st of this year.

In summary, we still have a lot of work to do in reviewing DOE's reports and conducting the technical exchanges and the other meetings. The SSPA is, I don't know, it's about 6 inches thick, probably 1500 pages. So staff has been working on that a lot the past couple of weeks.

And in summary, we are on schedule to deliver our potential preliminary comments to the Commission and to the Department of Energy.

CHAIRMAN HORNBERGER: Thank you very much, Jeff.

MR. CIOCCO: You're welcome.

CHAIRMAN HORNBERGER: Ray is going to take over.

MR. CIOCCO: Okay.

VICE CHAIRMAN WYMER:

MR. CIOCCO: Yes, sir. That concludes the presentation.

VICE CHAIRMAN WYMER: Okay. Milt, you got any questions or comments?

I had a couple of things. One is you say that the NRC is reviewing the Supplemental Science Performance Analysis to determine if there are impacts to its resolution. Have you come up with anything there yet that you would comment on?

MR. CIOCCO: We have a lot of comments right now, and one of the prevailing comments that comes up in several different areas is the repository footprint is the impacts from the modeling remains on the repository footprint and, you know, how are those going to be captured.

There was a question about the criticality issue if we now have waste package failure prior to 10,000 years, whereas in prior it had been screened out as a FEP, which didn't occur before 10,000 years.

Those are two that really stand out for me now. If anybody else wants to add anything else. But we're still really in the review process now.

VICE CHAIRMAN WYMER: What is your position or what is your position going to be, or do you have one on the degree of realism that DOE has in its performance assessment? That is, as compared to being conservative. You know, how far should they go? How far do you think they should go with respect to really modeling in a more realistic way what's going on? There are so many uncertainties left. You comment on that.

MR. CIOCCO: You mean as far as their supplemental work and supplemental signs of performance analysis?

VICE CHAIRMAN WYMER: Yes.

MR. CIOCCO: I'd like to get one of our performance assessment people. Might be able to help out here. Dave, or Tim, or somebody might --

VICE CHAIRMAN WYMER: The always fall back position, Tim McCartin.

MR. McCARTIN: Tim McCartin, NRC.

Well, from the regulatory standpoint, the rule does not require DOE to do a realistic analysis. They have to support what they've done and there are areas where they could elect to take a conservative approach because of the uncertainties are too great and the cost of collecting data, they would prefer to go to a conservative analysis. Other than that, I don't think there's anything in the NRC approach in our agreements where we force DOE to collect more information just for realism's sake. It's just here's your approach. We either agree or disagree with the information they have supports their approach, be it in some areas they tend to be more realistic, in other areas they tend to take a conservative approach.

VICE CHAIRMAN WYMER: And I guess you'd make a similar comment about the transparency of the analysis, how easy it is to understand?

MR. McCARTIN: Well, certainly transparency goes across the board that neither realism or conservatism drives you to transparency. We need to understand what's being done and the technical basis supporting the approach, be it realistic or conservative, certainly.

VICE CHAIRMAN WYMER: Since there's no formal requirement for it, you wouldn't demand it?

MR. McCARTIN: Would demand transparency?

VICE CHAIRMAN WYMER: Yes.

MR. McCARTIN: I think in terms of the rule we tend to put in requirements that we believe would promote transparency. Such as they have to give a basis -- a technical basis for all the FEPs they considered, why they've included some, why they haven't included some. They have to talk about an alternative models, uncertainties, etcetera. All the requirements are there that we think are necessary to have us understand the basis for what they've done.

Now, going beyond that in terms of the word actually transparency or traceability, or words you hear, you won't see those words in the rule. In the review plan you'll see there is additional guidance that in terms of information we would be expecting to see that would promote for a transparency and traceability. But I think if you look at all the things that are required of the performance assessment, etcetera, that I think if they provide a high quality documentation of all those areas, it should be transparent. But there's no -- in rule space you won't see the word transparent. You really can't put a "what does that mean" in terms of a requirement other than, like I said, you'll see more details on what we're expecting in a review plan.

VICE CHAIRMAN WYMER: Yes. Maybe one of the aspects of transparency is understandability by the public, and there's no requirement for that.

MR. McCARTIN: Well, it is a very difficult problem.

VICE CHAIRMAN WYMER: It is.

MR. McCARTIN: What we are requiring and what makes sense is we have to be able to review it. We have to understand all the DOE's analyses. But I'm the first to admit that I've been doing performance assessment for 20 years. When I read the DOE documents, they're not easy documents to read, and that's not because the text isn't good, that's not because necessarily things are traceable. It's a hard problem. There are a lot of different connections between all of this. You have to really sit down and think and -- we get 3 three years to review the license application. If it was real easy, maybe we could do it a lot quicker. But it's a -- it's a hard problem.

VICE CHAIRMAN WYMER: Yes.

MR. McCARTIN: And I sympathize trying to document it for the public would be, for the general public would be an extremely difficult thing to do. I think in that regard the DOE has tried to provide some summary documentation that does away with a lot of the technical details that we want to see. We want to get into the nuts and bolts of the entire calculations. So our review is more directed towards making sure all the truly technical aspects of what they've done are there for us to review.

I think the Department has provided some of the summary documents that tend to be more readable for the general public. But it's a hard problem.

It's only the two kinds of documents and our requirements are really directed towards the information we have to have to review.

VICE CHAIRMAN WYMER: Yes. I realize

that.

Thanks, Tim.

DR. LEVENSON: I'd like to follow-up a little bit, Tim, with as you know, this word conservatism bothers me always. If something is a best estimate, then in reviewing it from a regulatory or a safety standpoint you can say "Okay, that's the best estimate. Now because of uncertainty we're going to add a safety factor 2 or 5 or 10, and somebody in a responsible position estimates how big a safety factor is adequate."

When something is just covered under a layer of snow that says conservative, and you have no idea of knowing whether the safety factor is 2, 5, 10 or 1,000, how do you really handle that? Because if you don't have a best estimate, you have no idea how conservative is what is called conservative.

MR. McCARTIN: Certainly, yes. The layer of snow is what I think our review process is trying to melt away.

Once again, I mean there's no requirement to be conservative. What DOE has to do is put forward analyses that they can defend. And I think they have to clearly articulate we use this range of perimeters, this particular model, here is our basis and our rational for believing it is a reasonable approach.

The tests that the Commission uses typically has been reasonable assurance. As you know, the EPA standard puts a test of reasonable expectations, somewhat of a similar thing. We aren't expecting a realistic approach in every area. There's some areas, like I said, I mean it just makes more sense to we're not sure but we think this is conservative.

The DOE has tried to talk to where they believe they have conservatisms. I don't think there's any desire on our part to try to put a number on what an appropriate safety margin is or anything like that. We need to understand what the basis is for the particular approach.

In terms of a best estimate, that's where, you know, I think generally a range of values is more appropriate than a single point estimate where you'd have to defend exactly how selecting that value, what it does to the analysis. But I think we have the rule purposely allows DOE flexibility to determine what a reasonable approach for them is. And the burden is on DOE to explain why a particular approach and what their technical support is. Does that --

DR. LEVENSON: Would you expect them to

support something that's called conservative by an estimate of how conservative? Otherwise -- you know, in the context of for safety we never accept best estimates, whether it's your home hot water heater, or whatever. There's safety margins added. And you design an aircraft the safety margin is much smaller than designing a bridge. Each thing has its own safety margin.

MR. McCARTIN: Sure.

DR. LEVENSON: I'm hung up just because somebody calls something conservative, I don't know if it's conservative by 10 percent or 3 orders of magnitude. And I don't know, if I were making a decision, if I don't have some kind of best estimate underlying it, I don't know how I --

MR. McCARTIN: Sure. And it's one man conservatism is another man's realism. I mean, there's no strict definition of what is conservative.

Once again, I think the Department can explain what they've done and why. And it probably is best left to the reader to interrupt whether they believe that's conservative or not.

DR. LEVENSON: Well, the words you used is exactly what's bothered me, in that there's no -- not only is there no definition of conservatism, but if you go in and look in detail at specific numbers or pieces of models, you find there's absolutely no consistency in how much overestimate is there, which is one of the things that makes me kind of nervous about accepting a general definition of conservative.

If one person adds 50 percent, and another person adds two orders of magnitude, and I know that from a couple of specific pieces I've looked at, how do I evaluate the rest of it?

MR. McCARTIN: Right. Yes. I agree. The word conservative can mean varied things to varied people, and that's why I think our review will focus on more what they've done and the technical basis for it, whether they call it conservative or reasonable really doesn't factor into our review as much as what have they supported.

Now, part of the conservative aspect that they might look at would be they could look at the sensitivity analyses and where the results, the final results go depending on where certain perimeter values lie.

DR. LEVENSON: Yes, but recently involved in a completely different venue in the ICRP screening for dose on radioactive isotopes, and it turns out it probably is kind of useless because since they used similar problem -- they used various levels of conservatism, when you go through and do the analysis, the isotopes which pop out as the ones you should address, in fact, aren't the most important ones of all because just somebody happened to stick a bigger conservatism on the results of that isotope. I think that's one of the things that also concerns me is that using nonconsistent conservatisms means a sensitivity analysis resulting from it probably has very little value.

MR. McCARTIN: Well, certainly in an analysis like is being proposed for Yucca Mountain, there a lot of models, a lot of perimeters and there certainly is a range of uncertainties in the overall assessment.

I don't know if there is -- how you could even try to get a consistent level across the board because of the nature of some of the problems, be it igneous activity down to corrosion of the waste package, groundwater flow, etcetera. There's just such a variety.

I think the bottom line is DOE needs to really clearly identify what they've done and why, and we can evaluate that. And it isn't so much -- I mean, the emphasis is we're trying to make a decision whether public health and safety is protected. And so there is this allowance for conservative approaches in certain areas.

We could say that health and safety is protected, whether this is the most realistic calculation or not is not necessarily at the bottom line of the ultimate Commission decision.

DR. LEVENSON: Yes. But the health and safety is a much broader system problem because if my sticking conservatisms into the modeling you require 10 times as much fuel handling on the front end prior to casks being loaded, you significant impact public health and safety in the wrong direction, because you'd use conservative calculations somewhere else.

MR. McCARTIN: Certainly, yes. I mean, there are certain approaches that if you did, maybe the worker doses increased at the -- to the benefit of future populations and vice versa. However, I will stress there is nothing in our regulation that requires DOE to do a conservative calculation. If they feel it's warranted to do a more realistic calculation in certain areas, they certainly are free to do that.

VICE CHAIRMAN WYMER: You have to wonder to what extent the whole business is risk-informed.

It's risk related, but I'm not sure how informed it is.

MR. McCARTIN: Because of some areas may be conservative and other areas more realistic?

VICE CHAIRMAN WYMER: Yes. Yes.

MR. McCARTIN: Well, you can still do analyses in an area where you're conservative. You may do analysis, well, let's say what if the infiltration rate really -- the deep percolation rate is really a 100 times less. You could do a sensitivity analysis. Does the answer really change that much and have a sense of whether, even though that's difficult information to obtain, if I did obtain it I could bring the number down quite a bit, potentially the final dose number.

I mean, you can do "what if" kinds of analyses to see if indeed collecting more information here would make a difference. But I still maintain in a problem as complex as Yucca Mountain, it is a reasonable approach in certain areas to take what appears to be a conservative perimeter range or model to limit the cost of collecting more information that is very difficult to obtain.

VICE CHAIRMAN WYMER: Yes. I think we understand exactly what your point is. We're just expressing our frustration in not getting more precise information. We realize you don't need it necessarily to license a repository. But, I guess, sort of a follow on is with respect to risk-informed, how are you factoring into your analysis the most risk significant factors other than just doing a dose calculation at the site boundary?

MR. CIOCCO: We weren't looking at the risk at any dose calculations at all. Are you talking about as far as our sufficiency comments, preliminary comments.

Well, in the area of the waste form proposal, you know our staff looked at what they thought were the most significant, most important areas in waste form proposal. They looked at design drop height of the waste package. They looked at burn up levels of the fuel, welding flaws. So, I mean, there was an attempt in each area to look at the most significant risk information.

The Act didn't require us to do that. There's a certain amount of information that DOE has to provide that we had to evaluate in our draft comments. But we tried to, you know, pick areas particularly one in preclosure that were the most or at least fairly significant areas.

VICE CHAIRMAN WYMER: Are these the areas that you spent the most time on? You concentrated on? I sort have the impression that the NRC just takes a broad view of the whole thing and everything gets sort of the same emphasis in the issue resolution reports and the general review process. I don't see a conscious effort to concentrate on the most risk significant factors.

I know that they are addressed, I just don't see a concentration on those.

MR. CIOCCO: They are certainly addressed in the comments, you know, to the extent that we could. Like I said, we're still compelled to review what's -- you know, if there is a license application, they're still compelled to provide information to the proposed rule.

I mean, staff looked at areas in preclosure and postclosure, and all the areas identified and applied as much risk-information as they could. But we had to careful not to exclude anything as well. We had some bounds of what we could include and what we could exclude.

Tim?

MR. McCARTIN: Yes, Jeff, if I could just add. I mean, the technical exchanges that are conducted are relative to the KTIs, which those KTIs were all picked based upon topics that we thought were important to the calculation. Some a little more than others. But certainly all those we've been evaluating Yucca Mountain for quite a while, and those KTIs came out of what I would say the evaluation of better understanding of the risks, insights, etcetera, from those analyses and looking the DOE analyses.

VICE CHAIRMAN WYMER: Yes. I'm just really expressing what we heard a little earlier, having to do with forest and trees. There's a lot of attention paid to the trees, but then there is the forest, the broader aspects, the key things and there's so many detailed things, so many trees, that when you get done looking at those you sort of forget to look at the whole process. That's overstating it. You don't forget. But there's a limited amount of time to do all these things and you have to look at each of these individual problems, and it sort of leaves the overview kind of out there without really much attention or enough attention, or as much attention.

VICE CHAIRMAN WYMER: Thanks.

DR. HINZE: Could I ask a question of Tim.

VICE CHAIRMAN WYMER: Sure.

DR. HINZE: It kind of follows up to this. You talk about the many models, the many perimeters, and certainly the many analyses that DOE has had to investigate and follow through on. What percentage of these has the NRC, what percentage of the analyses has the NRC replicated in their study of the sufficiency and how far have you gone into duplicating the DOE studies?

MR. McCARTIN: Well, certainly we have reviewed all the documents that come in. We have our own TPA code that does an analysis of Yucca Mountain also. However, there are different approaches between ours and theirs and we have not tried to develop a precise duplicate of their model, but we have looked at the results of their models. And I think to differing degrees, it depends on certain areas, have looked at some detailed modeling to analyze what DOE has come up with.

Now in some areas, the nearfield is probably one of the areas where we've done more internal modeling relative to DOE's calculations, be it geochemistry or seepage, etcetera. We've done more in that particular area than other areas. Farfield transports, saturate it's own transport, we haven't done as much. But it's sort of a collection of different things. And as you know, we clearly have corrosion experiments at the center for the waste package. So there's a spectrum of activities. Is that what you were getting at or --

DR. HINZE: Well, I guess I'm getting at, you know, have you duplicated 75 percent of their studies? Have you duplicated 90 percent with the KTIs?

MR. McCARTIN: Well, I'm not --

DR. HINZE: In other words, I'm coming off the street and I'm asking you if as a regulator how closely you have tested out the results that the DOE has come up with?

MR. McCARTIN: I'd say we've tested out all of them from a broad perspective. There are certain things we do differently in our RPA code, but we certainly understand their approaches in all the areas.

A prime example, let me give you a limited example and maybe this will help. Would be in the area of waste package corrosion. We certainly have models to determine the timing of the first pit in our model for when the waste package fails, okay. Now, DOE has a decidedly different approach in that they have a patch model, etcetera.

We have looked at the bases in how their model developments, and so we understand that. We don't have a patch model in our TPA code, we just look when does the first pit corrode --

DR. HINZE: But that's probably even better to do it a different way and come up with the same results.

MR. McCARTIN: Yes. I would agree. Not necessarily getting the exact same results, but understanding why the two codes differ. And we have looked at the results and how they get the numbers they do.

DR. LEVENSON: I've got one more.

VICE CHAIRMAN WYMER: Go ahead.

DR. LEVENSON: Jeff, you mentioned that some of the things are outside the scope but you're going to be studying or reviewing them anyway. Will those things be included in the comments you forward to DOE or will your comments be limited to what's in your scope?

MR. CIOCCO: The comments will be limited. I had a slide on the subject matter of the comments. Very limited preclosure area, the postclosure excluding performance, quality assurance and expert elicitation. That's the current scope of the draft comments at this time.

Now, there are several other areas that will be pursued through issue resolution, through the process between now if there is a site recommendation and if the project carries forward. Those issues will be evaluated as we go.

DR. LEVENSON: But they will not be included in the comments for which we see the schedule here?

MR. McCARTIN: No, sir. That's correct. Yes.

DR. LEVENSON: That was my question.

VICE CHAIRMAN WYMER: I realize that what you're discussing is the process and we're going well beyond the process, but we're going to continue to do that.

I want to talk a little bit about the QA program. We've heard that DOE's QA program is well conceived and poorly executed. And one of the reasons for its poor execution is it's such an enormous complex with so many contractors and subcontractors and suppliers of materials and things that they haven't really got their arms around yet. How are you going to handle this deficiency?

MR. CIOCCO: I see Larry's coming up.

He's our QA.

Well, at this point we're not judging the outcome of anything.

VICE CHAIRMAN WYMER: I realize you're not.

MR. CIOCCO: We're just trying to present you the basis of how we're doing and it.

VICE CHAIRMAN WYMER: And how you're going to do it.

MR. CIOCCO: And then we showed what some of the issues are in implementing the program and in qualifying the data. And I'll let Larry take a shot here.

MR. CAMPBELL: I'm Larry Campbell, Division of Waste Management.

You're right. Historically going back to the late '80s DOE has always had exhibited problems with the implementation of their QA program. And it could be a combination of several reasons, including there's so many -- the national labs being, you know, not located at Las Vegas and a number of recent turnover.

What we have seen recently with the new M&O that recently was awarded the contract, I think that's Bechtel/SAIC, Inc., they appear to be aggressively addressing this problem. We hope in the September 6th and 7th QA management meetings coming up next week to fully understand their approach. We have conveyed to them that we expect their approach to consider lessons learned from their previous get-well plans that have not been successful.

We've had quite a bit of dialogue with them. I believe they recognize the problems with the many contractors. And one of the items that they recognize is still the need to instill in all the national labs, all the contractors, the nuclear culture.

So we will see what they present next week. We've expressed the very concern that you have as well as several other concerns.

We believe that we have seen with the new M&O, that's their maintenance -- their new contractor, they appear to be aggressive. And the Bechtel/SAIC combination does have extensive experience in the nuclear arena.

VICE CHAIRMAN WYMER: The only way to really convince yourself is going to be to observe audits and the audits are going to have to be many.

MR. CAMPBELL: Well, that's part of what we've discussed is an aggressive, both their office of quality assurance audit of the implementation of their get-well or their action plan as well their own internal self assessments and management assessments. And I would say next year that will be the focus of the majority of their observations and interactions both with their two on site representatives as well as the headquarters staff.

VICE CHAIRMAN WYMER: Thank you.

DR. LEVENSON: Ray, I've got kind of a follow-up question. I know it isn't NRC's role, but is DOE proposing a graded QA system as pretty much effectively operates in the reactor world today? And, in fact, under risk-informed ideas is changing pretty dramatically as utilities request that something which isn't critical for safety have a lower level of QA, etcetera, is that philosophy being involved here or are we having a single level of QA for everything whether it's relevant to safety or not?

MR. CAMPBELL: Well, to answer your question, I have two parts. Yes, DOE is pursuing a graded approach to quality assurance. For the purpose of this current plan and their corrective actions to prevent recurrence, they have not really proposed for that to be graded, namely because we're looking in the area of model validation, software control, data which spreads over the entire both high risk and low risk significant activities that they performed. And as Tim said previously, most of the KTI areas were singled out to be those areas that we do consider significant.

For some of the less significant, less risk significant activities as defined in their repository safety strategy, we have permitted them to use greater QA and concentrate on the higher areas. For example, in the qualification of data that was collected pre June 1998, they are using a graded approach and we have commented on that. And they are -- you know, that's one area. But they do plan to use the graded approach should they submit a license and application. And our review plan addresses graded QA, risk-informed, concentrating on the most risk significant activities.

VICE CHAIRMAN WYMER: As everybody in this room is aware that DOE's relying very heavily on the waste package performance to provide the release in transport of radionuclides. Will your process for looking at the sufficiency of the DOE information be fine meshed enough to pick up something like the effect of high fluoride ion concentrations? The reason I ask is I just heard recently that the potential exists for fluoride ion concentrations to get as high as .14 molar, which would lead to a significant rate of corrosion of the alloy 22.

Is the structure fine enough through the KTI process, or whatever, to accomplish this?

MR. CIOCCO: Yes. Tae Ahn.

MR. AHN: The effect of fluoride ion is on the drip shield not C22 container.

VICE CHAIRMAN WYMER: Oh, that's right. I'm sorry.

MR. AHN: Yes.

VICE CHAIRMAN WYMER: It is the drip shield.

MR. AHN: Right. We have agreement from DOE to incorporate the fluoride effect in assessment of drip shield.

VICE CHAIRMAN WYMER: Okay. And there's no significant effect on the waste package?

MR. AHN: I don't think so, other than early water intrusion onto the waste package by the drip shield failure.

VICE CHAIRMAN WYMER: Okay. And one other point is, it has to do with the coupled effects which are handled in the abstraction of the SSPA in a less than complete way. It's too complex, as I understand it, to run the programs to do the detailed analysis of the coupled effects and so they are abstracted and there's something lost in the abstraction with respect to the coupled processes. Would you agree with that?

MR. AHN: Yes. They have been trying to bound the chemistry on the surface of waste packages to capture that lost part during the abstraction process.

VICE CHAIRMAN WYMER: And do you think the SSPA planned work will pick up on this?

MR. AHN: Some of them, however, these commitment by DOE to NRC do by LA. So it's a licensing processing rather than the for sufficiency comment.

VICE CHAIRMAN WYMER: Okay. Okay, Bill?

DR. HINZE: Well, I have a couple of questions of Jeff.

Jeff, what percentage of the items will be closed-pending on November 1st?

MR. CIOCCO: I can tell you the status as of now in the KTI issue resolution process. I think you have the numbers right there.

There's 37 subissues out of the nine or ten key technical issues. Of those 37, let's see, 5 are closed, 30 are closed-pending and 2 are open. And the two that are open are in igneous activity. There's a technical exchange plan for September 5th.

DR. HINZE: What's the procedure for your to move the closed-pending to the closed? Can you tell me what the procedure will be and how this will be effected? Will you move from the closed-pending on these to closed? Will there be an official sanctioning then?

MR. CIOCCO: Between now and November 1st?

DR. HINZE: Well, you won't be able to do it by November 1st, but afterwards. Subsequent to your sufficiency report.

MR. CIOCCO: Yes. Jim Anderson works a lot in the issue resolution and runs our technical exchanges.

MR. ANDERSON: Jim Anderson, NRC.

The purpose of the meeting on September 5th on igneous activity is to specifically discuss the areas, the open areas. So it is our expectation that DOE would present us with a plan to give us the data we need by potential license application at that meeting.

DR. HINZE: I think I understand that, Jim. The question is removing closed-pending to closed.

MR. ANDERSON: Oh, closed-pending to closed. I'm sorry.

DR. HINZE: Right. What's the procedure here?

MR. ANDERSON: Sure. To move to closed position on a KTI subissue, we would have to have all the agreements in that subissue provided to us. We would have to do a review of all those documents. And at that point if we believe that DOE has presented us with all the information we would need to make a licensing decision, then we would say the issue is closed. And we could either do that via a meeting, public meeting with DOE, or we could do that with a publicly available letter documenting our review of those documents.

DR. HINZE: Well, I guess what I'm getting at is I've sat in on a number of the tech exchanges and it's easy for me to visualize what DOE is going to do in their closed-pending, whether the aeromagnetics, or whether it's the rock mechanics, or whatever. But that may be my visualization of that might be quite different than what they actually do and what they end up with.

So you're going to evaluate that, and my question is now how do you move from the closed-pending to the closed? Will this be an official action then? Will you be moving from closed-pending to closed on 30 of the issues, subissues? Am I coming through at all?

MR. ANDERSON: I guess I'm not understanding your question. Are you asking by November 1st?

DR. HINZE: Well, my question is you have three classes of subissues; you have closed, closed-pending and open, if I understand correctly.

MR. ANDERSON: Right.

DR. HINZE: And a large percentage of these currently are and will be by November 1st be in the closed-pending status. Will you be moving those to closed in subsequent activities and how will you go about this?

MR. ANDERSON: The goal of issue resolution is to do that, to move to a closed position by LA. So that by LA or any potential LA we would have all the information we need to do our regulatory decision making in a three year window. That's the goal.

DR. HINZE: Okay.

MR. CIOCCO: So we're giving DOE the opportunity to provide the information with these agreements.

DR. HINZE: So just between November 1st of this year and the license application, at that point you will proceed through to the closed issue; that's what I was --

MR. ANDERSON: Yes. Most of the agreements if you look at the wording are now looking at fiscal year '03 and in that time frame. So, you know, it's not a near term thing. It's probably closer to the LA time period where we actually might get into a position like that.

DR. HINZE: So the large majority are in closed-pending rather than closed then?

MR. ANDERSON: That's correct. Only five are closed at this point.

DR. HINZE: Five are closed.

MR. ANDERSON: And if we do get to a closed pending with the igneous activities on 32 of the subissues, would be closed-pending as of November 1st.

DR. HINZE: Okay. Thank you.

DR. LEVENSON: Let me just ask a follow-up question to that. KTI business has been around now for some years. Have any issues been moved from closed-pending to closed to date?

MR. ANDERSON: I know of one issue at least that's moved from closed to closed-pending back to closed. And that was dealing with one of the unsaturated/saturated under isothermal conditions subissues. Now I couldn't give you details without researching a little bit.

DR. HINZE: I just wanted to follow-up with, Jeff, it was my understanding that the open issue and the consequences of igneous activity also included something more than what you have here on your page 14 and 15; that there is a need for the DOE to consider the exposure to the critical group, particularly the incorporation of high level waste into the ash and the remobilization of the ash between the site and the critical group.

MR. TRAPP: Jeff, this is John Trapp.

Yes, you're exactly right, Bill. There are some additional issues aside from those there are raised here. The difference is the issues that are considered under sufficiency review versus those that are not under sufficiency review. However, in the meeting on the 5th we do assume from our discussions with DOE that we should be able to get to a closed-pending on all the issues.

DR. HINZE: Okay. Help me here, John.

You're telling me that some of the open issues are not in the sufficiency review?

MR. TRAPP: Exactly.

DR. HINZE: Why is that true if you feel that they're important enough to be open issues?

MR. TRAPP: That I'll let Jeff go into, because it's basically the definition of what the sufficiency review encompasses.

MR. CIOCCO: It's that 50 word independent clause in the Nuclear Waste Policy Act that says "at-depth site characterization analysis and the waste form proposal." It was our interpretation of that was to look at processes below the ground, the features, events and processes below the ground, which was the scope for the sufficiency review.

So John, he's got -- he's talking about physical process models which we feel that are within the scope of sufficiency. He's talking about the interaction of the magma with the repository. Now whenever he gets outside of that below the ground, the at-depth site characterization analysis, he's moving out into his issue resolution area, which we don't feel is within the scope of preliminary comments on the sufficiency of at-depth site characterization analysis.

It's not to say that they won't be addressed. John has a technical exchange to address them.

DR. HINZE: Will there be any lesser evaluation of them as a result of them not being in the --

MR. CIOCCO: Oh, not at all. Not at all. As John said, they're going to address each of those issues within his key technical issue. The KTIs are a much broader --

DR. HINZE: Okay. I --

MR. CIOCCO: It's a much broader set of issues than what's included in the preliminary sufficiency comments.

DR. HINZE: This helps to clarify what you're doing in the sufficiency review as well.

MR. CIOCCO: Good.

DR. HINZE: Thank you.

MR. CIOCCO: You're welcome.

VICE CHAIRMAN WYMER: Are there any questions or comments from the ACNW staff here?

MS. DEERING: I have one.

VICE CHAIRMAN WYMER: Lynn?

MS. DEERING: Jeff, last year the Committee was briefed on the sufficiency review guidance, and I hadn't heard you mention that and I just wonder if you could -- how does that play in to what you're doing now?

MR. CIOCCO: The guidance that the staff prepared last year has really been overtaken by events. It was premised on regulatory framework that isn't totally in place. So the comments are based on, as the Act said, what's required for any license application. So you fall back to what's in the proposed rule, what's required per license application in proposed Part 63.21. You have to look at all those areas.

From that you take down what the specific language in the Act is at that site characterization analysis and waste form proposal. So we focused then in on those particular areas of a potential license application which would be applicable. And then we used the publicly available total systems performance assessment, integrated IRSR or issue resolution status report. And we used the other IRSRs as the basis for conducting the review and the acceptance criteria which are in them as well.

MS. DEERING: Okay. So the criteria are in that IRSR?

MR. CIOCCO: Absolutely.

MS. DEERING: Okay.

MR. CIOCCO: Absolutely.

MS. DEERING: Thanks.

VICE CHAIRMAN WYMER: Well, we have a little time left. And in the interest and pursuit of allowing public participation, I'd like to ask for comments from the audience. Judy? Judy Treichel.

MS. TREICHEL: I enjoyed the discuss --

VICE CHAIRMAN WYMER: Judy, there might be someone here that doesn't know you, including the reporters.

MS. TREICHEL: Oh, I'm sorry. Yes.

VICE CHAIRMAN WYMER: Please identify yourself.

MS. TREICHEL: Judy Treichel, Nevada Nuclear Waste Task Force. Sorry.

I enjoyed your discuss about public participation and what it should be, and it certainly couldn't come any sooner. We're expected in Nevada -- the citizens of Nevada are expected next week to have their one shot at being able to participate in a hearing where their only opportunity for their comments to be received about the site being recommended for development of a repository will be heard. That's it. Then we're done. We're out of it until it possibly goes to licensing, and then the public in any real sense won't have standing.

So, this is it. It's our big shot. And on your slide number 5 it talks about that in Section 114 of the Act that together with a recommendation of the site, the Secretary shall make available to the public a comprehensive statement of the basis of such recommendation. We don't have any idea, "the public," about what the basis is. We don't have Part 63, we don't have 963.

And further on back in this presentation on page 19 you talk about conducting a limited review of the preliminary site suitability evaluation which evaluates the performance against the guidelines. We don't have any guidelines, either.

We also, "the public" and my organization which spends a lot of time representing "the public," does not have a copy of this. And yet we are going into our one shot.

So, I don't know what, if anything, the NRC is able to do. But I don't think it's sufficient. If the NRC has anything to say about public participation, I don't believe it's sufficient. And you need not talk about whether reports or anything that's done is understandable or readable as far as the general public if this is the way that things are done. Because it really doesn't matter. You're going to be holding one of the most important technical exchanges, the one that's been discussed here on igneous activity, the same day of that hearing. And there is no resolution. There's a lot of stuff that's still up in the air.

One of the things that "the public" particularly "the public" in Amargosa Valley would like to know is what the doses are. If you had igneous activity, if you had the scenario that's talked about with the ash falling. Not one that's weighted by probability. And that hasn't happened yet either.

So there's a huge gap and you can talk a lot about public participation, but you're seeing probably the award winning case of a slap in the face to the public with this system right now.

Thank you.

VICE CHAIRMAN WYMER: Thank you, Judy.

Is there any other comments from the audience? Any rebuttal? Yes, well the staff can rebut too. Are there additional comments or questions, or observations.

DR. HINZE: Bill has a comment.

VICE CHAIRMAN WYMER: Oh, Bill?

MR. REAMER: Bill Reamer, NRC staff.

And let me just point out the number of technical meetings that we've had with DOE over the past year and a half. I would say in the order of a dozen, all of those have been public meetings. They've covered each of our key technical issues. We've endeavored to explain all along the way everything that the NRC staff is doing in the area of issue resolution in a manner that involves the public.

We've held many meetings in Nevada, and we will continue to do that to carry on a dialogue with the citizens of Nevada to keep them informed as best we can about what the NRC is doing, what it's role is and how it's carrying out that role.

I regret if there's a conflict in meetings that we schedule and our scheduled by other entities involved. We do our very best to avoid conflicts, but in some cases it's not always possible. And so that remains to be, I think, just a fact that we have to live with.

But we are -- we do hear the comments that the public makes. We do hear the comments that Judy Treichel makes. And we do our best to be responsive to them, to take them into account and to show through tangible actions that what the public says has meaning to us.

VICE CHAIRMAN WYMER: Thank you, Bill.

At this point I'll pass the gavel back to George Hornberger who is fully informed of everything that's gone before.

CHAIRMAN HORNBERGER: Where are we, Ray? Do we have --

VICE CHAIRMAN WYMER: We're all washed up. I think we're pretty well to the bottom of the barrel here. We've had comments from almost everybody and had a pretty good discussion.

DR. LEVENSON: We've topped it off.

VICE CHAIRMAN WYMER: We've topped it off.

We asked a lot of very inappropriate questions based on what the presentation was and got good answers.

CHAIRMAN HORNBERGER: Good. I'm glad to hear that. I'm glad to hear that.

VICE CHAIRMAN WYMER: So, I think you've come in in time to adjourn the meeting.

CHAIRMAN HORNBERGER: Are there any other comments or questions anyone want to make?

Thanks very much, Jeff.

MR. CIOCCO: You're welcome.

CHAIRMAN HORNBERGER: Thanks to everybody.

We don't have anything else on our morning list. Is there anything we need to pick up on from earlier? Okay.

We'll be adjourned until 1:30.

(Whereupon, at 11:47 a.m. the meeting was adjourned until 1:30 p.m. this same day.)

A-F-T-E-R-N-O-O-N S-E-S-S-I-O-N

(1:30 a.m.)

CHAIRMAN HORNBERGER: The afternoon session will please come to order. This afternoon we're first going to once more dabble in performance analysis and, hence, I will turn this over to my colleague who always handles performance assessments for us. John.

DR. GARRICK: Or mishandles. Thank you, George.

This is a very interesting presentation that we're looking forward to, especially given that earlier this month we were able to observe the technical exchange meeting on performance assessment and get kind of pumped on the issues and what's going on and the agreements that have been made. And, of course, the committee has seen the Supplemental Science and Performance Analysis and, given that we've been reviewing to some extent the TSPA-SR, we were very pleased to see that a number of issues that came to our mind in looking at the TSPA-SR were addressed and are being addressed in the Supplemental Science and Performance Analysis, particularly issues having to do with a more deliberate and systematic process of trying to quantify some of the uncertainties, some new information, particularly on solubilities, and of course. the lower temperature operating modes that are under consideration. These all seem to be items that we were left with questions about when we looked at the TSPA-SR, so this is appropriate.

Also, maybe you can answer the question of why this isn't just an appendix or an extension of the TSPA rather than a separate and somewhat isolated document.

We are pleased to have with us today Doctor William Boyle and the person that's been doing a lot of the work, Robert Hoard, and so without further comment, unless there's some opening comments that others would like to make, we'll turn it over to you, Bill.

DR. BOYLE: Thank you. As Chairman Hornberger mentioned dabbling, I am the dabbler of this group and Rob is the one that does the real work, along with many, many other people. For those of you that have seen the documents, it's quite a bit. Thank you for the introduction. There is a lot to cover here today in the materials that you have. We hope to stay on time. I'll give the first part of the talk, and then I'll turn it over to Rob and then I'll finish up again.

Here's the outline of the talk, and I will give an overview of Volumes 1 and 2, purpose and contents, and Rob will largely talk about the results from Volume 1 and I will talk about Volume 2 and the conclusions. As I mentioned, there is a lot of material in the SSPA, as we call the Supplemental Science and Performance Analysis for fiscal year 2001.

Volume 1 itself comes in two parts. Total, there's 2,000 some odd pages, so in the hour today that I have, Rob and I have to present them at the rate of 30 pages a minute just to get through, just to give you an idea at the rate at which we're going to proceed.

CHAIRMAN HORNBERGER: That's better than my laser printer.

MR. HOWARD: Although it's probably not as clear.

DR. BOYLE: We're going to try.

DR. GARRICK: Now we're getting to the real issue.

DR. BOYLE: The SSPA, the purpose of it. These items right here, they're actually taken out of the Technical Work Plan which was prepared for this document before the document was prepared itself. There was a lot of discussion this morning about conservatism and how to treat uncertainties, and so one of the purposes of the SSPA was to quantify some of the uncertainties and also quantify some of the statements about conservatism and document those results.

We also were going to look at system sensitivity analyses and subsystem sensitivity analyses, look at higher temperature operating modes, which we had been for years, but also now look at a range and look at a lower temperature operating mode at a system level and also at some subsystems level.

I'm convinced that through the years most of the scientists and engineers on the project had considered multiple lines of evidence. It's just that we hadn't really been explicit about including these multiple lines in one document. The SSPA provided an opportunity to do that. And since the last TSPA, we had been gathering more data and so it gave us a chance to capture some recent data.

The content. I always find it easier to talk about Volume 2, and I think it portrays a bias on my part of being comfortable with total system performance. Volume 2 captures the system level analyses, whether they were sensitivity analyses of the system or the TSPA itself. In Volume 2 we did a

TSPA for higher temperature operating mode and we also did for a low temperature operating mode and these TSPa were premised upon the data that were documented in Volume 1 which included unquantified uncertainty analyses, updates and scientific information, whether they were new measurements or new models, and also examining cooler thermal operating mode analysis.

A little more detail about those items in Volume 1 on the things that we captured there, unquantified uncertainty analysis. What we mean by that is for those parts of the TSPA-SR for which we had a bound or had nothing, if you will, we went out and asked the scientists and engineers, well, can you come up with a representation. Instead of a bound, can you give us a distribution? Instead of nothing or a bound, can you give us a different model? And so with numbers associated with them so that we were trying to replace bounds and single values including zero or nothing with more realistic or more quantitative representations.

As I also mentioned, we did have updates in scientific information. We were continuing to do testing, and some of those new test results are captured and, in the process of gathering new data, a lot of the investigators also came up with new models to help explain the new data and/or existing data.

And then we also related to the lower temperature operating mode system analysis. We asked the investigators, is there anything you need to do at the process level? Specifically, to accommodate a lower temperature operating mode. So we asked that they do that. And we also asked at the same time to pay particular attention to just temperature dependcies. Is there something that you could put in there to capture a temperature dependency such that we might see a difference over a range of temperatures for operating modes?

The first that was on page three, "document new results for quantification of uncertainties and conservatism," and so here's a little more information on that about how we went about evaluating that significance of uncertainty and conservatism or optimism. We first did process level sensitivity analyses. We went to the investigators and said, look, do it a different way and see if the results come out differently. Those are documented in Volume 1 and, as appropriate, other lines of evidence backing up different models was incorporated there.

Then for some of those different process models from Volume 1 we carried forth the TSPA. The first thing that was done with them, the new model or the new data, was plugged into the TSPA-SR. We wanted to do our sensitivity studies with respect to it and so we would put an item in, run the sensitivity study, revert it back to the way it was before and then put the next item in and do the next sensitivity study.

And then at the end we took some subset of all those things for which sensitivity studies had been done and plugged them into a new TSPA, if you will, the TSPA for SSPA, and then we ran it both hot and cold and ended up with the two TSPAs which you'll see on various charts. They're referred to -- I showed it on page four -- HTOM and LTOM, higher temperature operating mode and lower temperature operating mode.

I briefly mentioned twice on that previous slide. We didn't always carry everything forward. For everything that's in Volume 1, it didn't necessarily make it to a sensitivity study and for the things considered in sensitivity studies, they didn't necessarily make it into the final TSPA. Here are a list of reasons why things did not get carried forth. It was the new model, people thought it might have a low probability of occurrence or during the result of making the new model, it was found to be insignificant at the component level or in the sensitivity study it was determined that it was insignificant at the system level or people were just not that convinced that there were enough data to support the model. It was easy enough to dream up the new model but really were there enough data to support it? Here were some examples of things that perhaps didn't have enough data to support them being carried forward.

Related to that is this last item. The model was still so conceptual that they didn't feel that it was appropriate to carry it forward.

Now, I will admit that with respect to low and insignificant, there were no quantitative measures for this. This was left up to the various scientists and TSPA analysts as to whether something went forward or not. We did not have criteria in advance that said, all right, if it has less than a probability of X, don't take it forward, nor did we have any criteria that said if it moves the TSPA results by less than this, don't carry it forward. It was not that quantitative.

And here are some more examples of the various things that, if you will, these were considered in Volume 1 where we told people, try and come up with new models. So they're in Volume 1 but they were not carried forth to volume 2 for inclusion in the final TSPA. So you can go to Volume 1 and read about different modeling results for the unsaturated zone flow fields or different ways we treated uncertainty in aging and phase stability of alloy 22. The glass degradation rate, colloid mass concentrations, drift degradation effects. The effects of rock bolts and rock fall. What effects they would have on seepage and also unsaturated zone transport.

This is just a partial listing and I'll show you in a few pages where you can get a more complete listing of the things that were considered and where they were considered. So now I've talked some about things that weren't included but many things were included into the TSPA for the SSPA, sometimes referred to as the Supplemental Total System Performance Assessment.

We did put in long-term climate out for a million years and the accompanying changes and net infiltration. We incorporated new test data related to seepage, new test results from exploratory study facilities and also changed models on flow focusing. We also made changes in the waste package degradation stress corrosion cracking model. I think we changed the threshold. We changed various representations or thresholds for these items related to defects.

We also introduced this model of improper heat treatment which influences the results prior to 10,000 years. We changed results on how we did in-package chemistry. We changed how we treated the cladding with respect to how we handled creep and stress corrosion cracking. I'll speak more about this example, solubility, neptunium and other radio-nuclides. We changed we represented the in-package transport with adding diffusion and absorption on oxides and hydroxides of corrosion materials.

We also changed the in-package and engineered barrier system retardation. Changed Kds. And we also used results from the Nye County drilling. I believe it was Jeff Ciocco or somebody mentioned this morning the lack of data in the saturated zone at 20 kilometers and we had new data for that and so we changed our representation of the saturated zone.

Now, I just mentioned a moment ago that there was a way to keep track of everything we had considered in Volume 1 and what got passed forward to Volume 2, and it's the next nine slides of which this is the first, and I won't go through every line and every box. It would take us the rest of the day. But this table is in the SSPA. All the nine pages are laid out the same.

We start off with a key attribute of the system, whatever it is -- in this case, it's limited water -- entering in-placement drifts, and then we looked at smaller parts of it, whether it was climate or netted filtration or unsaturated zone flow, and then we kept breaking it down as we moved to the right until we got to these three columns right here. If there's an X in any of these three columns, it means it was treated in some way in Volume 1, whether it was a brief qualitative description, a full analysis that ran on for pages, new data. In some way, if there's an X in a box, it is described in Volume 1 and this column tells in what section of Volume 1 you'll find the treatment of that item. So if you find some item of technical interest over here, you can jump over to this column and see what section of Volume 1 has the treatment of that issue.

Now, the reason we had three columns here is that these three columns list the motivating factors if why that item was in Volume 1 in the first place. Was it driven by an unquantified uncertainty analysis, a desire to change a bound to a full representation, or instead was it driven by new data and the development of a new model or was it driven by consideration of a cooler thermal operating mode? And as you can see, you can have Xs in more than one box.

The last two columns show what we did with the item when we got over to performance assessment. This second-to-last column shows did we incorporate it as a sensitivity study using the TSPA-SR model? Did we include it as a one off study? The last column shows whether or not it made it into the final TSPA for the SSPA.

If I go forward to page -- let's see if I can find it. At any rate, there was a question this morning about coupled processes and how we had represented it before. If I could find which one of the pages -- the first page? Let's see. THC. It might be the second one. You'll see that it didn't make it into the final TSPA, but you can see that we did do work at the process level and it would be documented in Volume 1. Here it is. Yes, on transport. This one.

Effect of coupled thermal-hydrologic, thermal-hydro-chemical and thermal-hydro-mechanical processes on transport. You can see that there's Xs here so it was covered in Volume 1 but we didn't carry it forth into the TSPA, even as a sensitivity study.

I think Rob may talk about thermal-mechanical as a specific example and Rob will talk about more examples from this table. But the reason why I think in part this particular item was not carried forward was even at the process level, they were found not to have a very large effect at the process level so people said, well, if it doesn't affect the process level, perhaps it won't affect the system level. We'll leave it out for now.

And that's the last page of the table. As I've mentioned, this table is in the SSPA itself.

This is from Volume 2. I'm up to page 21. Again, to demonstrate my bias of comfort with performance assessment. If you were to ask me out of all these pages which would be the one to keep and you could only keep one, it would be either page 21 or, as you'll see later on, page 43. These are the results of the system analyses. The black curve here is a plot of means. For nominal scenario, there is no igneous event. No igneous events are factored into this. Just a nominal calculation. This is the result from the report last December. Plotted the mean. The black curve referred to as the base case. The higher temperature operating mode. Its results are in red. And the lower temperature operating mode results are in blue.

An important point is this one down here in the lower left that I can summarize as the blue and the red are similar to each other and they're much more like each other than either one is like the TSPA-SR. And so, at least as measured by system performance at 20 kilometers, we don't see that great a difference in operating modes. The red and the blue are similar, yet they are significantly different from the base case.

The differences we do see between the red and the blue, the analysts do believe that it is caused by temperature dependence and general corrosion way back here that eventually manifests itself even in these large time frames. The large spikes, the spikiness of this relative to that is caused by the inclusion of a climate change out to a million years. Solubility updates which we'll talk about a bit more. It produced about an order of magnitude decrease.

These early failures. If you see in the base case, there were no releases until after 10,000 years and for the SSPA there are small releases prior to 10,000 years and those were caused by early waste package failures. Has to do with welding. The fact that a waste package lid weld would be done incorrectly and not caught during inspection. And so a model was developed to capture that phenomenon and so these releases are related to that model indicating that there were weld failures and lid failures and, therefore, releases.

DR. GARRICK: Was that based on some new evidence that you obtained, other than just putting in a different model?

DR. BOYLE: Go ahead, Rob.

MR. HOWARD: That was a re-interpretation of some of the information that we had previously looked at with respect to possible failure mechanisms and aging and phase stability effects and what those could do. I've got some back-up information. When we're finished with this, I'll make sure that we touch upon some more details of that.

DR. BOYLE: Yes. And along those lines, when we started, even before the SSPA came along when we were working on the unquantified uncertainty analyses and when we were asking scientists and engineers for different representations, we always asked that it be based upon data and measurements from at least somewhere. We could always do sensitivity studies simply by asking the TSPA analyst to turn the knob this way or that way, and that's not what we wanted. When we wanted different models, we wanted them based upon data from somewhere. Didn't necessarily have to be the project though.

DR. HINZE: Bill, if I might. One question. One of the concerns about the higher temperature operating system would be the effect on coupled processes.

DR. BOYLE: Right.

DR. HINZE: There was this thermal-hydrologic, thermo-mechanical, etcetera, and that this might be a prominent effect. You have showed us on page 17 that the supplemental scientific model on these did not make it into the new TSPA.

DR. BOYLE: Right.

DR. HINZE: Did it not make it because you didn't have the sufficient information or it was insignificant or which of them -- by which you eliminated it?

DR. BOYLE: It's my recollection that Eric Sonnenthal at Lawrence Berkeley Lab did the calculations. Certainly hot like TCS, thermal-hydrologic and chemical. And I know they've been presented at a meeting we had with the Nuclear Waste Technical Review Board and the changes that were looked at in terms of amount of this mineral that precipitated or that one that dissolved were small. I believe it was Bo Bodvarsson that made the presentation.

For some of them it was one percent of one percent. And this was for the hot case, and it was believed that if we get that little at hot, we would expect even less change for cold. So I'm not even sure that Eric ran them cold. But the reason it wasn't carried forward is because so little change was seen at the process levi.

DR. HINZE: Would we be able to find the background information on that in these volumes?

DR. BOYLE: Ye

DR. HINZE: It'll be in Volume 1 then?

DR. BOYLE: Yes. Go to that column and go to --

DR. HINZE: It'll explain why it is deleted?

DR. BOYLE: It should. Right. And if the explanation there isn't sufficient, we can call up LBL or Rob has go some back-up slides.

MR. HOWARD: Yes. We can touch upon that one as well. Unless you guys want to deal with it.

DR. GARRICK: No. That's fine. Go ahead.

DR. BOYLE: I will go through some

examples of things either at the process level -- this is from Volume 1 -- or sensitivity level that provided insights into those system level results which is everything all wrapped up together. This is an example of how we changed things from the TSPA-SR. Here's the representation for neptunium solubility we used in TSPA-SR. It's this curve right here. And so if you know the pH, you know the solubility, it's a single number. Given the pH, the solubility is known absolutely. There's no uncertainty. That's the way we represented it in the TSPA-SR.

The way we represented it in Chapter 9, you can see, of Volume 1 of the SSBA is using these data points they developed a model such that, given the pH, there's a range in values that people -- a distribution of values. If you were to take a vertical cross section here at any pH would have a distribution of solubilities for the pH and so it was this distribution that they then sampled from in the TSPA for the SSPA. So we went from a constant for a given pH in the TSPA-SR to a distribution in the SSPA. This is what was done for neptunium.

This is how it propagated forward into the system level. This is one of the sensitivity studies from Chapter 3 of Volume 2 in which we put the new representation into the old TSPA. So this is why this base case, that's the results from the TSPA-SR and the red represents what the TSPA-SR would look like if we included these new radio-nuclide solubilities. This red line represents the neptunium example I had shown you on the previous page plus changes in plutonium solubility, thorium, uranium and technetium solubility. But the one that has the most effect is the neptunium 237 solubility.

As another example, this gets back to the one that I mentioned before, the lid failure. Again, I'll emphasize that the TSPA-SR had no releases prior to 10,000 years and this is the sensitivity study putting in the early failure case which was driven by improper heat treatment of the welds on the waste package lids. This is the result, which back to the definition of conservative or not. You could make the argument that our TSPA-SR was non-conservative for this phenomenon because now we have doses, although they're very small. We have doses with the SSPA where we had none before.

This is my last example. This is a sensitivity study where we looked at sorption in the engineered barrier system. Again, here is the results from the TSPA-SR and here's the sensitivity study with new representation using different sorption coefficients.

So at this point, I believe I turn it over to Rob and he goes through many example

DR. HINZE: Bill, can I ask you a general question. First, it was my understanding that one of the purposes of the SSPA was development of multiple lines of evidence.

DR. BOYLE: Right.

DR. HINZE: You've remarked about that, but that these lines of evidence should be derived independent of PA and therefore would be, if I can quote, "subject to the" -- my God -- "limitations of performance assessment." I didn't realize there were any. Let's say that there are some limitations to performance assessment. Sorry, John.

DR. GARRICK: You've been away too long.

DR. HINZE: Maybe not. Maybe not. Can you explain to us what kind of work you did that followed on this and how did you use geological analogs and so forth?

DR. BOYLE: Right. It was all these multiple lines of evidence were captured in Volume 1 and it's sub-section by sub-section. Most sub-sections have a specific sub-sub-section that deals with the multiple lines of evidence. What people did was let's say we have some representation, a number, a model based upon our measurements for Yucca Mountain.

What they did was they went out and looked at well, were there other data sets or other things out there that shed positive light on our representation that would cause us to believe them more? That's what was done in the SSPA. It was more of a documenting oh, and here's these other things that we can observe around the world or measurements made by others elsewhere that make us feel comfortable that we have the right representation, but what was not done is take those same things and change our numbers, which would be another -- if they were really germane examples, other lines of evidence, you might argue that if they're that germane, perhaps they should be factored into the representation we're using. But at this point, that hasn't been done.

MR. HOWARD: So that the multiple lines of evidence showed no discrepancies with the PA and therefore, there are no limitations to PA?

DR. BOYLE: No. I don't think we said that. The multiple lines of evidence were developed for very specific things. Nobody had the -- you know, some solubility or some THC reaction. Nobody went out to find multiple lines of evidence for the PA itself. But they just focused in on the small items with the belief that if we could prove that the parts were supported, that we were assembling them correctly--

DR. HINZE: But you didn't really look at the safety issue in this then. Is that correct?

MR. HOWARD: Yes. That's one way to look at it. What the multiple lines of evidence do is force us to reexamine our conceptual underpinnings on what are the fundamental processes that we understand. For example, the issue with the stability of passive films over long periods of times and what evidence do we have that metals behave that way? We went out and we looked at josephineite, which is a nickel-based rock.

DR. BOYLE: Mineral.

MR. HOWARD: That's a more sophisticated term. We looked at how that material behaves over long periods of time. We went and we looked at different underground openings, caves, Egyptian tombs. What does seepage look like or not look like in those conditions. So it was more of the conceptual underpinnings. Do we see analogs in nature that behave the way we're describing our system or counter to the way we're describing our system and why.

DR. HINZE: You limited to that because you couldn't carry that to the total safety issue? It's hard to extend it to that.

MR. HOWARD: Yes. You wouldn't want to do a dose or consequence calculation based on this information because you have to make sure that whatever that process is, it gets integrated into the system that you're actually trying to analyze. So there's really now satisfying way of taking that and redoing a calc for Yucca Mountain with those kinds of inputs.

DR. BOYLE: As I mentioned before once or twice, the SSPA was an activity that came about after the unquantified uncertainty analyses started, and I described the unquantified uncertainty analyses, and looking at replacing bounds with more distributions, if you will. When we were working with the investigators on that, we specifically told them, feel free. Whatever numbers you can come up with from wherever. We didn't care. The Waste Forum people mentioned some long-term glass dissolution tests in Canada. We said, okay, fine, give us your best scientific answer. They mentioned dissolution of volcanic glasses on the sea floor as information that provided insight into their answer. Although we were encouraging them to use such numbers for that purpose for unquantified uncertainty analyses, I think there's a general tendency in the project not to use such outside sources because there's questions about QAa, there's questions about how applicable are they, sub-sea floor versus a repository.

And so I think through the years the project has tended to rely a lot upon our own measurements and only use these other lines as shedding some light on the issue but not actually affecting the actual number we're using in the calculation.

DR. HINZE: Thank you.

MR. HOWARD: Okay. What I'm going to do is briefly go through some of the reasons why the dose results that Bill just showed looked the way that they do and why there may not be that much difference between the two operating modes. Then we'll get back to some of these more fundamental questions when we wrap up on the coupled processes.

The question was raised about the coupled processes and could we reduce uncertainty or better quantify uncertainties by going to lower temperatures. A lot of times our goal wasn't necessarily to reduce uncertainty. So we didn't walk in with the expectation that all uncertainties are reducible and to further simplify, all uncertainties are reducible by simply reducing the temperature variability within the process. Nature doesn't always work that way, but we did want to take a look at coupled processes and the uncertainty associated with them and what the impacts of neglecting those processes or representing those uncertainties in a conservative manner might mean to sub-system performance as well as total system performance.

So we looked at the effect of thermal conductivity and thermal radiation approaches. So those were modeled uncertainties that we had in the TSPA-SR. We didn't include thermal radiation. We had an effective thermal conductivity that we used instead. We looked at impacts of dry out during ventilation, coupling of models, localized effect of seepage is in there, fracture heterogeneity, mountain-scale gas-phase convection. We took a look at that and have a better reason why we didn't have to incorporate that into the TSPA. And again, rock properties on vapor storage.

Process uncertainties. How coupled processes may change the hydrologic properties, and I'll show you some examples of that.

VICE CHAIRMAN WYMER: Excuse me. One of the things I get out of these presentations is an enlarged vocabulary but you always manage to come up with something I've never heard of before. What is imbition?

MR. HOWARD: That's a mis-spelling actually. But if you need to actually come up with a new term, we could probably come up with one real quick. I don't want to cheat you out of it.

Input data uncertainty. We'll go through some of these. There's only a couple of them that turn out to be all that important as far as the thermal analysis go.

The question earlier about coupled processes and their effects on performance. Looking at thermal-mechanical effects, coupling of temperature and mechanical effects in the host rock on not transport but unsaturated zone flow. What this graph shows you is for the two operating modes that we looked at, these are ratios of the vertical stresses over the initial stresses. As you can see, they don't change that much. There's some change in the extent of the permeability changes, but the permeability changes are small in both cases and they're similar. So whether we were at elevated temperatures or below boiling, we still have this effect and, in either case, the effect is small. So you're not changing the permeability that much. They're not changing by an order of magnitude or anything like that, which might be something in a natural system that you would start to think about if they were on an order of magnitude. They're not going to influence total system results that much and, in fact, they don't influence ambient results enough and that's one of the reasons why we didn't propagate this effect all the way through the total system

DR. HINZE: What would that look like after 500 years? Would there be a difference?

MR. HOWARD: Stresses would go down. I probably have the results here. I don't have it in my head, but it's going to be negligible. We tried to pick what were the most extensive results we could get out of these.

CHAIRMAN HORNBERGER: That last figure you showed was actually an isotropy ratio. So this is dilation of the fracture preferentially in one direction because of the stress changes.

MR. HOWARD: That's right.

CHAIRMAN HORNBERGER: Okay. Thanks.

MR. HOWARD: Thermal seepage. One

difference between the TSPA-SR and these supplemental results is the amount of seepage that we see is increased. It was like 13 percent on average for the repository for the TSPA-SR and for the supplemental analysis it was on the order of 48 percent for the higher temperature operating mode and 45 percent for the low temperature operating mode. The 45 percent being an ambient type model.

So the seepage, since they're so similar between the two cases, is not going to influence in any dramatic way differences on how water contacts the waste packages and then would affect radio-nuclides through the system. So that's not going to have a whole lot of effect between the two operating modes.

Thermal histories. After the first several thousand years, these systems look fairly similar. So after the thermal pulse, you don't see that much difference in the temperature and relative humidity profiles of the systems. This is a recurring theme. That initial thermal pulse that lasts anywhere from 500 to 2,0000 years, dependent on where you are in the repository. You can tell the differences. We can model the differences in temperature. We used the same process models to do that. We just have different initial conditions to get at them. What this curve shows is the profiles. If you just shift the low temperature operating mode in time, it fairly matches the high temperature operating mode.

Do I want to say anything else about this? Paul Harrington is going to show this graph back on the same equivalent time scale tomorrow when he talks about design. They are similar.

If you look at effects on waste package temperature, one of the things that could influence how this performs is different waste package temperature profiles. This is particularly important if you do have a temperature-dependent general corrosion model, which I'll show you in a couple of slides from now. But the idea here is that whether you're at a high temperature operating mode or a low temperature operating mode, the variability for location and waste package type is about 20 degrees C, so there's about a 20 degree C spread dependent on where you are in the system at any given time for the high temperature operating mode and the same is true for the low temperature operating mode. They start to overlap at later times.

The difference is in the variability in the initial condition, so you've got a 90 degree difference in spread between operating modes.

Relative humidity, and this is important for when corrosion processes can start. The low temperature operating mode, low relative humidity duration is similar to the high temperature operating mode. Disregard the spikes. These are artifacts of the initial conditions in the modeling scheme we used, but the general trend is that again if you're looking at relative humidities for where a waste package might be in the repository system, they're fairly similar for most of the time for both high temperature and low temperature operating modes.

So relative humidity does go higher quicker for the low temperature operating mode but again, after about 1,000 years, they even out.

DR. LEVENSON: Why is there no data for the low temperature case in the first 500-600 years?

DR. GARRICK: Mel, microphone.

DR. LEVENSON: Why is there no low temperature data for the first 500 years?

MR. HOWARD: It's 300 years actually. What we're doing is for these models, the low temperature operating mode, we assumed -- and this was just a science and analysis assumption. It's not meant to represent an actual design solution. We were looking for an initial condition. We assumed 300 years of force ventilation to get us at the low temperature initial condition that we wanted. So it's really just that we assumed a difference in closure times between the two operating modes.

VICE CHAIRMAN WYMER: Three hundred years of ventilation.

MR. HOWARD: Again, that's not meant to represent a design solution. We were trying to get it at initial condition.

DR. GARRICK: I was going to suggest that you're going to ventilate it for 300 years for sure.

DR. LEVENSON: So to some extent, it gives you a little artifact because you're having different ventilating conditions for the two cases whereas in reality I guess you would expect much higher initial humidities for the low temperature cases. Right?

MR. HOWARD: As long as it's being ventilated.

DR. LEVENSON: Yes, yes, but by using two different periods of ventilation, it's not the direct comparison.

CHAIRMAN HORNBERGER: On these slides, I'm not sure that I'm clear on what the stippled area is we're looking at. These are temperatures at various locations in the footprint?

MR. HOWARD: Right. This is just where, if you're a waste package on the north end versus the south end. In this, if you're a high level waste package or a PWR or BWR. In the thermal-hydrologic models we represent different types of waste packages with different thermal profiles. So high level waste waste packages are typically much cooler than a PWR waste package with high burn-up.

VICE CHAIRMAN WYMER: Will they be isolated? I thought these things were going to be mixed together.

MR. HOWARD: They are mixed together, but there's still going to be variability between waste packages, so waste package to waste package variability as well as variability between different areas of the repository. So waste packages in the center of a repository tend to be hotter than waste packages located around the edges.

VICE CHAIRMAN WYMER: That is with respect to type however.

MR. HOWARD: Right. This was location so this was whether you're on the edge.

VICE CHAIRMAN WYMER: I understood that.

MR. HOWARD: And this is with respect to type, so you've got high level waste package you typically see higher relative humidities because they're --

VICE CHAIRMAN WYMER: With it all mixed together, it's a little -- well okay, go ahead.

MR. HOWARD: We do have to represent -- we don't have to. We choose to represent both variability and uncertainty in our analyses.

A different way of looking at the same results. These are between the high temperature operating mode and low temperature operating mode. It's the same temperature scale for each one of these at different time slices. So at closure, obviously high temperature operating mode. The entire repository footprint is going to be much hotter than the low temperature system. But the variability in the system in either condition is about the same. The difference is between the two systems. So you don't see -- if you're looking at trying to reduce overall variability in the system, this doesn't help you out a whole lot there. Looking out at 10,000 years, the systems really start to look similar as far as temperature profiles go.

This is the same kind of information showing relative humidities. Typically the relative humidities of the lower temperature operating mode are higher at earlier times than the high temperature operating mode. But again, in this time between 2,000 and 10,000 years, they tend to converge.

DR. GARRICK: When does the peak temperature occur?

MR. HOWARD: The peak temperature occurs for the high temperature operating mode about 15 to 100 years -- shortly after closure. And it would be the same for the low temperature operating mode. So within the first 50 years after closure. Turn the ventilation fans off. Temperatures go up.

Sensitivity of waste package temperatures to infiltration rates. We're looking at what's going on at the surface. For example, what would be the impact if we were wrong about our climate scenarios? You can see that there isn't a whole lot of sensitivity to what the infiltration rate is. So you get a little bit more quenching in the high temperature operating modes because you can get a little bit better delta T dependency. But it's not enough to if you're looking at trying to reduce any variability, you're not going to get there that way.

This is a rather or can be a rather complicated viewgraph, but I just want to draw your attention to a couple of the key points. This has to do with what I talked about a little bit earlier with respect to conceptual model uncertainty and parameter uncertainty. What I'm trying to demonstrate here is what parts of the model or the parameters have the biggest influence on temperatures?

So you can see that the big players are what is the real value of the lithophysal porosity and the thermal conductivity or what variability or uncertainty in these parameters is going to give you the largest variability and uncertainty in your thermal calculations?

The other key point is the ventilation efficiency time dependence. This is actually a knob that engineers may decide that they're going to turn if they want to go after a lower temperature operating mode and there's a big dependence on what the efficiency is and also the duration of the ventilation period.

Seepage water chemistry. We took a look at what the incoming water in the drift would look at between the two different operating modes and again, the story is during that thermal pulse there are differences but they do tend to come back close to ambient temperatures after several thousand years. So $CO_2$ concentrations go down rather dramatically during that thermal pulse but then come back up to around ambient for the high temperature operating mode where the low temperature operating mode stays pretty close to ambient for the entire time.

Chloride concentrations. These numbers here actually represent what the final saturation was right before dry out and what the initial saturation is during rewetting. But again, after that about 2,000 year period, chloride concentrations incoming to the drift get back close to ambient.

pH. A little bit more variability in pH than in chloride concentrations but again, the story is similar. Once you get out in time, the temperatures go back up to ambient and high temperature and the low temperature track reasonably well when you've got an aqueous system.

Fluoride concentrations. I believe someone brought up the question about fluoride impacts. Yes, they were be more on the drip shield than on the waste package and also on the cladding there is some dependence on fluorides.

VICE CHAIRMAN WYMER: Of course, these all are before any kind of evaporation.

MR. HOWARD: That's right. Well, this includes the effect of dryout, as you can see that we don't -- for the high temperature operating mode anyway. We don't have values during this period because of dryout.

VICE CHAIRMAN WYMER: You're not saying that this is the composition on the --

MR. HOWARD: Yes, you're right. You're talking about evaporative concentration. You're correct. Yes.

More of a summary information on the in-drift water chemistry. So the incoming seepage in our models reacts with the in-drift environment and what we see again here is that except for this several thousand year period, the pHs for high temperature operating mode and low temperature operating mode are fairly similar. They only differ by about one pH value.

The $CO_2$ concentrations. Again, as temperatures go up, $CO_2$ concentrations go down for the high temperature operating mode but as the system cools, they come back towards where they are for the low temperature operating mode.

VICE CHAIRMAN WYMER: But again, it would be wrong to consider that these are the conditions at the waste package. For example, the pH will drop substantially from iron corrosion.

MR. HOWARD: I believe these results do reflect some mixing with the in-drift corrosion products. I'll have to check on that.

VICE CHAIRMAN WYMER: Yes, you better check on that.

MR. HOWARD: Waste package general corrosion. We developed for the supplemental analyses a temperature dependent general corrosion model.

MR. HAMDAN: Somebody is trying to call us.

DR. GARRICK: Pardon?

MR. HAMDAN: Somebody from DOE is trying to --

DR. GARRICK: They're trying to get our attention? Does somebody from DOE Las Vegas want to make a comment?

MR. HOWARD: Is that Doctor Blink?

DR. BLINK: Rob, can you hear me?

MR. HOWARD: Yes, go ahead, Jim.

DR. BLINK: Slide 37, the chemistry, does ont include any interactions within the drift. The water chemistry is the water chemistry up in the near field rock just before it comes down through the dry out zone. The gas chemistry is at the drift wall. The next step in the model then equiliibrates those two.

MR. HOWARD: Okay. Thank you.

DR. GARRICK: Yes. Don't hesitate to speak up.

MR. HOWARD: Even if you're going to call your boss wrong.

DR. GARRICK: Especially don't hesitate to speak up.

MR. HOWARD: Thanks, Jim.

Waste package general corrosion. We did ask the waste package materials scientists to come up with a temperature dependent general corrosion model for alloy 22. One thing that we typically see in metal behavior is that as temperatures go down, corrosion rates tend to go down. Fortunately or unfortunately -- I think that is, I say, fortunately but it does make life difficult. When you do pick a material that's appropriate for the environment, it's difficult to get some of these effects in.

So whereas in the TSPA-SR where we use general corrosion data that was generated from the long-term corrosion test facilities at Lawrence Livermore, we did not see any temperature dependency in general corrosion rates of alloy 22. Nonetheless, we suspected that there might be one and so the analysts got some cyclic polarization measurements from UVA who was doing work for the project and we fitted a temperature dependency based on an arrhenius relationship so we could get some temperature dependency into these evaluations to find out what could be the effect if in fact over the years we find out that in fact there is a correlation between general corrosion rates and temperature.

So just to give you a little bit of insight into what that might look like, if we assumed average pressurized water reactor located in a central part of the repository so it had that thermal profile, it was in the hottest part of the repository, whether it was a high temperature operating mode or a low temperature operating mode, and assuming that corrosion started immediately upon inplacement, these are kind of the general effects that you would get as far as general corrosion rates. So if you're looking at a 20 centimeter thick or millimeter thick piece of metal, it would take you quite a while to corrode through the system under general corrosion conditions.

That's not the results that we show because we do have other issues that affect how waste packages fail. There's the microbial induced enhanced general corrosion rates and aging and phase stability as well as stress corrosion cracking. So waste packages in our analysis do fail at earlier times but this is just kind of a simplistic way of showing you what those temperature dependencies are and what they could mean as far as penetration into a waste package.

DR. GARRICK: On these curves where you show the 75 and 25th percentiles and the medians, what's the principle source of the uncertainty?

MR. HOWARD: It's uncertainty in the measurements.

DR. GARRICK: Uncertainty in the measurement. So it's information uncertainty.

MR. HOWARD: Yes.

DR. GARRICK: This doesn't have anything to modeling uncertainty in it.

MR. HOWARD: I don't know how I separate the two out. I mean as far as alternative conceptual models?

DR. GARRICK: Yes. Well, generally we think of uncertainty coming from two primary sources. One is information or data uncertainty and that can be broken down into several categories and then the other broad category is modeling uncertainty. I was just curious where this -- I would guess this is information uncertainty.

MR. HOWARD: Yes. We're going to have someone explain how stupid their boss is again. Go ahead, Doctor Lee.

DR. LEE: This is Joon Lee. For what Rob said about the uncertainty, he's right. It's all -- uncertainty. But for modeling uncertainty, in our actual modeling for general corrosion we took a conservative approach, i.e., we assumed the constant corrosion rate not depending on temperature --not depending on time. So in terms of modeling uncertainty, because we took the conservative approach, I don't think there is any significant modeling uncertainty in the results.

VICE CHAIRMAN WYMER: Well, I noticed in these other earlier curves where you had pH and concentrations and so forth, these chemistry parameters, you did not show any uncertainty and I was just curious as to whether or not that was accounted for in this as well.

DR. LEE: In terms of the data we have alloy 22 of a range of pH conditions and chemistry conditions, we haven't seen any noticeable dependency on those chemistry conditions. So for this temperature dependent corrosion model, we observed that from the -- data from University of Virginia, we did see some range of temperature dependency. This is why we came up with this model.

VICE CHAIRMAN WYMER: There's a fair amount of scatter in the actual experimental corrosion data. I'm surprised that your bounds are that close.

MR. HOWARD: Yes. In fact, in the analysis we did talk about some of that scatter. We have a different data set that we looked at. The first time we did it, we got an activation energy at around 66 kilojoules per whatever the units are. This one is 36 and we got another one activation energy that was 32. So dependent on the data set, you can get a difference in the rates.

For the 66 kilojoules -- what is the units for that?

VICE CHAIRMAN WYMER: Kilojoules per mole.

MR. HOWARD: Kilojoules per mole. There was one or two data points that seemed fairly inconsistent with what the other measurements were showing us and we did explain why we took those out and used the 36 kilojoules per mole.

VICE CHAIRMAN WYMER: This activation energy is down in the diffusion controlled region which is a little bit surprising.

MR. HOWARD: It's good material.

DR. LEE: This is Joon Lee again. The process of governing the general corrosion behaviors with such highly corrosion resistant materials could be the decision of -- kilic hours through that -- on alloy 22. So it is kind of consistent with what we understand of the general corrosion behavior of these materials.

VICE CHAIRMAN WYMER: The eight or nine kilic hours per mole, which is the units I used, being a little older than the rest of you, is generally diffusion controlled in an aqueous solution, not in films. But okay.

MR. HOWARD: So what happens to waste package failure rates when we implement this model along with the other changes we made with respect to stress corrosion cracking thresholds? What you see here is that these are the early failures represented. They're dependent on what the realization is. There's either zero, one or two failures.

If you noticed in the results that Bill put up earlier on the total system results out at these later times, doses for the low temperature operating mode were at one time step about an order of magnitude lower than they were for the high temperature operating mode and what you're seeing there is the difference in the failure rates at that particular time step and then they pretty much converge at much later time. So that difference right there is where you see the difference in the dose results.

Looking at the information in a slightly different fashion, these are temperature relative humidity trajectories for the high temperature operating mode and the low temperature operating mode and looking at how they intersect a so-called window of susceptibility for local or crevice corrosion.

In our analyses, there's another aspect of this window, if you will. It's actually a three dimensional plot and that is pH. So if you look at temperature chlorides and pH in the TSPA Rev. 0 and in the science and engineering report, we described a window of susceptibility for crevice corrosion based on potential for sodium chlorides, salts and where you can actually get an aqueous film on the waste package surface at a given temperature and relative humidity.

We expanded that out. There is some concern about the potential for an aggressive magnesium chloride environment that the waste package may see. And you can see that if you just consider temperature relative humidity and chlorides, the high temperature operating mode would be a little bit more susceptible to this localized attack than the low temperature operating mode. In our models, because of the pH criterion, none of our waste packages in the analysis fail due to localized corrosion.

But if you're looking for margin, you can screen out, if you will, the potential for this localized attack for the low temperature operating mode based on a temperature criterion only. For the high temperature operating mode, the argument is a little bit more difficult because you're looking at the pH as well.

VICE CHAIRMAN WYMER: You have the relative humidity reaching 60 percent at 3,000 years in high temperature operating mode. I thought it was something on the order of 1,000 years or even less than 1,000 years when it got up to 60 percent, or doesn't it make a whole lot of difference? You had another plot that showed it earlier. You may be getting up to about 60 percent at 1,000 years.

MR. HOWARD: Yes. If you look at probably somewhere on the top part of this curve. So that's 600 years at one end and then 3,000 at the other. So somewhere in there. It's an area. I'll try to get through these a little bit more quickly.

Waste form mobilization. We do have temperature dependcies in our models. They didn't typically tend to affect differences in the total system results, mainly because for most waste packages, when they're failing at much later times, the temperatures are fairly similar. So in package diffusion coefficients, there wasn't a strong temperature dependency there. We did have in-pack absorption in these models. Temperature dependency is uncertain. We can make kind of a qualitative analysis that says that higher absorption us likely at higher temperatures but we didn't really see those results.

Cladding creep is temperature-dependent but when you looked at the total creep, those effects were negligible. And then the clad unzipping rate goes up with higher temperatures but not dramatically so.

EBS transport. Temperature dependency there. The saturation of the invert obviously changes with the thermal profile. The diffusion coefficient changes with both the temperature and the saturation of the invert. Condensate thickness will change as a function of temperature. What that thin film is on engineer barrier surfaces. And the evaporation/condensation fluxes are somewhat different.

There is a negligible difference between the high temperature operating mode and low temperature operating mode, again because we don't see too many failures at early times when the temperatures or the differences are the greatest.

Doctor Boyle.

CHAIRMAN HORNBERGER: I think some of these results are because the transport through the invert is all by diffusion. Right? And so it's controlled by the concentration in the invert independent of what water is there.

MR. HOWARD: At early times, all the transport is diffused transport. As long as the drip shield remains intact. At the later times where you're seeing the higher doses, you do get effective releases.

DR. HINZE: All of these are without any backfill?

MR. HOWARD: That is correct.

DR. BOYLE: So Rob just went through a lot of Volume 1 and the various details and now I'm back to the system level which is described in Volume 2. I notice I forgot to ask the graphics people to actually label these figures. I mean they are the figure numbers and you can go and see what they are but this one upper left is the TSPA-SR. This one is the higher temperature operating mode and you can find out by going in at 3,000 years and 200,000 years and you'll find that the doses here are higher than there. Not by much. So the one lower left is lower temperature operating mode.

And this is the other figure that I offered as a candidate, again demonstrating my bias for comfort with TSPAs, that if you needed one figure and only one, one sheet of paper, this was the alterative. The other one was page 21 which took the means of these three figures which are the reds, the red curves, and plotted them all on page 21 in three different colors there. This red curve became black. This one stayed red and that red one became blue.

But what these figures demonstrate is some idea of the uncertainty but also you can get some insight into the conservatism. Back when all we had was TSPA-SR, our claim was look, we modeled it conservatively. We put in bounds in places. We didn't use all the available information. We left some of the uncertainty aside and modeled some things conservatively.

So without doing these calculations for

LTOM and HTOM, if our claim about this was correct, what we should have seen is what we ended up seeing, and that is that in general, other than for these early releases due to the improper heat treatment, our doses are less in these two cases compared to this but we also have the larger spread in uncertainties which is easiest to see at a million years, if you will. Here it spans a couple orders of magnitude, three orders of magnitude, if you will, whereas here we've got all the way from the bottom of the graph all the way up to -- you know, it's many more orders of magnitude because we added more uncertainty but also decreased our conservatism.

Bearing these results in mind, all three of them, the next two slides are slices through the information. What was done for this case is a vertical slice through those prior slides. Find for each HTOM and LTOM and the TSPA-SR and slice them at their time of peak mean dose and look at the distribution of all those horse tails. Plot up either as a histogram in the lower figure or as a CDF, cumulative distribution function, in the upper figure and, depending on how you -- these two figures show the same information. It's just a different way of representing it. And it's the same information as shown in the horse tail on the prior page and it's whatever we find convenient of understanding the results.

But this one shows it quite well. The very steep, cumulative distribution function shows not a great deal of uncertainty whereas the red and blue for the SSPA results, the shallower slope, shows a much greater uncertainty in the results. You can look at the values and the doses are less for the SSPA which gives some indication to the conservatism.

You can see it down here as histograms or if you wanted to, you could have quasi-probability density functions by just connecting the tops of the bars and creating PDFs, if you will, and you can see that the blue and red are very similar and shifted. They're much broader but also the peak is shifted to lower doses than the black which represents the TSPA-SR.

That represented a vertical slice at a time slice for the horse tail diagrams. And here was another way to gain insight. This is we slice the horse tail results at a given dose rate. Specifically at 0.1 millirems per year and again, we have them plotted up as cumulative distribution functions or as histograms. As you can see, this one is to 100,000 years only. We don't even have the blue and the red because they don't show up at this level until out at 200,000 years. But you can see again, these results are very similar to the vertical slice I showed on the prior page. The much broader spread in the blue and red. The increase in the uncertainty. The much narrower results for the black, the TSPA-SR.

And so our claims of conservatism were borne out for the changes that we made in the SSPA.

And these last slides are some words that deal with the major conclusion, and they're just words to match those figures I had shown, the supplemental model, which is the SSPA model, shows significantly wider ranges of doses at a given time or times to reach given doses. And we can represent quantitatively as we did with the histograms or the cumulative distribution function. It's the result of the additional uncertainties and updated models that were put into the SSPA model, and we did that by replacing simplified or bounding models, or data sets with new models. And some of those examples are the ones that Rob in particular and myself, I showed a few examples of them, but Rob showed many.

And the low and high temperature operating modes, they showed similar effects. You know, they look much more like each other than either one looked like the TSPA-SR.

Also, after the first 10,000 years this gets back to that meaning of the word conservative. And it seems as you can see on slide 21, but on that page the blue and red curves are significantly less than the black curve. And in that case since the black curve was giving higher doses, it was conservative. And so conservative with respect to the SSPA model, and that's right. The magnitude of dose is less for the SSPA model and occurs later in time.

And that difference on page 21, if you will, or it's in the horsetails on page 43 but you have to go to each of the three figures, at 30,000 years difference the mean estimate is about 3 orders of magnitude. And the time of the peck mean dose, the difference is about one order, but that's at the time of the peck mean dose for the SSPA, it's about one order of magnitude.

And then this last bullet gives the delays in reaching 0.1 milligrams per year and 10 milligrams per year.

And it is true at higher doses and later times, the low temperature operating mode appears to show lower and delayed doses. And Rob also showed it with respect to waste package failures, and that's actually what drove that. But when you compare the horsetail diagrams, you know, they look remarkably similar.

Now, during the period prior to 10,000 years the base case appears to be slightly nonconservative. The TSPA-SR appears to be slightly nonconservative with respect to the supplemental model if we define conservative as, you know, the ratio of doses, if you will. And in this the TSPA-SR had no doses prior to 10,000 doses. In the SSPA the doses prior to 10,000 years were .00006 milligrams per year for the low temperature operating mode and --

MR. HOWARD: That's three significant digits.

DR. BOYLE: Right. Right.

So it does raise the question of, you know, conservatism and how you want to define it.

All of these results to date that we're presenting where for the nominal case, no vulcanism. But I knew John Trapp was going to be here, so we put in some slides on vulcanism. And so the SSPA did deal a bit with igneous disruption. And in this case, again, this shows the results from the black dash is the TSPA-SR and the blue and red, the red's underneath the blue there and you don't see the difference out here until we get to ground water contribution. But the eruptive doses increase by about a factor of 20 to 25 and they dominate for, oh, approximately 10,000 years, more than 10,000 years. And the difference between the TSPA-SR and the SSPA were driven by changes in the biosphere dose conversion factors, wind speed, number of packages damaged.

And the interesting thing is is that if all you were interested in was well what's the peak whenever it occurred, the peak for the TSPA-SR is about $10^{-1}$ and for the SSPA it was $10^{-1}$, but there was a significant shift in time.

And for those that want to see all the horsetail diagrams, there they are. And, again, the SSPA HTOM and LPOM look much more like each other than either one looks like the TSPA-SR.

And this is my last slide. And what it lists here are some of the major things that drove those changes in system level performances. There was updated neptunium solubility, which we showed. The climate model produced changes, we didn't show that as a specific example here. Rob discussed temperature dependent general corrosion. This had a very strong effect and we also showed the effect of the early failure of a few waste packages, and Rob discussed that.

And in winding up, I do want to get across that we did try to be risk-informed, if you will, in particular with respect to what ended up in here. That when we -- as I've mentioned a couple of times already, that even before the SSPA when we were working on quantifying some of the unquantified uncertainties, when we met with the scientists and engineers, we always told them to focus on those things that they thought would have the biggest effect. You know, that were always -- most jobs in any discipline are limited by time and money. And so we wanted people to focus on those things that they thought had the most importance.

And as I showed in that nine page table as we progressed through these efforts from identification of an issue, to treating it at the process level, to including it as a sensitivity study and moving on to TSPA, things dropped out. And the things that dropped out were the ones that at that point seemed to have less impact. So we were always driven by trying to capture the most important items.

And then one last item it has to do with a discussion that came up this morning, and it relates to this clock, and it has to do with bounds. And I believe it may have been Dr. Levenson or Professor Hinze had identified that in the TSPA-SR, and actually probably in the SSPA itself is when we put in bounds, we haven't been entirely systematic about it. That one investigator may put in the bound at the 99th percentile or the 99.9 percentile and another may use three standard deviations out. Well, whatever it is, we were not systematic and thorough with respect to that and it does raise the question -- there's a number of questions.

If you're going to use bounds, they do come at a price, but they do have a benefit. As Tim McCartin had identified when you use a bound, you perhaps -- the benefit there is a savings of time and money. You know, that you just say well I'm not going to measure rainfall anymore, I'm just going to take it at 400 inches a year, and I know that it's nowhere near that, so I don't need to measure it anymore and we're done with it. But it comes at the prices, you know, an obfuscation of the importance of some of the other perimeters.

But given that we probably will continue to use bounds in the future, to some extent it raises the issue well is there a better way of doing it, you know, then perhaps we've done in the past. Is it appropriate, for example, that give instructions to the different investigators, no matter what field they're in, will always pick something three standard deviations out, or six standard deviations, or is there a better way. And if there is, what is that better way?

So with that, I believe we still have time for questions for Rob and myself.

DR. GARRICK: Okay. Thank you.

I think we'll ask each of the members, the consultant and staff, ACNW and NRC. Bill, do you have any questions?

DR. HINZE: Well, I think I've shot my wad with my performance assessment question, but on page 49 referring to the igneous disruption, did you do any sensitivity study to determine which were the major factors here? The change in the conversion factors, the wind speed and the number of packages damaged? And I'm wondering how much you varied the number of package damage per event?

DR. BOYLE: You know, that's a detail of the TSPA. But if it's anywhere, it's in chapter 4, I think, which volume 2 is much smaller. And I don't have --

DR. HINZE: Well, I'll just go to my CD-ROMs and search.

DR. BOYLE: Yes. I don't think we've got any TSPA analyst back east to help us out, and that was kind of the reason why.

DR. HINZE: Do you have any idea how many number of packages --

DR. GARRICK: Out west.

DR. HINZE: -- what the realization was, what the range of on the number of packages damaged per event?

DR. BOYLE: I believe it was on the order of 50 to 80, but I need to verify that.

DR. HINZE: That's all I have at this time. Thank you.

DR. BOYLE: Milt?

DR. LEVENSON: Yes, I have one comment about sort of your final statement about the use of bounding analysis because it saves a little money on analysis. The consequence of that conservatism is it means you install the drip shields when you didn't need them. You're talking about billions of dollars, and it's a little bit of false economy.

DR. BOYLE: That's a point well taken, and I just want to -- myself personally, as an individual, I am a proponent of using as few bounds as possible for myself.

DR. GARRICK: Ray?

VICE CHAIRMAN WYMER: I just had a point of understanding for myself, not anything more.

In your last viewgraph what is the new neptunium solubility data?

DR. BOYLE: Yes. That was -- I'll look up--

MR. HOWARD: Let Christine Stockman answer that.

DR. BOYLE: Oh, Christine Stockman is there?

MS. STOCKMAN: Yes.

DR. BOYLE: Well, there we go. Slide 22. Well, it was mentioned.

MS. STOCKMAN: Yes. The data there is the Argonne drip tests.

VICE CHAIRMAN WYMER: Okay.

MS. STOCKMAN: We also have another plot that shows the Wilson batch test as well.

So this is the neptunium concentrations in repository type condition tests.

VICE CHAIRMAN WYMER: So this is actual new experimental results?

MS. STOCKMAN: Actually, some of this is up to five years old, but yes.

DR. GARRICK: Yes, it's the use of experimental results that already existed.

DR. BOYLE: Yes. and this is a nonexpert. My interpretation is is that for good, bad or indifferent, you know, the instructions people took for the preparation of the TSPA-SR were to be conservative or bounding. And people interpreted that variably, and in this case it led, you know, and with no criticism, it led to somebody saying okay it's going to be that top curve, that's it. No uncertainly. I know it's a bound and it certainly does bound the data. And so they accomplished that.

And so as Christine has mentioned, some of the data is quite old, some of the board members recognize. So it's more just a different view towards how to model that data.

VICE CHAIRMAN WYMER: And again, it's a question of my understand on that same viewgraph, your last slide, viewgraph, whatever it was. You say the temperature-dependent general corrosion 700,000 year delay in peak dose. If you could explain that a little bit?

DR. BOYLE: Okay. In the TSPA-SR the

peak, it's easiest to see on slide 21, I think, is in the 200 something -- 200 some odd thousand years on slide 21, that black curve turns over. Whereas, the blue and the red they still haven't actually peaked at a million years. So that's the 700,000 year difference. It's from a peak on that black curve on page 21 at 300,000, let's say, or 270,000 out to close to a million years.

VICE CHAIRMAN WYMER: Okay. And the same explanation goes to 350,000 year delay and the 1 mrem/yr delay?

DR. BOYLE: Yes, right. Right.

VICE CHAIRMAN WYMER: Okay.

DR. BOYLE: Yes. That one you can get by slicing at specified dose rate.

VICE CHAIRMAN WYMER: Okay. I read it as something different and I couldn't quite see how you could by, say, running your temperature up you could shut the thing off 700,000 years.

DR. BOYLE: Yes.

MR. HOWARD: Again, there were other changes in the waste package model that went along with just the temperature dependent corrosion rates. And TSPA Rev. 0 for ICN-01 for the SR, the thresholds for stress corrosion cracking were considerably lower than the thresholds that we had in the SSPA, again, where we had given the analysts the instructions to be conservative, that was borne out in these results. So it's not just temperature general corrosion, there was another ways package failure.

VICE CHAIRMAN WYMER: I understand.

DR. LEVENSON: Can we make the general conclusion that since the high temperature and low temperature are closer to each other than either one of them is to the TSPA-SR, that it's things other than temperature that are making those changes?

DR. BOYLE: Yes, but actually that there are slight differences between the blue and the red, and those are attributable in --

DR. LEVENSON: Oh, yes, yes. But they're much less than the difference between either high or low and the black.

MR. HOWARD: Yes, that's correct.

DR. BOYLE: Yes, but it's my -- part of that large difference was driven by this temperature dependence and what in a -- in a gross sense imagine, if you will and Joon Lee could correct me for a long time, but to a nonexpert the way I imagined the way the results came out, the way they did with respect to the temperature dependence on corrosion was in the

TSPA-SR we had a conservative value that had no temperature dependence in it. It was a flat line. And then we replaced it with something that had a slope that, you know, at the higher end of that sloped line we have corrosion rates at higher temperatures. But it also brought along much lower corrosion rates at lower temperatures, which is where we spent 99.9 percent of our time. So it was even that temperature dependence that did drive these results. But it wasn't the hot versus cold so much as just putting in a temperature dependence.

DR. LEVENSON: Yes, that's what confused me a little bit, your use of the term temperature dependence.

DR. HINZE: Yes, you just changed the model.

DR. BOYLE: Right. That's true.

MR. HOWARD: The other issue on waste package performance was, again, with the TSPA-SR we used 20 to 30 percent of the yield strength as distress thresholds for initiating stress corrosion cracking. And the supplemental analysis we looked at 80 percent. That was a dramatic difference there on the order of about 40,000 years before you could see those kinds of effects.

MR. LEE: Well, Rob, let me do that one. This is Joon Lee.

And the 20 to 30 percent used in SR is based on -- rate that there are in absence of project Alloy 22 data. That 80 to 90 percent used in SSPA is actually just for project data for Alloy 22 for repository 11 exposure conditions. So that is the big difference in terms of the quality of data.

VICE CHAIRMAN WYMER: That's all I have.

DR. GARRICK: George?

CHAIRMAN HORNBERGER: So, if we scaled the unquantified uncertainties or conservatisms, or whatever you want to call it, for TSPA-SR and so that they were 100, where do we stand now with SSPA? Have we gotten 25, 50 or 75 for those? See what I'm saying? How much is left?

DR. BOYLE: Yes. You know, that's in a sense in some ways a moving target. You know, the PIs always want to make it nicer and better, you know. I would hate to put a number on it.

MR. HOWARD: I'll do it. What do we have left, maybe 25 plus or minus 100.

CHAIRMAN HORNBERGER: Yes, it's those PIs that get you.

MR. HOWARD: No, it's a good question but it becomes philosophical. I mean, at what scale do we want to get the uncertainties in? Do we want to get them in at the macro scale, the micro scale, what degree of coupling do we want to get into. I mean, as far as understanding the risks, I'll be less fictitious and say, you know, I think reasonably we're all there but about 20, 15 percent. The question is how much do we really want to go after that and will we get additional insight? I mean, I don't want to say that here's the real answer, those results should never be looked at that way. But are we going to get more insight into how the system behaves, you know, that's a different question.

DR. GARRICK: If I thought you were really that good, I would be very reassured. But where we have probably done more comprehensive risk assessment than anywhere else is in nuclear power plants. And we're nowhere near calculating core damage frequencies within those kind of ranges.

The uncertainties between the 5th and 95th percentile on a core damage frequency, particularly if we account for both information and modeling uncertainty, is ever so much greater than what you're saying you've achieved on something where I just don't think you're anywhere near in terms of supporting evidence that we have in calculating core damages.

MR. HOWARD: Then I guess I didn't understand the question. You're looking at do I think that this range of uncertainty in these results is going to get wider or smaller? That's obviously not the question that you're asking.

DR. GARRICK: Well, I guess that's not the way I'm interpreting it.

MR. HOWARD: Okay.

CHAIRMAN HORNBERGER: Well, the question I think that -- the way I meant to frame it, and I obviously wasn't very precise, what we saw was very, very large differences between TSPA-SR and SSPA. A couple of orders of magnitude on peak dose. Are there are a couple other orders of magnitude left in there? That is if in fact are there other unquantified uncertainties that if you went in and quantified them in much the same way you've done here, would the calculated doses drop another couple orders of magnitude.

DR. BOYLE: Yes. And that gets back, it's possible. And I say that because a lot of the quantification of uncertainties that happened in the SSPA was the addition of a model where we didn't have anything before. You know, we had a constant value or just didn't even represent the phenomenon at all. And so, given, you know, our investigators could keep coming up with more and more models which might tend to keep driving the results down and to the right. And it's possible that they would go lower and lower, and further out and further out in time. It's whether it would be one order of magnitude or two. It's hard to say.

But an interesting observation I'll make is all these plots are always on with log-log scales, which can be quite. They're quite informative, there's no doubt about it. But if you take the same results and plot them linear-linear, I mean, it becomes -- if we had some of these results linear-linear, particularly results in the 10,000 year time frame, the period of regulatory compliance, we're already on the zero axis and there's no sense in going any lower.

DR. GARRICK: Yes. George?

CHAIRMAN HORNBERGER: Yes. I had heard somebody told me that the SSPA was not done under your quality assurance program. Is that correct?

MR. HOWARD: No. No, that's not correct. No, it's not correct. We did follow our QA program. We did not use the same controls that we used for the

AMRs and PMRs that supported the TSPA-SR. So to use the collegial term, we grade it based on what it was that we were trying to accomplish.

We did prepare, review and approve these documents in accordance with our technical report procedure. What we didn't do was go in and qualify all of the data that we needed to do, quality all the codes that we had to change to implement some of these new models. We didn't do that work because we didn't feel like that was appropriate for where we were in the program and what we were trying to accomplish with this particular set of analysis. But we did use a QA program, it's just a different set of controls.

CHAIRMAN HORNBERGER: What was it that you were trying to accomplish? You said it wasn't appropriate for what you were trying to accomplish. What was it succinctly that you were trying to accomplish?

MR. HOWARD: Well, I'll go back, I guess it was Bill's slide 3. You know, to quantify the uncertainties. The updates and the scientific information we wanted to put in -- the updates and the scientific information we wanted to capture new results, because some of the results that were incorporated into the TSPA-SR were, you know, getting to be about a year old and we wanted to have additional information as we went into the site recommendation process.

And then the comparison of the thermal operating modes, you know, we made some pretty serious assumptions about a design configuration to get us an initial condition. We didn't go in and analyze a design or an operating mode that was specified by the designers because we weren't interested in that particular aspect. We recognized that if we were going to carry this stuff into a license application, we'd have to specify more details of the design, all of these analyses would have to be redone and the information would be updated and incorporated into the baseline.

DR. BOYLE: You know, Rob and I have had this question within the project, actually. And on slide 3 when I presented it earlier today I mentioned that, you know, the purpose of the document was taken from the technical work plan for the document. And Section 18 of that technical work plan, I think it goes on for about two pages, it provides a description of the special quality assurance controls that we applied to the work effort. And, you know, the rational and everything behind them. And the fact that we could apply special QA controls is allowed for by the procedures.

Whenever Bechtel/SAIC goes to do any work,they need to fill out a form and they need to check whether it's, you know, it effects this or that or this and that. And down at the bottom of that form it says oh by the way, if you're going to apply special QA controls, document it in Section 18 of the technical work plan. So, it's all provided for by procedures. Perhaps it's not used that often, but it was done according to the requirements of the QARD. But as Rob has said, the quality level of some of the inputs and analyses is not the same as in the AMRs and PMRs, but we know that that difference exists and it was written explicitly in the technical work plan that for those things that aren't of appropriate quality, if we were to ever take them forward in a license application -- of course, we're aware that --

CHAIRMAN HORNBERGER: Okay. I think that's all for now.

DR. GARRICK: Okay. The reason the Committee keeps pushing and sort of harping on this question of conservatism is that it's the Committee's view that somewhere along the lines there needs to be an assessment that we all have confidence in that indicates this is the best shot at what the experts actually think will happen. And then if we can convince ourselves that it has solid scientific and technical basis and makes sense, then we're in a position to talk about something that we can use as a baseline against which to deal with the question of well how much of a safety margin should we put on this estimate. And that's very hard to do when the analyses is based on a mix of bounding analysis, conservative assumptions and distributions. And in some cases, even the distributions are qualified as being conservative distributions, which is even more vague and confusing than a bounding value or a conservative number.

So, the protocol that seems to be evolving in the risk business as to what constitutes a risk assessment is an assessment that is the expert's best shot at what they expect to happen. And we get the feeling, to be sure, the TSPA-SR was not that. And so it seemed to be more of a aiming at compliance rather than trying to deal with the other less prescriptive of aspect of compliance, which is that it must also be risk informed.

So, that's one of the reasons we press this issue very hard. It makes it much easier to deal with the question of well, what else do we need to put on this in terms of defense in-depth or safety margin to feel that we have adequately complied with the fundamental requirements of the Act and the rules.

The other thing that we look for very hard, and I think the Supplemental Science and Performance Analysis does a much better job of that than the TSPA, but there are still problems, is trying to establish a real strong linkage between the model and the analysis that's performed and the supporting evidence and to see just exactly where the information basis is pretty solid and supports what's been done and where it isn't, and whether or not the computations having to do with uncertainty are consistent with that.

And that linking of the evidence with the analyses was pretty difficult. I think that's one thing that makes these analyses ever so much more transparent and scrutable is if you can make the strong connection. You know, we talk about expert opinion or expert elicitation; that's not what we're interested in. What we're interested in is what is the basis of the expert's opinion and what is the supporting evidence for that.

So, when we looked at the TSPA-SR we were struggling with trying to provide that linkage in some cases.

One of the other things that's kind of bothered me about this whole process is that we keep talking about different sources of evidences, different lines of evidences. And I sometimes get the feeling that what's getting on here is that you have lines of evidence space and you draw a thin diagram here and you say this the TSPA and this is something else in order to display the fact that you have different lines of evidence and are not totally dependent upon the TSPA. It seems very arbitrary. Of course, this is a view I've never understood with respect to the TRB as what their hangup here is on the TSPA. Because anything you can do over here in this space, you can do over here in this space and call it part of the TSPA.

So there's been some confusion about these various documents that you have; the engineering document, the TSPA document, the Supplemental Science document and just exactly how they are connected together. And we had a presentation from Carol Hanlon on that, and that helped a great deal. But to me all I see is a performance assessment and all of these contribute to the credibility of that performance assessment.

As far as additional questions, I wanted to -- well, I had some questions about data, but I don't think I'll get into them because they're pretty detailed and I'll do those at another time. We are going to have some discussions tomorrow on TSPA, and another opportunities to deal with them.

So maybe what I ought to do, given the time of day, is first ask if there's any questions on the part of the staff and then we'll go to the NRC staff.

Yes, Latif?

MR. HAMDAN: Yes. My comments also pertains to the supporting evidence that Dr. Garrick talk about. And since the supporting evidence played some role in the SSPA I have two questions. A: Can you tell us what percentage of the concepts and the assumptions and the SSPA differences between was corroborated by natural analogs or some other evidence? And B: Was there was case where the evidence actually refuted some of the assumptions or concepts you had that caused you to change the TSPA?

DR. BOYLE: Do you want to try?

MR. HOWARD: I'll give it a try. As far as an exact percentage of what was supported by these other lines of evidence, the information wasn't organized in such a manner that it would make, you know, such a ratio all that meaningful.

We did in every section of volume 1 that was relevant to one of the expected processes at Yucca Mountain sections 3 through 14 try to discuss other lines of evidence that touched upon what the analyses were that we were presenting. And in some cases the same line of evidence may have been true for a couple of processes in the rock as it was for a couple of processes in the drift. So, we used it in different areas of the analysis. So, that would make that percentage calculation somewhat confusing. But we did try to cover it in every area.

With respect to finding lines of evidence that would refute our analysis, there isn't any in the SSPA. That's not to say that there isn't any out there in the literature or the world. We just didn't get into this document. We're still looking for it. I mean, we need to look at it. We need to consider alternative conceptual models, alternative interpretations of data, alternative analogs.

So we recognize that the effort can't be bias towards or just present everything that would support your analysis. It also means looking at stuff that might be contrary to it. In fact, that may manifest itself in the uncertainty of the process models that we apply.

MR. HAMDAN: Okay. May I have a brief follow-up?

DR. GARRICK: Sure. Go ahead.

MR. HAMDAN: Maybe that's where part of the problem is. I appreciate what Bill, you know, the bias that Bill had, his performance and his slides 21 and 43, that's great. And I understand it. But it seems to me that for the public and for that matter in NRC the emphasis should be on the evidence and then it what it supports and what it doesn't support. And this seems to be -- we talk about it and NRC talks about it, DOE talks about it but -- and I'll just suggest that it might be worthwhile for DOE to give -- I mean, to put a little time in this time to give a presentation on the supporting evidence and see where you stand on it.

MR. HOWARD: Yes. I guess my view of it, and I have my own personal conceptual difficulties in separating out what these other lines evidence are separate from the performance assessment. And, again, trying to get information to people who want or need to understand it, you do have to package it differently for different audiences. And I think that's part of the problem we're confronting with these analysis.

To give you an idea, you know, the supporting information, and Bill's maybe more bias towards TSPA results, but the majority of our effort went into the supporting analysis that -- I was able to take volume 2 with me on the plane. It's a rather thin document. Volume 1 is about 1500 or 1600 pages it takes two big three ring binders to carry around double sided copies.

So, our emphasis was placed on the supporting process level analyses. And I think that, you know, what I have seen with the review process in the KTIs is that the waiting on what the NRC staff seem to be interested in, they look at that supporting information. And I think Tim said it earlier, he's got to be able to understand what's behind it. It's not a trivial exercise and we can't ever seem to manage to, you know, make it so that it's easy for everybody to understand in one particular kind of document just because audiences are so varied. But we do have supporting information for it, it's just that people always want to say "well, give me the bottom line."

DR. GARRICK: All right. I want to give the NRC staff an opportunity to ask questions or raise a comment, or whatever. Anybody? Yes.

MR. AHN: Tae Ahn, NRC.

Well you're going to have a long list of questions to be discussed in the coming low temperature technical exchange, however I have a few clarification questions. One is regarding the neptunium solubility measurement. You took data from -- testing -- basically derived Arrogone -- searching well water, correct?

MR. HOWARD: Christine, are you still there?

MS. STOCKMAN: Yes, that is correct. The Argonne tests are equivalent to -- water.

MR. AHN: Okay. The second question is the uniform corrosion rate from the immerse tests, that again was derived from four representative chemistry, solution chemistry you have. It's not any test from -- solution from --

MR. HOWARD: The temperature dependent corrosion data?

MR. AHN: Yes.

MR. HOWARD: Dr. Lee?

MR. LEE: Yes. The temperature-dependent

model is the combination of the data -- data from long term testing facility in which case we have full represent table of chemistry solutions there.

MR. AHN: Okay. That's what I meant.

MR. LEE: Yes.

MR. AHN: Okay. The last one is what is the reason you did not see the temperature effect from the immersion test? Do you have any idea?

MR. LEE: Our understanding is that the data from long term testing facility, again, is based on weight loss measurement. For Alloy 22 the corrosion rate is so low the weight loss is very insignificant over the time, you know, after two years. So that basically it's kind of a insensitivity over measurement technique.

MR. AHN: Okay. Okay. Thank you.

MR. DAM: This is Bill Dam, NRC.

As you know, the NRC comments on SSPA are forthcoming, but I just wanted to remind or mention that we've had various technical exchanges and agreements and one of the agreements or the technical exchange we had the nearfield environment in January mention was made today about Eric Sonnenthal's work on thermal chemical processes and the fact that THC processes are not a part of the modeling.

One of the agreements we have at that meeting was to supply us with the code -- which is the Berkeley model they're using to do those THC calculations. And as I recall, the agreement was that they would supply that code in February about a month later. I think it's gotten hung up in some licensing agreements or something. But for us to look and see those results, it's important for us to have the tools to do that. Having that code is very important.

I would just like to encourage you to maybe let the DOE know that --

MR. HOWARD: Message received.

MR. DAM: Message received. Thanks.

DR. GARRICK: Any other questions from the audience? All right, George. Oh, excuse me.

DR. HINZE: May I ask a question?

DR. GARRICK: Yes, Bill?

DR. HINZE: How close are we to coming to closure on the thermal mechanical hydrologic couple processes? Is this a closed-pending, or is this a closed? And if we're in a closed-pending, how far are we away from closing?

MR. HOWARD: I think that in general it's closed-pending, but there's quite a few agreement items that we have to deal with. One was just mentioned. So we're doing work to meet the agreement items. I don't have my tabulations.

DR. HINZE: Is there a time frame on that? Is there a time frame?

MR. HOWARD: Our agreement items, some of them, and they vary, have you know specific dates where others have dates that say prior to a license application.

DR. HINZE: Because of the significance of this to the temperature operational mode, these items are very critical and especially whether we're 90 percent of the way there or whether we're only 30 percent of the way there.

DR. GARRICK: Thank you. Thank you very much. Excellent presentation and discussion. We appreciate it very much.

CHAIRMAN HORNBERGER: Thanks Bill and Ron.

MR. HOWARD: I do have extra CD-ROMs of volume 1 and volume 2 of the SSPA. I don't want to carry them back with me.

DR. GARRICK: Yes. Because my CD only works about halfway.

DR. BOYLE: And for those of you that don't get one of these from Rob, you can always contact us and we can get you more CDs. But if you can't wait and you have a high speed Internet access, it's all available at our website. www.ymp.gov.

CHAIRMAN HORNBERGER: We're going to take a fifteen minute break and reconvene just before 4:00, a couple minutes before 4:00.

(Whereupon, at 3:45 p.m. the meeting was adjourned.)

## CERTIFICATE

This is to certify that the attached proceedings before the United States Nuclear Regulatory Commission in the matter of:

Name of Proceeding: Advisory Committee on Nuclear Waste

Docket Number: (Not Applicable)

Location: Rockville, Maryland

were held as herein appears, and that this is the original transcript thereof for the file of the United States Nuclear Regulatory Commission taken by me and, thereafter reduced to typewriting by me or under the direction of the court reporting company, and that the transcript is a true and accurate record of the foregoing proceedings.

Rebecca Davis

Rebecca Davis
Official Reporter
Neal R. Gross & Co., Inc.

# Process For Developing Potential Preliminary Comments On The Sufficiency Of Department Of Energy Information

Presented to:
**Advisory Committee On Nuclear Waste**
**10:30 – 12:00 PM**
**August 28, 2001**

Presented by:
**Jeff Ciocco, 301-415-6391, jac3@nrc.gov**
**Division of Waste Management**
**Office of Nuclear Material Safety and Safeguards**

# Objective Of This Presentation

- Provide an understanding of the process preparing the potential U.S. Nuclear Regulatory Commission's (NRC) preliminary comments and where we are today

# Outline of Presentation

- Present the completion schedule for the potential comments
- Describe what the NRC is required to do
- Describe how the NRC is preparing potential preliminary comments
- Describe the basis for NRC's potential comments
- Present the path forward to produce NRC's potential preliminary comments
- Compare the NRC's Viability Assessment comments to Issue Resolution status
- Summarize

# Preliminary Comments Completion Schedule

| | |
|---|---|
| • August 28 | Advisory Committee on Nuclear Waste Presentation |
| • September 5 | Igneous Activity Technical Exchange, Las Vegas, Nevada |
| • September 6-7 | Quality Assurance Management Meeting, Las Vegas, Nevada |
| • September 13-14 | Range Of Thermal Operating Modes Technical Exchange, Las Vegas, Nevada |
| • September 14 | NRC Concurrence Process Begins |
| • November 1 | Preliminary Comments to the DOE |

What We Are Required To Do

# Reading the Act

- By Section 114(a)(1) of the Nuclear Waste Policy Act, "Together with any recommendation of a site under this paragraph, the Secretary shall make available to the public, and submit to the President, a comprehensive statement of the basis of such recommendation, including the following:"

- By 114(a)(1)(E), **we are required to provide** "preliminary comments of the Commission concerning the extent to which the at-depth site characterization analysis and the waste form proposal for such site seem to be sufficient for inclusion in any application to be submitted by the Secretary for licensing of such site as a repository"

How We Are Preparing Potential Comments

# Interpretation of the Act

- Interpretation of "**preliminary comments**"
  - contrasts the preliminary comments from the final decision made on the adequacy of the DOE's information in a possible license application
  - means no pre-judgment of matters which can only be decided in a construction authorization decision
  - means the preliminary comments do not become final
- Interpretation of "**at-depth site characterization analysis**"
  - means evaluating features, events, and processes below the ground surface

How We Are Preparing Potential Comments

# Interpretation of the Act (continued)

- Interpretation of "**waste form proposal**"
  - means the design, selection, and evaluation of components of the engineered barrier system
  - components of the engineered barrier system include waste form, waste package, cladding, drip shield, and drifts
- Interpretation of "**seem to be sufficient for inclusion**"
  - means the data and approach are appropriate
  - means we accept the DOE's plans and schedules to collect added information
  - means there will be enough acceptable information for inclusion in a potential license application
  - means we could conduct a safety evaluation of the potential application with the information
  - includes DOE's consideration of quality assurance program

How We Are Preparing Potential Comments

# Using The High-Level Waste Safety Evaluation Process

- Issue resolution is the key tenet of the high-level waste review process
- Issue Resolution Process utilizes
  - performance assessment analyses
  - preclosure safety analyses
  - issue resolution status reports
  - independent investigations
  - public technical exchanges with the DOE
- Issue resolution process was basis for NRC's June 1999, Viability Assessment comments

How We Are Preparing Potential Comments

# Subject Matter of Potential Preliminary Comments

- Repository Safety Before Permanent Closure (Preclosure) evaluates
  - waste form characterization (burn-up levels of fuel)
  - waste package design (thermal design, welding flaws, design drop height)
  - subsurface designs and design analyses (seismic loading)
- Repository Safety After Permanent Closure (Postclosure) evaluates
  - multiple barriers (identification and description of barriers)
  - scenario analysis (sufficient range of features, events, processes)
  - 10 model abstractions (sufficient data and analysis, or plans)
- Quality Assurance
- Expert Elicitation (procedural acceptability)

How We Are Preparing Potential Comments

# Applying Prelicensing Issue Resolution Results To Potential Comments

- Potential comments build on continuing prelicensing activities
- Issue resolution technical exchange agreements are the basis for the preclosure and postclosure draft comments
- Issue resolution status corresponds to defined potential comments:

| **Issue Resolution** | | **Potential Preliminary Comments** |
|---|---|---|
| • Closed: No additional information needed for licensing decision<br>• Closed-Pending: Department of Energy approach and agreements to provide information for licensing decision | ⇔ | • Areas That Appear To Have Sufficient Information And Areas For Which DOE Has Agreed To Obtain Additional Needed Information |
| • Open: Department of Energy has not addressed questions or agreed to provide information for licensing decision | ⇔ | • Areas That Appear To Need More Information |

Basis for the Potential Preliminary Comments

# Issue Resolution Process

- The goal of the issue resolution process is to resolve the postclosure and preclosure performance issues prior to DOE submitting a potential license application

- Issue resolution at the staff level is reached when
  - DOE's approach and available information acceptably address staff questions, and
  - no information beyond what is currently available will likely be required for regulatory decision making at the time of any future license application

Basis for the Potential Preliminary Comments

# Approach to Risk-Informing The Issue Resolution Process

- Risk insights gained through the performance assessment analyses provide the basis for the areas discussed at the Issue Resolution Technical Exchanges
- The agreements reached during the technical exchanges form the basis for the path forward and represent those items determined by both the DOE and staff analyses as important to repository performance, safety, and waste isolation
- Scenario analysis is an example of risk-informing the issue resolution process
  - scenario analysis is designed to focus on those features, events, and processes most important to performance
  - screening either on grounds of low probability or low consequence is a way to risk-inform the process

Basis for the Potential Preliminary Comments

# Results Of Issue Resolution

- Staff and the DOE conducted numerous public meetings this past year on issue resolution
- As of August 2001,
  - the consequences of Igneous Activity remains open
  - the implementation of the DOE Quality Assurance Program is undergoing enhanced review and evaluation, and
  - the NRC is currently reviewing the Supplemental Science and Performance Analyses report to determine if there are impacts to issue resolution
- Additional meetings are scheduled in September to discuss Igneous Activity, the Range of Thermal Operating Modes, and Quality Assurance

## Basis for the Potential Preliminary Comments

# Igneous Activity

- Probability of Igneous Activity is closed pending
  - DOE agrees to provide a single point sensitivity analysis using a probability value of $10^{-7}$ a year
  - DOE agrees to perform an analysis of new aeromagnetic data to decide the presence of more buried igneous bodies in the site area

- Consequence of Igneous Activity is open
  - NRC expects DOE to provide plans to address consequence of Igneous Activity at the September 5th Technical Exchange
  - DOE needs more information to support assumptions for magma interactions with the repository, waste package, and waste form

Basis for the Potential Preliminary Comments

# Igneous Activity (continued)

- DOE only evaluates a limited set of physical processes that occur during basaltic igneous events

- DOE needs to consider more directly physical processes for the interaction between magma and the repository drifts, engineered barriers, and waste forms, specifically
  - number of drifts affected by the magma
  - waste packages and waste forms affected by the magma

Basis for the Potential Preliminary Comments

# Quality Assurance Program

- DOE is preparing a Corrective Actions Plan to address the quality assurance problems identified below
- NRC will evaluate the acceptability of DOE's approach for its Corrective Actions Plan at the Quality Assurance Management Meeting on September 6, 2001
- Problem areas identified in 2001
  1. model validation
     - DOE found inadequate model validation supporting reports, such as the performance assessment
     - previous corrective actions not effective
     - DOE issued a Corrective Action Report for failure to follow applicable procedures
  2. technical inconsistencies
     - NRC identified inconsistencies between the performance assessment for site recommendation and model reports, computer codes, and hand calculations

Basis for the Preliminary Comments

# Quality Assurance Program (continued)

3. software controls
   - DOE issued a Corrective Action Report for software controls in June 2001
- DOE follow-up actions underway

- Status of issues pertaining to prior (1998-1999) Quality Assurance problems
  - DOE has completed all corrective actions except for confirming the adequacy of data and software
  - DOE follow-up actions remain ongoing

# Comparing Viability Assessment Comments to Issue Resolution

- Viability Assessment comments of June 1999 identified the following areas needing more information for inclusion in potential high-quality license application
  - repository design
  - waste package corrosion
  - quantity and chemistry of water contacting the waste packages and waste forms
  - saturated zone flow and transport
  - volcanic disruption of waste package, and
  - quality assurance
- The issue resolution process identifies
  - the consequences of Igneous Activity as open
  - the implementation of the DOE Quality Assurance Program under enhanced review and evaluation, and
  - the ongoing NRC review of the Supplemental Science and Performance Analyses report to determine if there are impacts to issue resolution

# Path Forward

- Finish reviewing the Supplemental Science and Performance Analyses Report
- Conduct a limited review of the Preliminary Site Suitability Evaluation
- Conduct the Igneous Activity and Range of Thermal Operating Modes technical exchanges and the Quality Assurance management meeting
- Finalize the potential preliminary comments
- Deliver the preliminary comments to DOE by November 1, 2001

# Summary of Preliminary Comments

- A lot of work remains reviewing DOE reports and conducting technical exchanges and other meetings
- We are on schedule to deliver potential preliminary comments to the Commission and the DOE

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

YUCCA MOUNTAIN PROJECT

# Update on the Supplemental Science and Performance Analyses

Presented to:
**Advisory Committee on Nuclear Waste**

Presented by:


**William J. Boyle**
**Advisor, Office of Licensing and Regulatory Compliance**
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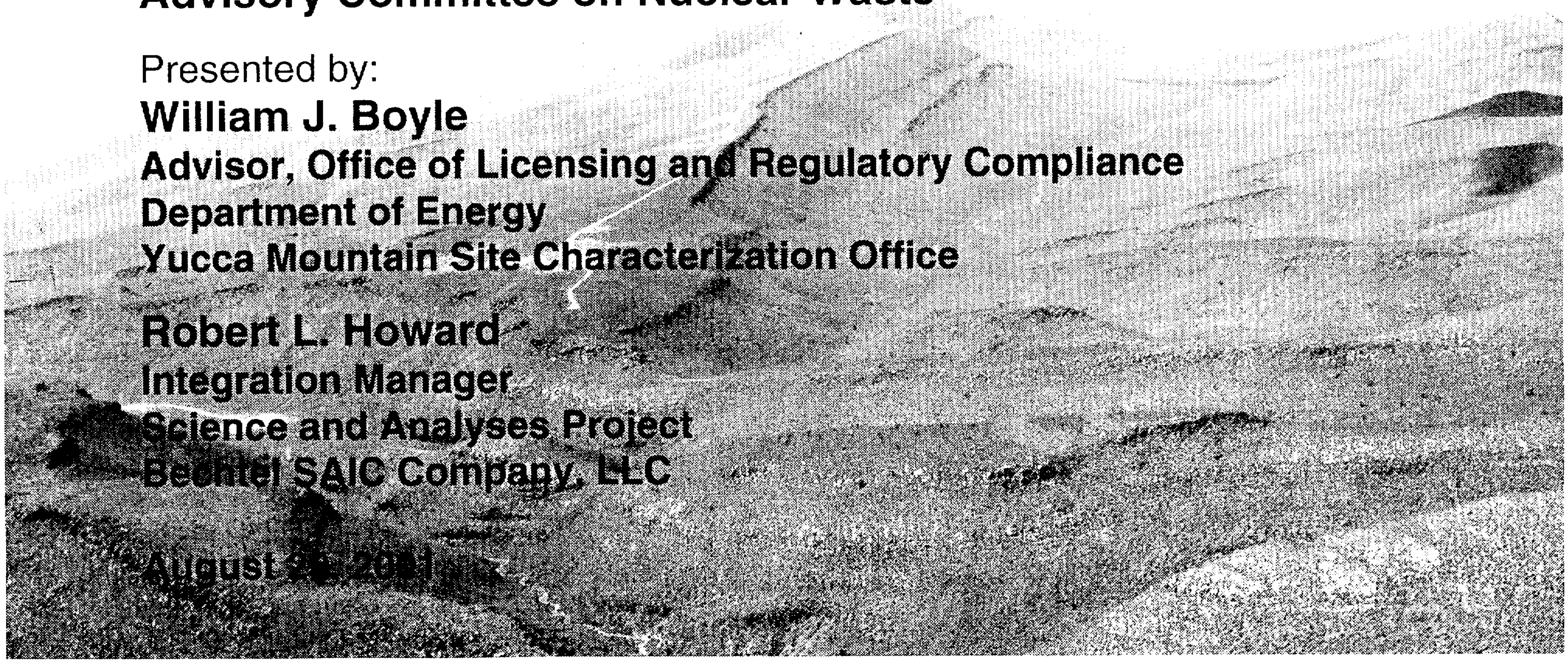

**August [illegible], 2001**

# Outline

- Overview of Volumes 1 and 2, FY 2001 Supplemental Science and Performance Analyses
  - Purpose
  - Contents
- Results
  - Volume 1
  - Volume 2
- Conclusions

# Supplemental Science and Performance Analyses - Purpose

- **Document new results for**
  - Quantification of uncertainties and conservatism
  - System and subsystem sensitivity analyses
  - Evaluating the effects of coupled processes over a range of thermal operating modes
  - Summarizing multiple lines of evidence
  - New science

# Supplemental Science and Performance Analyses - Content

- **Supplemental Science and Performance Analyses Volume 1**
  - Unquantified uncertainty analysis
  - Update in scientific information
    - New data, analyses and models
  - Cooler thermal operating mode analysis
- **Supplemental Science and Performance Analyses Volume 2**
  - Performance assessment sensitivity analyses
  - Supplemental Total System Performance Assessment (TSPA) model
    - High Temperature Operating Mode (HTOM)
    - Low Temperature Operating Mode (LTOM)

# Scope of Supplemental Science and Performance Analyses

## Three General Types of Information

- **Unquantified uncertainties analysis**
  - Specific uncertainties that were not treated explicity in the Analysis and Process Model Reports supporting the Yucca Mountain Science and Engineering Report have been quantified including parameter bounds, conceptual models, assumptions, and in some cases input parameters consisting of statistically biased or skewed distributions
- **Updates in scientific information**
  - This includes new experimental results, new conceptual models, new analytical approaches, and the identification and discussion of multiple lines of evidence

# Scope of Supplemental Science and Performance Analyses

## Three General Types of Information

(Continued)

- **Thermal operating mode analyses**
  - **Includes process level information regarding thermal dependencies; how the process responds to a range of thermal inputs and the impacts on uncertainty in process level results**

# Approach to Evaluating Significance of Uncertainty and Conservatism/Optimism

- **Conduct component-level sensitivity analyses**
  - Documented in Volume 1
  - Include other lines of evidence, as appropriate
- **Conduct system-level one-off sensitivity analyses**
  - Variants of the sensitivity and barrier importance analyses documented in Total System Performance Assessment-Site Recommendation Rev 00 ICN 01
  - Use the Rev 00 ICN 01 Total System Performance Assessment-Site Recommendation Model, i.e., the warm thermal operating mode, as the basis for comparison
- **Combine component models into a supplemental Total System Performance Assessment model**
- **Evaluate sensitivity to thermal operating mode by using different thermal-hydrologic analyses inputs**

# Reasons for Not Including Supplemental Science in the Supplemental Total System Performance Assessment

- **Revised model determined to have low probability of occurrence**
- **Model is determined to be insignificant at the component level**
- **Model is determined to be insignificant at the system level**
- **Model is sufficiently uncertain and inclusion would be non-conservative**
  - **Drift shadow concentration boundary**
  - **Ex-package transport to invert**
  - **Unsaturated zone transport model**
- **Model is still conceptual**

# Examples of Supplemental Science Not Included in Supplemental Total System Performance Assessment

- Unsaturated zone flow fields
- Uncertainty in aging and phase stability of Alloy 22
- Defense high-level waste degradation rate
- Colloid mass concentration
- Drift degradation effects on seepage
- Unsaturated zone transport model

# Examples of Supplemental Models Included in Supplemental Total System Performance Assessment

- Long-term climate and net infiltration
- Seepage (including lower lithophysal model)
- Waste package degradation
  - Stress corrosion cracking model
  - Weld stress, stress state, and defect geometry
  - Improper heat treatment
- In-package chemistry
- Cladding

# Examples of Supplemental Models <u>Included</u> in Supplemental Total System Performance Assessment

(Continued)

- **Solubility**
- **In-package transport**
- **In-package and engineered barrier system retardation**
- **Saturated zone alluvial properties and matrix diffusion**

# Summary of Supplemental Models and Analyses

| Key Attributes Of System | Process Model (Section of S&ER) | Topic Of Supplemental Scientific Model Or Analysis | Reason For Supplemental Scientific Model Or Analysis: Unquantified Uncertainty Analysis | Reason For Supplemental Scientific Model Or Analysis: Update in Scientific Information | Reason For Supplemental Scientific Model Or Analysis: Cooler Thermal Operating Mode Analysis | Section of Volume 1 | Performance Assessment Treatment Of Supplemental Scientific Model Or Analysis[a]: TSPA Sensitivity Analysis | Performance Assessment Treatment Of Supplemental Scientific Model Or Analysis[a]: Included in Supplemental TSPA Model |
|---|---|---|---|---|---|---|---|---|
| Limited Water Entering Emplacement Drifts | Climate (4.2.1) | Post-10,000-year Climate Model | | X | | 3.3.1 | X | X |
| | Net Infiltration (4.2.1) | Infiltration for post-10,000-year Climate Model | | X | | 3.3.2 | X | X |
| | Unsaturated Zone Flow (4.2.1) | Flow in PTn | | X | | 3.3.3 | | |
| | | 3-D flow fields for cooler design; flow fields for post-10,000 yr climate, lateral flow; variable thickness of PTn; fault property uncertainty | | X | X | 3.3.4 | | |
| | | Effects of lithophysal properties on thermal properties | | X | | 3.3.5 | | |
| | Coupled Effects on UZ Flow (4.2.2) | Mountain-scale Thermal-Hydrologic effects | | X | X | 3.3.5 | | |
| | | Mountain-scale Thermal-Hydrologic-Chemical effects | | X | X | 3.3.6 | | |
| | | Mountain-scale Thermal-Hydrologic-Mechanical effects | | X | X | 3.3.7 | | |
| | Seepage into Emplacement Drifts (4.2.1) | Flow-focussing within heterogeneous permeability field; episodic seepage | X | | X | 4.3.1, 4.3.2, 4.3.5 | X | X |
| | | Effects rock bolts and drift degradation on seepage | X | | | 4.3.3, 4.3.4 | | |
| | Coupled Effects on Seepage (4.2.2) | Thermal effects on seepage | X | | X | 4.3.5 | X | X |
| | | Thermal-Hydrologic-Chemical effects on seepage | X | | X | 4.3.6 | | |
| | | Thermal-Hydrologic-Mechanical effects on seepage | | X | X | 4.3.7 | | |

# Summary of Supplemental Models and Analyses

(Continued)

| Key Attributes of System | Process Model (Section of Yucca Mountain Science and Engineering Report) | Topic of Supplemental Scientific Model or Analysis | Reason for Supplemental Scientific Model or Analysis: Unquantified Uncertainty Analysis | Reason: Update in Scientific Information | Reason: Cooler Thermal Operating Mode Analysis | Section of Volume 1 | Performance Assessment Treatment of Supplemental Scientific Model or Analysis (Discussed in Volume 2): TSPA Sensitivity Analysis | PA Treatment: Included in Supplemental TSPA Model |
|---|---|---|---|---|---|---|---|---|
| Long-Lived Waste Package and Drip Shield | Water Diversion Performance of EBS (4.2.3) | Multiscale thermal-hydrolic model, including effects of rock dryout | X | | X | 5.3.1 | | X |
| | | Thermal property sets | X | X | | 5.3.1 | | X |
| | | Effect of in-drift convection on temperatures, humidities, invert saturations, and evaporation rates | X | | X | 5.3.2 | | |
| | | Composition of liquid and gas entering drift | X | | X | 6.3.1 | X | X |
| | | Evolution of in-drift chemical environment | X | | X | 6.3.3 | X | X |
| | | Thermo-Hydro-Chemical model comparison to plug-flow reactor and fracture plugging experiment | | X | | 6.3.1 | | |
| | | Rockfall | | X | | 6.3.4 | | |
| | In-Drift Moisture Distribution (4.2.5) | Environment on surface of drip shields and waste packages | X | | | 5.3.2 | | |
| | | Condensation under drip shields | X | | | 8.3.2 | X | |
| | | Evaporation of seepage | X | | X | 8.3.1<br>5.3.2 | X | X |
| | | Effect of breached drip shields or waste package on seepage | X | | X | 8.3.3 | X | X |
| | | Waste package release flow geometry (flow-through, bathtub) | X | | | 8.3.4 | X | |
| | Drip Shield Degradation and Performance (4.2.4) | Local chemical environment on surface of drip shields (including Mg, Pb) and potential for initiating localized corrosion | X | | | 7.3.1 | | |

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# Summary of Supplemental Models and Analyses

(Continued)

| Key Attributes of System | Process Model (Section of Yucca Mountain Science and Engineering Report) | Topic of Supplemental Scientific Model or Analysis | Reason for Supplemental Scientific Model or Analysis | | | Section of Volume 1 | Performance Assessment Treatment of Supplemental Scientific Model or Analysis (Discussed in Volume 2) | |
|---|---|---|---|---|---|---|---|---|
| | | | Unquantified Uncertainty Analysis | Update in Scientific Information | Cooler Thermal Operating Mode Analysis | | TSPA Sensitivity Analysis | Included in Supplemental TSPA Model |
| Long-Lived Waste Package and Drip Shield | Waste Package Degradation and Performance (4.2.4) | Local chemical environment on surface of waste packages (including Mg, Pb) and potential for initiating localized corrosion | X | | | 7.3.1 | | |
| | | Aging and phase stability effects on A-22 | X | X | | 7.3.2 | X | |
| | | Uncertainty in weld stress state following mitigation | X | | | 7.3.3 | X | X |
| | | Weld defects | X | | | 7.3.3 | X | X |
| | | Early failure due to improper heat treatment | X | | X | 7.3.6 | X | X |
| | | General corrosion rate of A-22: Temperature dependency | X | | X | 7.3.5 | X | X |
| | | General corrosion rate of A-22: Uncertainty/variability partition | X | | | 7.3.5 | X | X |
| | | Long-term stability of passive films on A-22 | X | | | 7.3.4 | | |
| | | Stress threshold for initiation of stress corrosion cracking | X | X | | 7.3.3 | X | X |
| | | Probability of non-detection of manufacturing defects | | X | | 7.4.3 | X | X |
| | | Number of defects | | X | | 7.3.5 | X | X |
| | | Distribution of crack growth exponent (repassivation slope) | X | X | | 7.3.7 | X | X |

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# Summary of Supplemental Models and Analyses
(Continued)

| Key Attributes of System | Process Model (Section of Yucca Mountain Science and Engineering Report) | Topic of Supplemental Scientific Model or Analysis | Reason for Supplemental Scientific Model or Analysis | | | Section of Volume 1 | Performance Assessment Treatment of Supplemental Scientific Model or Analysis (Discussed in Volume 2) | |
|---|---|---|---|---|---|---|---|---|
| | | | Unquantified Uncertainty Analysis | Update in Scientific Information | Cooler Thermal Operating Mode Analysis | | TSPA Sensitivity Analysis | Included in Supplemental TSPA Model |
| Limited Release of Radionuclides from the Engineered Barriers | In-Package Environments (4.2.6) | Effect of HLW glass degradation rate and steel degradation rate on in-package chemistry | X | | X | 9.3.1 | X | X |
| | Cladding Degradation and Performance (4.2.6) | Effect of initial perforations, creep rupture, stress corrosion cracking, localized corrosion, seismic failure, rock overburden failure, and unzipping velocity on cladding degradation | X | | X | 9.3.3 | X | X |

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# Summary of Supplemental Models and Analyses
(Continued)

| Key Attributes of System | Process Model (Section of Yucca Mountain Science and Engineering Report) | Topic of Supplemental Scientific Model or Analysis | Reason for Supplemental Scientific Model or Analysis | | | Section of Volume 1 | Performance Assessment Treatment of Supplemental Scientific Model or Analysis (Discussed in Volume 2) | |
|---|---|---|---|---|---|---|---|---|
| | | | Unquantified Uncertainty Analysis | Update in Scientific Information | Cooler Thermal Operating Mode Analysis | | TSPA Sensitivity Analysis | Included in Supplemental TSPA Model |
| Limited Release of Radionuclides from the Engineered Barriers | DHLW Degradation and Performance (4.2.6) | HLW glass degradation rates | X | X | X | 9.3.1 | | |
| | Dissolved Radionuclide Concentrations (4.2.6) | Solubility of neptunium, thorium, plutonium, and technetium | X | X | X | 9.3.2 | X | X |
| | Colloid-Associated Radionuclide Concentrations (4.2.6) | Colloid mass concentrations | X | | | 9.3.4 | X | |
| | EBS (Invert) Degradation and Transport (4.2.6, 4.2.7) | Diffusion inside waste package | X | X | | 10.3.1 | X | X |
| | | Transport pathway from inside waste package to invert | X | X | | 10.3.2 | | |
| | | Sorption inside waste package | X | X | | 10.3.4 | X | X |
| | | Sorption in invert | X | X | | 10.3.4 | X | X |
| | | Diffusion through invert | X | | | 10.3.3 | X | X |
| | | Colloid stability in the invert | X | | | 10.3.5 | | |
| | | Microbial transport of colloids | X | X | | 10.3.6 | | |

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# Summary of Supplemental Models and Analyses

(Continued)

| Key Attributes of System | Process Model (Section of Yucca Mountain Science and Engineering Report) | Topic of Supplemental Scientific Model or Analysis | Reason for Supplemental Scientific Model or Analysis | | | Section of Volume 1 | Performance Assessment Treatment of Supplemental Scientific Model or Analysis (Discussed in Volume 2) | |
|---|---|---|---|---|---|---|---|---|
| | | | Unquantified Uncertainty Analysis | Update in Scientific Information | Cooler Thermal Operating Mode Analysis | | TSPA Sensitivity Analysis | Included in Supplemental TSPA Model |
| Delay and Dilution of Radionuclide Concentrations by the Natural Barriers | Unsaturated Zone Radionuclide Transport (Advective Pathways; Retardation; Dispersion; Dilution) (4.2.8) | Effect of drift shadow zone - advection/diffusion splitting | X | | X | 11.3.1 | X | X |
| | | Effect of drift shadow zone - concentration boundary condition on EBS release rates | X | | | 11.3.1 | | |
| | | Effect of matrix diffusion | X | | | 11.3.2, 11.3.3 | | |
| | | 3-D transport | | | X | 11.3.2 | | |
| | | Effect of coupled Thermo-Hydrologic, Thermo-Hydro-Chemical, and Thermo-Hydro-Mechanical processes on transport | | X | X | 11.3.5 | | |
| | Saturated Zone Radionuclide Flow and Transport (4.2.9) | Groundwater specific discharge | X | X | | 12.3.1 | X | |
| | | Effective diffusion coefficient in volcanic tuffs | X | | | 12.3.2 | X | |
| | | Flowing interval spacing | | | | 12.3.2 | X | |
| | | Flowing interval (fracture) porosity | X | | | 12.3.2 | X | |
| | | Effective porosity in the alluvium | X | | | 12.3.2 | X | |
| | | Correlation of the effective diffusion coefficient with matrix porosity | X | | | 12.3.2 | X | |
| | | Bulk density of the alluvium | X | X | | 12.3.2 | X | X |

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# Summary of Supplemental Models and Analyses

(Continued)

| Key Attributes of System | Process Model (Section of Yucca Mountain Science and Engineering Report) | Topic of Supplemental Scientific Model or Analysis | Reason for Supplemental Scientific Model or Analysis: Unquantified Uncertainty Analysis | Update in Scientific Information | Cooler Thermal Operating Mode Analysis | Section of Volume 1 | Performance Assessment Treatment of Supplemental Scientific Model or Analysis (Discussed in Volume 2): TSPA Sensitivity Analysis | Included in Supplemental TSPA Model |
|---|---|---|---|---|---|---|---|---|
| Delay and Dilution of Radionuclide Concentrations by the Natural Barriers | Saturated Zone Radionuclide Transport (4.2.9) | Retardation for radionuclides irreversibly sorbed on colloids in the alluvium | X | X | | 12.3.2 | X | |
| | | No matrix diffusion in volcanic tuffs case | | | | 12.5.2 | X | |
| | | Presence or absence of alluvium | | | | 12.5.2 | X | |
| | | Sorption coefficient in alluvium for I, Tc | X | X | | 12.3.2 | | X |
| | | Sorption coefficient in alluvium for Np, U | X | X | | 12.3.2 | X | |
| | | Sorption coefficient for Np in volcanic tuffs | X | | | 12.3.2 | X | |
| | | Kc model for groundwater colloid concentrations Pu, Am | | X | | 12.5.2 | X | |
| | | Enhanced matrix diffusion in volcanic tuffs | | | | 12.5.2 | X | |
| | | Effective longitudinal dispersivity | X | X | | 12.3.2 | X | |
| | | New dispersion tensor | | X | | 12.3.2 | | |
| | | Flexible design | | | X | 12.3.2 | | |
| | | Different conceptual models of the large hydraulic gradient and their effects on the flow path and specific discharge | | X | | 12.3.1 | | |
| | | Hydraulic head and map of potentiometric surface | | X | | 12.3.1 | | |

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# Summary of Supplemental Models and Analyses

(Continued)

| Key Attributes of System | Process Model (Section of Yucca Mountain Science and Engineering Report) | Topic of Supplemental Scientific Model or Analysis | Reason for Supplemental Scientific Model or Analysis | | | Section of Volume 1 | Performance Assessment Treatment of Supplemental Scientific Model or Analysis (Discussed in Volume 2) | |
|---|---|---|---|---|---|---|---|---|
| | | | Unquantified Uncertainty Analysis | Update in Scientific Information | Cooler Thermal Operating Mode Analysis | | TSPA Sensitivity Analysis | Included in Supplemental TSPA Model |
| Delay and Dilution of Radionuclide Concentrations by the Natural Barriers | Biosphere (4.2.10) | Receptor of interest | X | | | 13.3.1 | | |
| | | Comparison of dose assessment methods | X | | | 13.3.2 | | |
| | | Radionuclide removal from soil by leaching | X | | | 13.3.3 | | |
| | | Uncertainties not captured by GENII-S | X | | | 13.3.4 | | |
| | | Influence of climate change on groundwater usage and BDCFs | X | | | 13.3.5, 13.3.7 | | |
| | | BDCFs for groundwater and igneous releases | | X | | 13.3.6, 13.3.8, 13.4 | X | X |

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# Summary of Supplemental Models and Analyses

(Continued)

| Key Attributes of System | Process Model (Section of Yucca Mountain Science and Engineering Report) | Topic of Supplemental Scientific Model or Analysis | Reason for Supplemental Scientific Model or Analysis | | | Section of Volume 1 | Performance Assessment Treatment of Supplemental Scientific Model or Analysis (Discussed in Volume 2) | |
|---|---|---|---|---|---|---|---|---|
| | | | Unquantified Uncertainty Analysis | Update in Scientific Information | Cooler Thermal Operating Mode Analysis | | TSPA Sensitivity Analysis | Included in Supplemental TSPA Model |
| Low Mean Annual Dose Considering Potentially Disruptive Events | Volcanism/Igneous Activity (4.3.2) | Probability of dike intersection of repository for the operating mode described in S&ER | | X | | 14.3.3.1 | | X |
| | | Scaling factors to evaluate impacts of repository design changes | | | X | 14.3.3.2 | | |
| | | Contribution to release of Zones 1 and 2 | | X | | 14.3.3.3 | X | |
| | | Sensitivity to waste particle size distribution | | X | | 14.3.3.4 | X | |
| | | New wind speed data | | X | | 14.3.3.5 | X | X |
| | | Explanation of method for handling ash/waste particle size and density | | X | | 14.3.3.6 | | |
| | | Volcanism inputs for Supplemental TSPA Model | | X | | 14.3.3.7 | | X |
| | | New aeromagnetic data | | X | | 14.3.3.8 | | |

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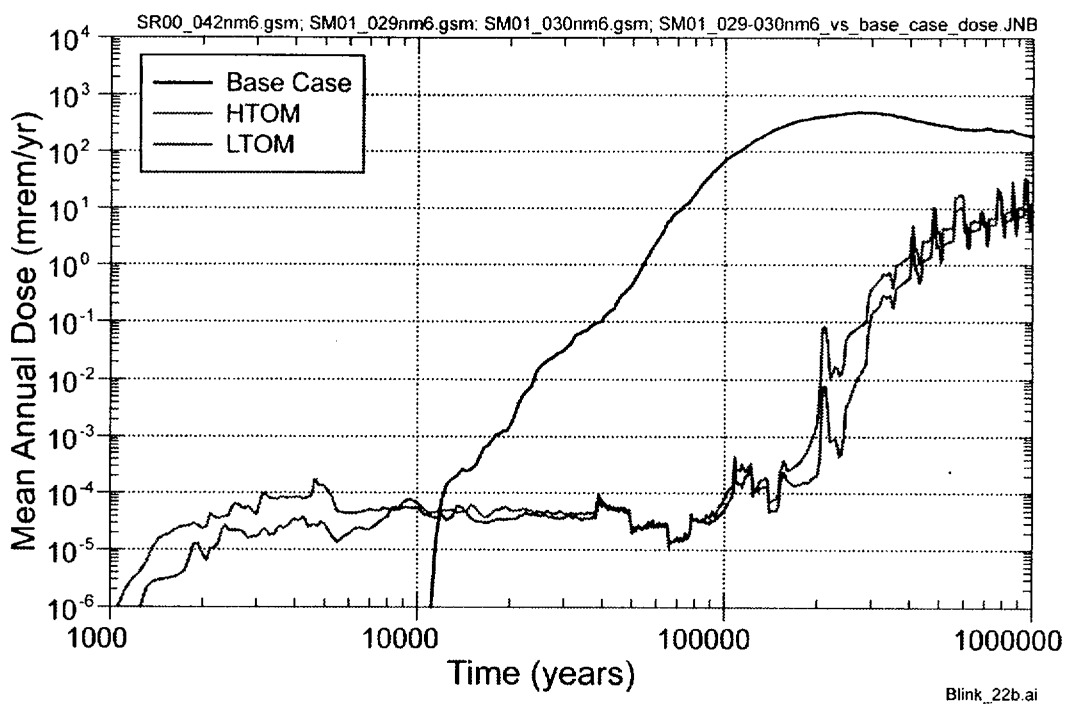
NOTE: S&ER = Yucca Mountain Science and Engineering Report

[a] Performance assessment treatment of supplemental scientific model or analysis discussed in SSPA Volume 2

**Legend**

- TSPA - Total System Performance Assessment
- PTn - Paintbrush nonwelded unit
- EBS - Engineered Barrier System
- Mg - Magnesium
- Pb - Lead
- A-22 - Alloy 22
- HLW - High-level waste
- DHLW - Defense high-level waste
- BDCFs - Biosphere dose conversion factors
- GENII-S - Code for statistical and deterministic simulations of radiation doses to humans from radionuclides in the environment
- 3-D - Three dimensional
- I - Iodine
- Tc - Technetium
- Np - Neptunium
- U - Uranium
- Pu - Plutonium
- Am - Americium

# Total Dose - Nominal Scenario

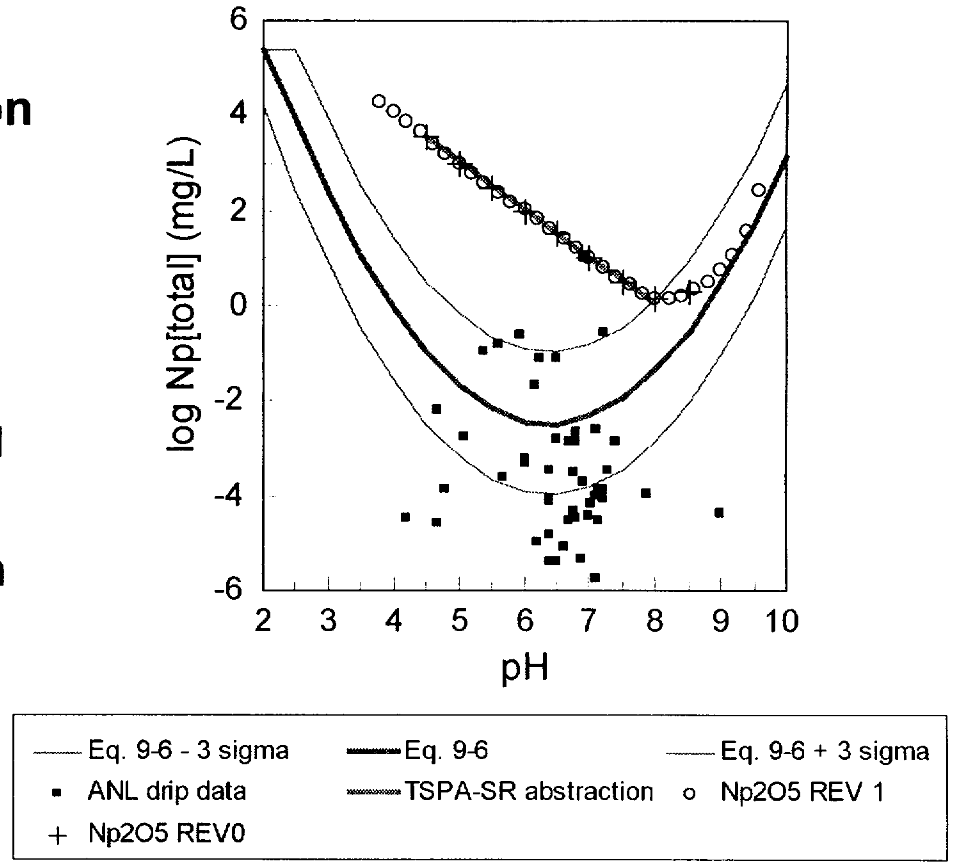



*Because most waste package failures are well beyond the thermal pulse, High Temperature Operating Mode and Low Temperature Operating Mode mean dose rates are similar*

- **Early waste package failure—small doses prior to 100,000 years**
- **Temperature dependent general corrosion delay in larger doses**
- **Post 10,000 year climate changes—about 10x dose variation**
- **Solubility updates—about 10x decrease in peak dose**

# Neptunium Solubility Model in Total System Performance Assessment- Site Recommendation Rev 00

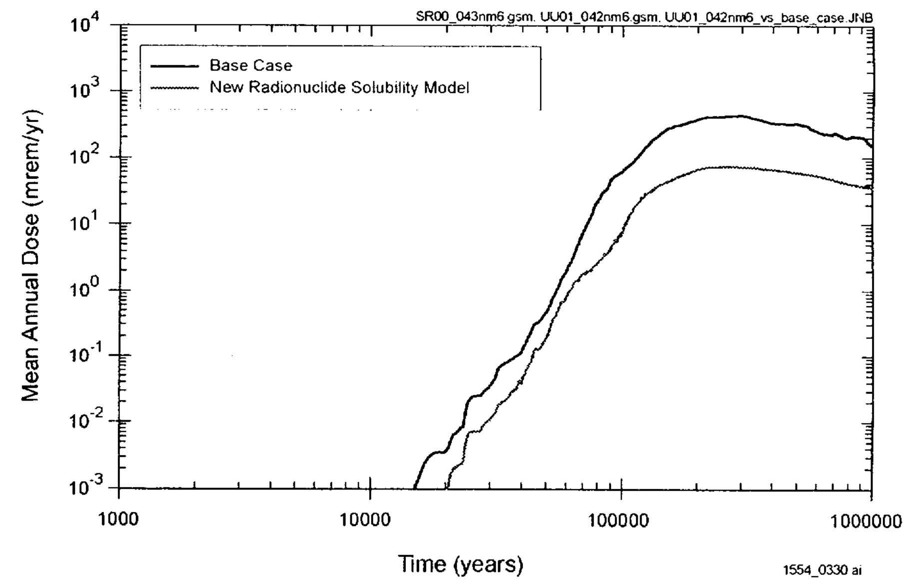
- **TSPA-SR Rev 00 assessment of dissolved Np concentration based on conservative assumptions**
  - **Uses bounding chemistries**
  - **Pure phases ($Np_2O_5$) assumed to control concentrations**
  - **Np solubility is a function of pH and $f_{CO2}$**
- **$Np_2O_5$ solubility curve (as a function of pH) bounds laboratory measured Np concentrations from Argonne National Laboratory drip tests**
- **TSPA-SR Rev 00 model, which is based on $Np_2O_5$ solubility, does not explain the large spread (uncertainty) in measurements of Np concentration**




**Source: Supplemental Science and Performance Analyses, Volume 1, Figure 9-6b.**

# Comparison of Mean Annual Dose Estimates for Results Including New Radionuclide Solubility Models and Results of TSPA-SR Base-Case Models

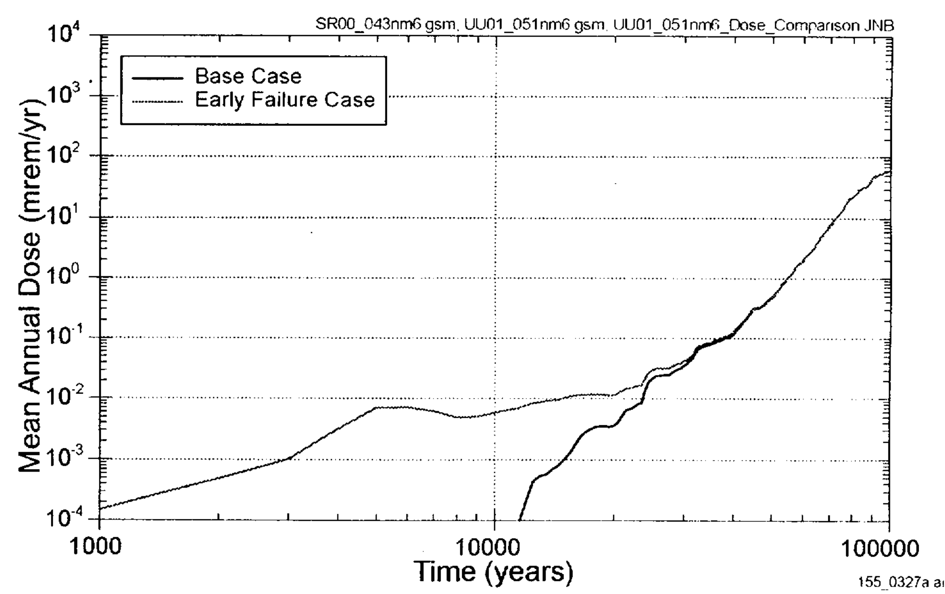
- **The decrease in the mean annual dose estimate is controlled by the revised model and uncertainty distribution for Neptunium-237**
- **The revised model for NP-237 is a preliminary secondary phase representation to address unquantified uncertainties**




**Source: Supplemental Science and Performance Analyses, Volume 2, Figure 3.2.7.3-1(a).**

# Effect of Higher Probability of Early Waste Package Failures

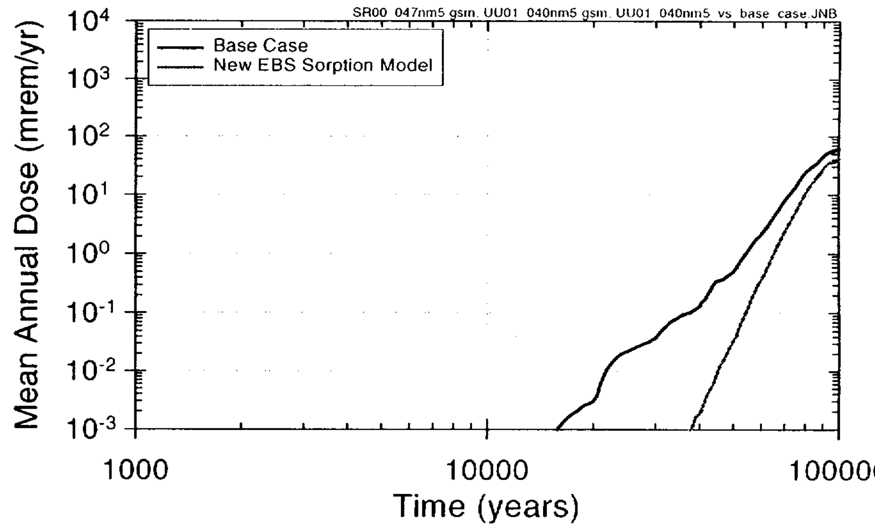
- **Total System Performance Assessment-Site Recommendation base-case model has no waste package failures before 10,000 years; lack of early failures based on reliability studies in the literature**
- **Further analysis considered possible effects of improper heat treatment of the waste packages**
- **This analysis led to a higher estimate of the probability of early failures**




**Source: Supplemental Science and Performance Analyses, Volume 2, Figure 3.2.5.4-1(a).**

# Effect of Radionuclide Sorption in the Engineered Barrier System

- **Total System Performance Assessment-Site Recommendation base-case model includes no sorption in the waste package or invert**
- **Further analysis developed estimates of effective sorption coefficients**
- **The most important effect is reduction of source concentration because of sorption onto corrosion products within the waste package**




**Source: Supplemental Science and Performance Analyses, Volume 2, Figure 3.2.8-2(a).**

# Key Thermal-Hydrologic Environment Uncertainties Evaluated in Supplemental Science and Performance Analyses Vol. 1

## Model (Conceptual) Uncertainty

Use of effective thermal conductivity and thermal radiation approaches

Neglecting dryout during ventilation

Coupling of submodels

Localized effects of seepage

Neglecting fracture heterogeneity impacts on seepage

Neglecting effects of mountain-scale gas-phase convection

Effects of lithophysal porosity on vapor storage

## Process Uncertainty

Hysteresis of imbition misspelled

THM & THC changes to hydrologic properties

## Input Data Uncertainty

Invert properties

Host rock bulk permeability

Host rock thermal conductivity (wet & dry)

Host rock heat capacity

Host rock lithophysal porosity

WP thermal output

Ventilation duration and efficiency

NOTE:

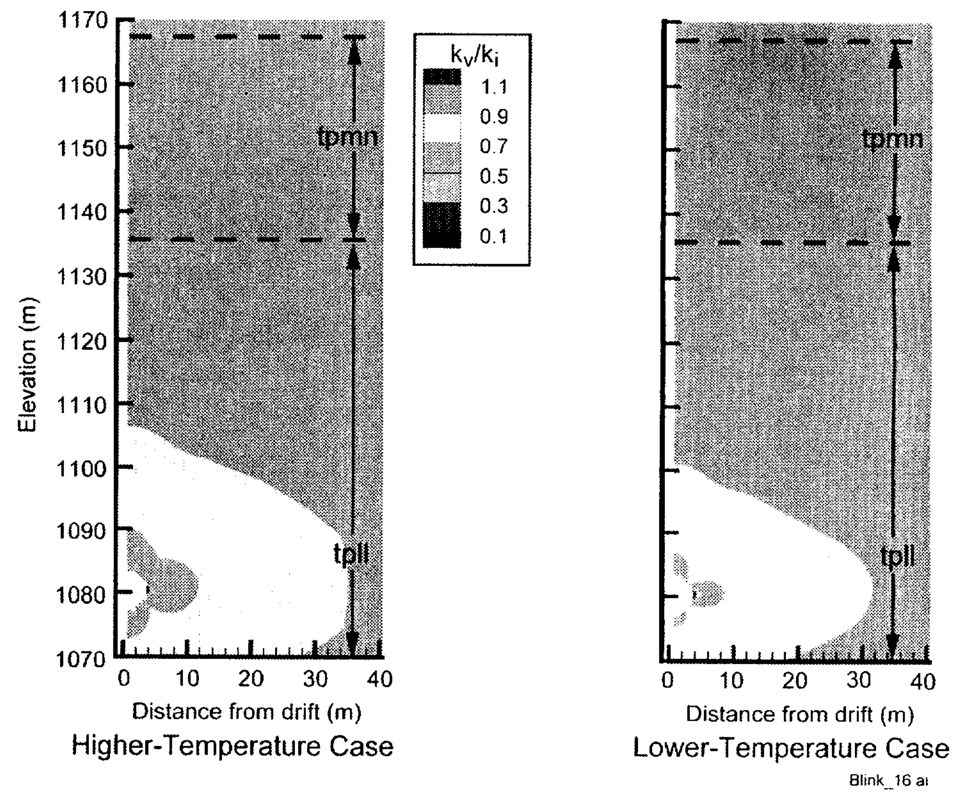
DKM = dual permeability model

THM = thermal-hydrologic-mechanical

THC = thermal-hydrologic-chemical

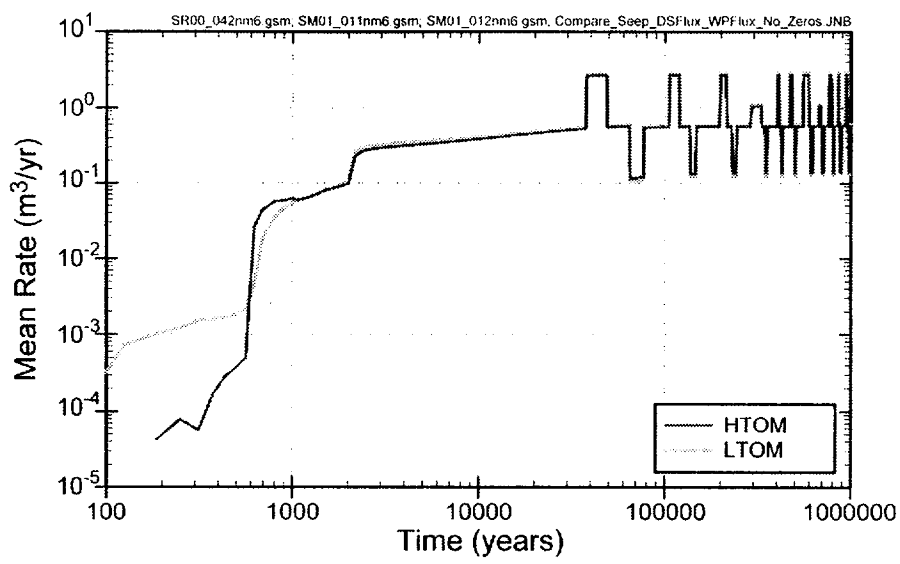
# Thermal-Mechanical Caused Permeability Changes

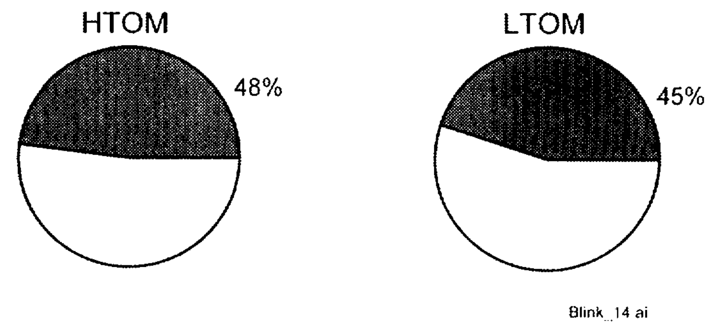
- **At 10 years, both thermal cases show an overall decrease in permeability around the drift due to thermal stress induced by decay heat**
- **This decrease overcomes the initial excavation-induced permeability increases, except possibly in areas very close to the crown of the drift**




***High Temperature Operating Mode and Low Temperature Operating Mode are similar***

# Thermal Seepage in Total System Performance Assessment

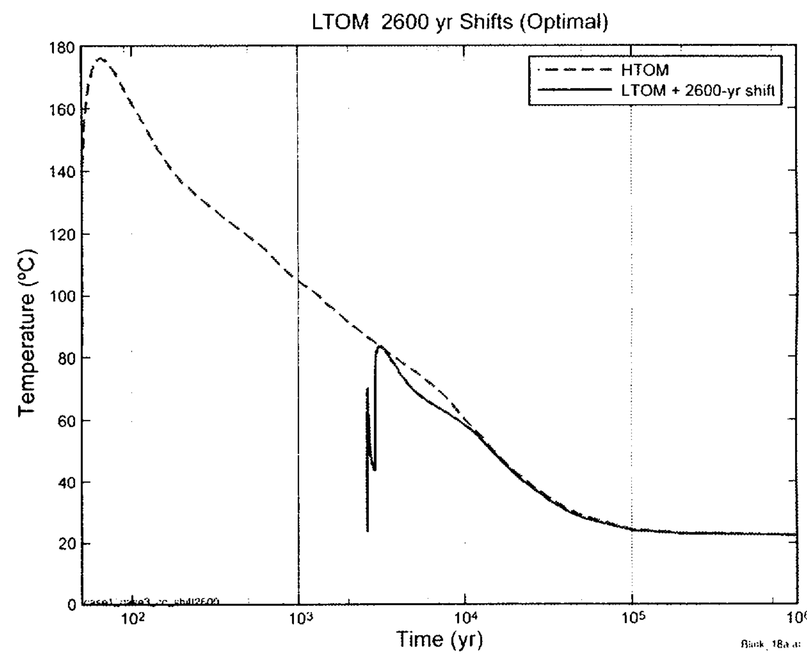



- **Low Temperature Operating Mode seepage**
  - **Total System Performance Assessment model ~ Ambient model**
- **High Temperature Operating Mode seepage**
  - **Process model < TSPA model < Ambient model**

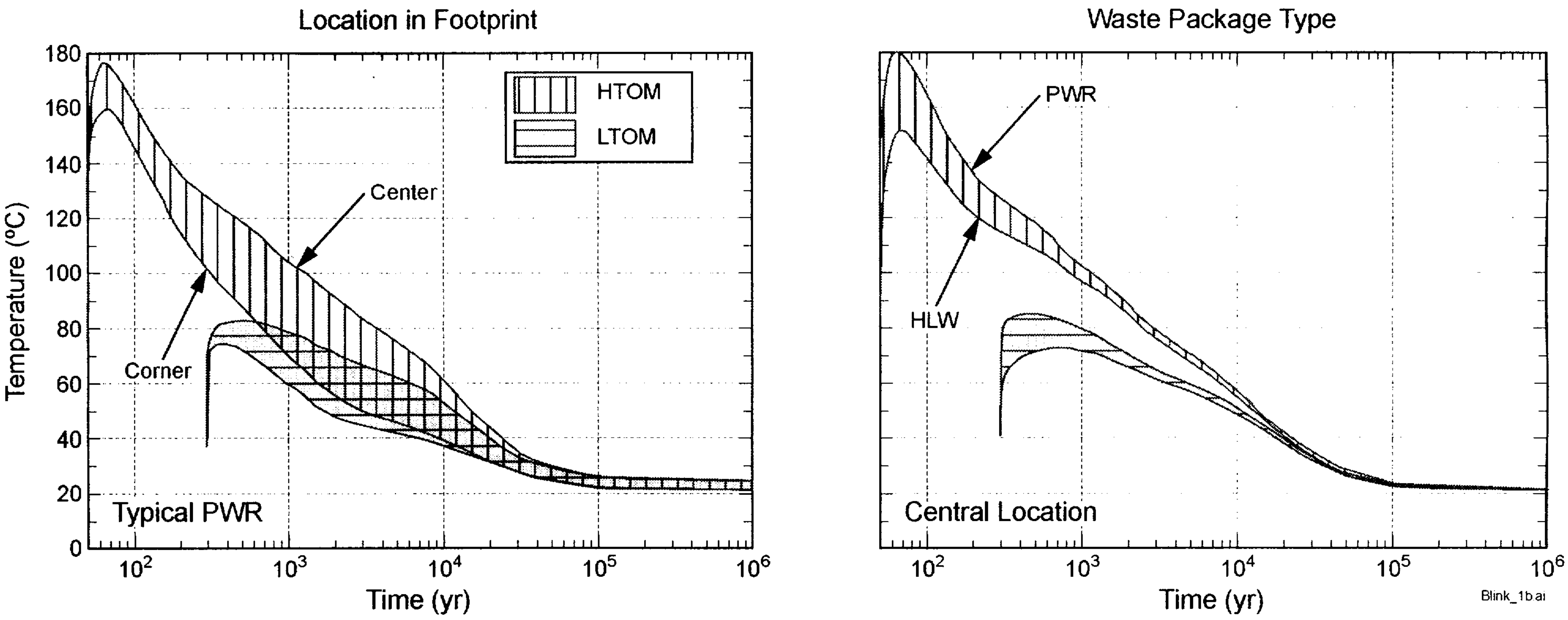
# The Low Temperature Operating Mode Thermal History is Similar to the High Temperature Operating Mode after a Few Thousand Years

- **High Temperature Operating Mode models include the Low Temperature Operating Mode environments**
- **High temperature parts of the models could increase High Temperature Operating Mode uncertainty compared to Low Temperature Operating Mode**




***High Temperature Operating Mode and Low Temperature Operating Mode performance are similar because the High Temperature Operating Mode thermal pulse does not significantly affect the Engineered Barrier System or Natural Barrier System***

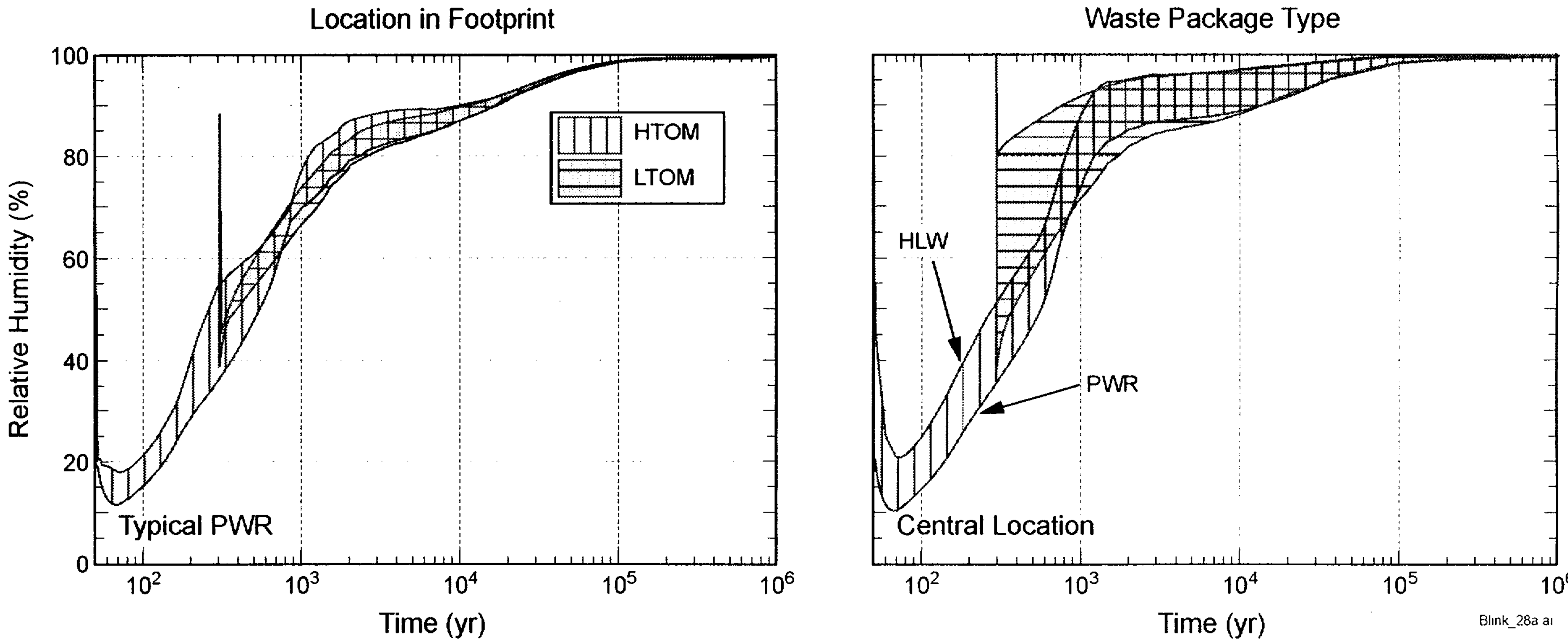
# Waste Package Temperature Sensitivity to Location and Waste Package Type




- **The variability range for location and waste package type is ~20°C**
- **The variability range for operating mode is ~90°C**

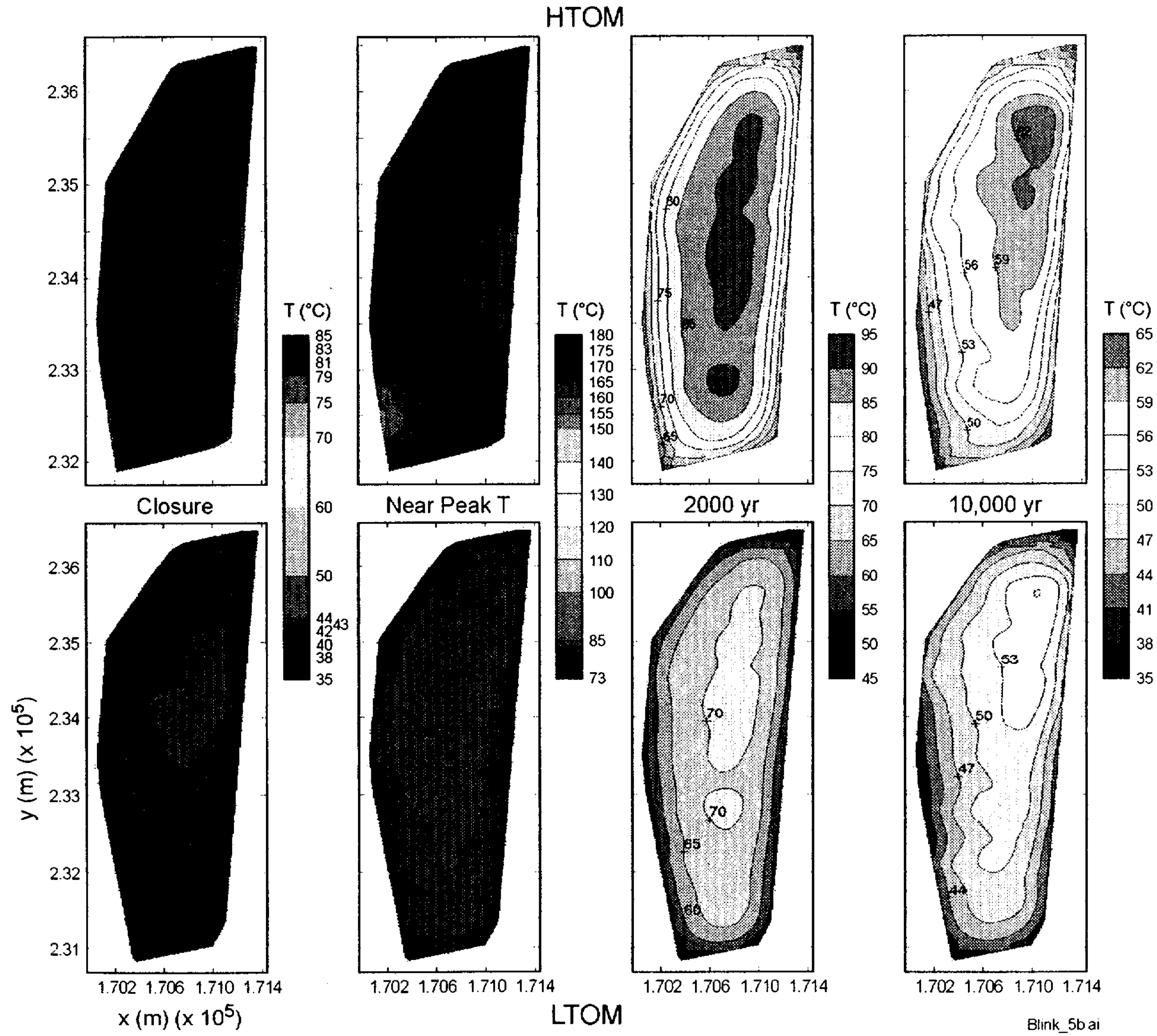
# Sensitivity of Waste Package Relative Humidity to Infiltration Rate and Operating Mode

## (All Waste Package Types and Locations)




***Low Temperature Operating Mode low Relative Humidity duration is similar to High Temperature Operating Mode***

# Typical Pressurized-Water Reactor Waste Package Temperature Sensitivity to Location




- **Common color bar for each time period**
- **Similar distributions at 10,000 years**

*Spatial variability similar for High Temperature Operating Mode and Low Temperature Operating Mode*

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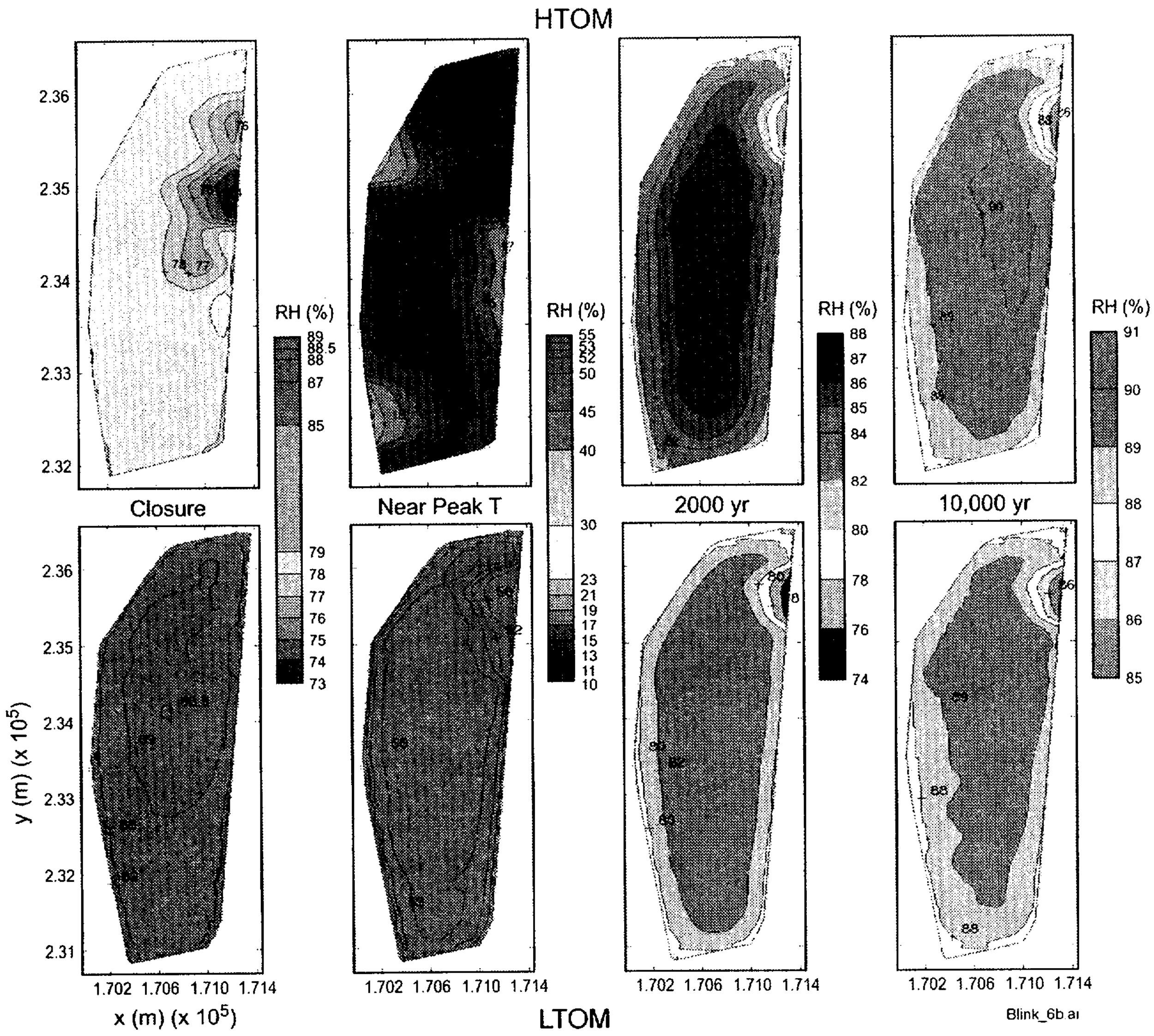
# Typical Pressurized-Water Reactor Waste Package Humidity Sensitivity to Location




- **Earlier two snapshots have drier High Temperature Operating Mode**
  - **Earlier "real" time has higher waste package heat**
  - **Near-field dryout**
- **10,000 year snapshots have similar RH**
  - **Similar temperature**

***Spatial variability similar for High Temperature Operating Mode and Low Temperature Operating Mode***

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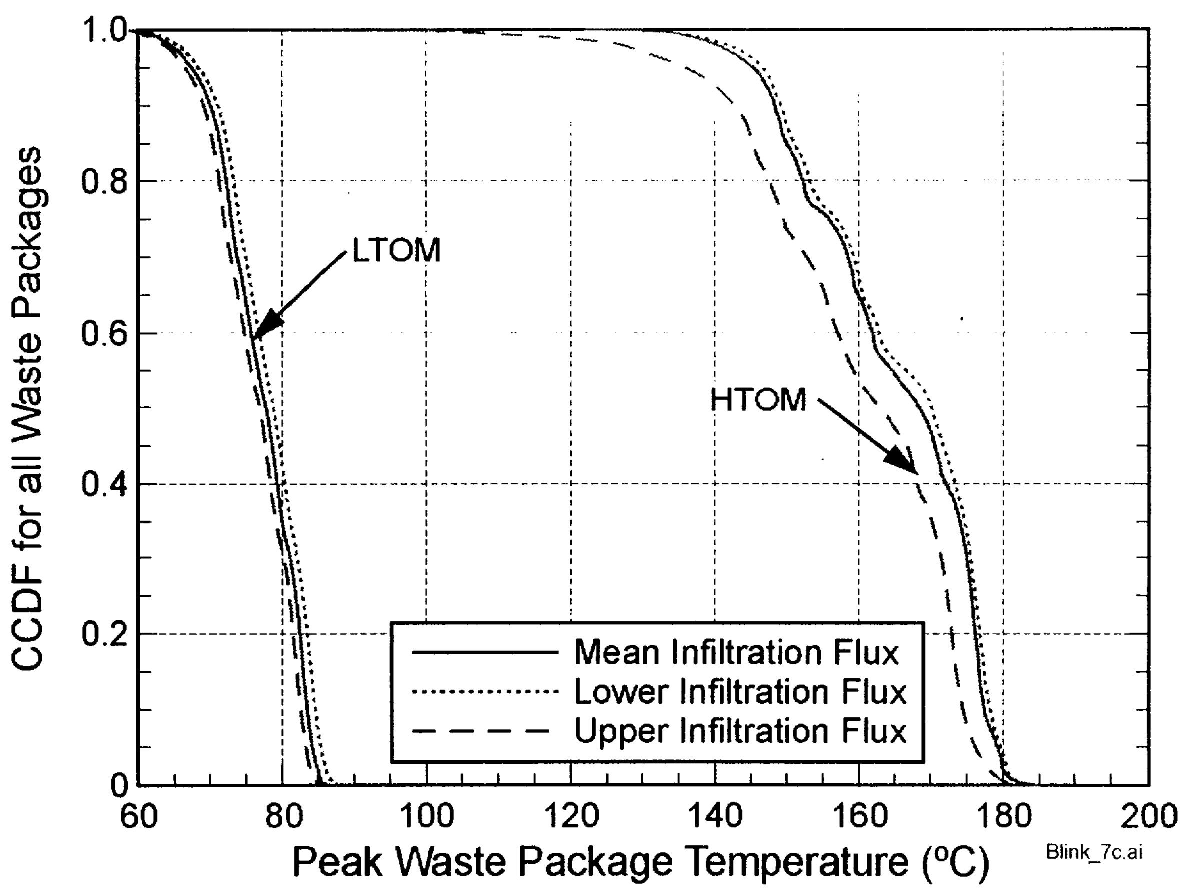
# Sensitivity of Waste Package Temperature to Infiltration Rate and Operating Mode
## (All Waste Package Types and Locations)




- **Waste Packages in the High Temperature Operating Mode**
  - **Exhibit larger temperature variability**
  - **Stronger dependence on infiltration flux**

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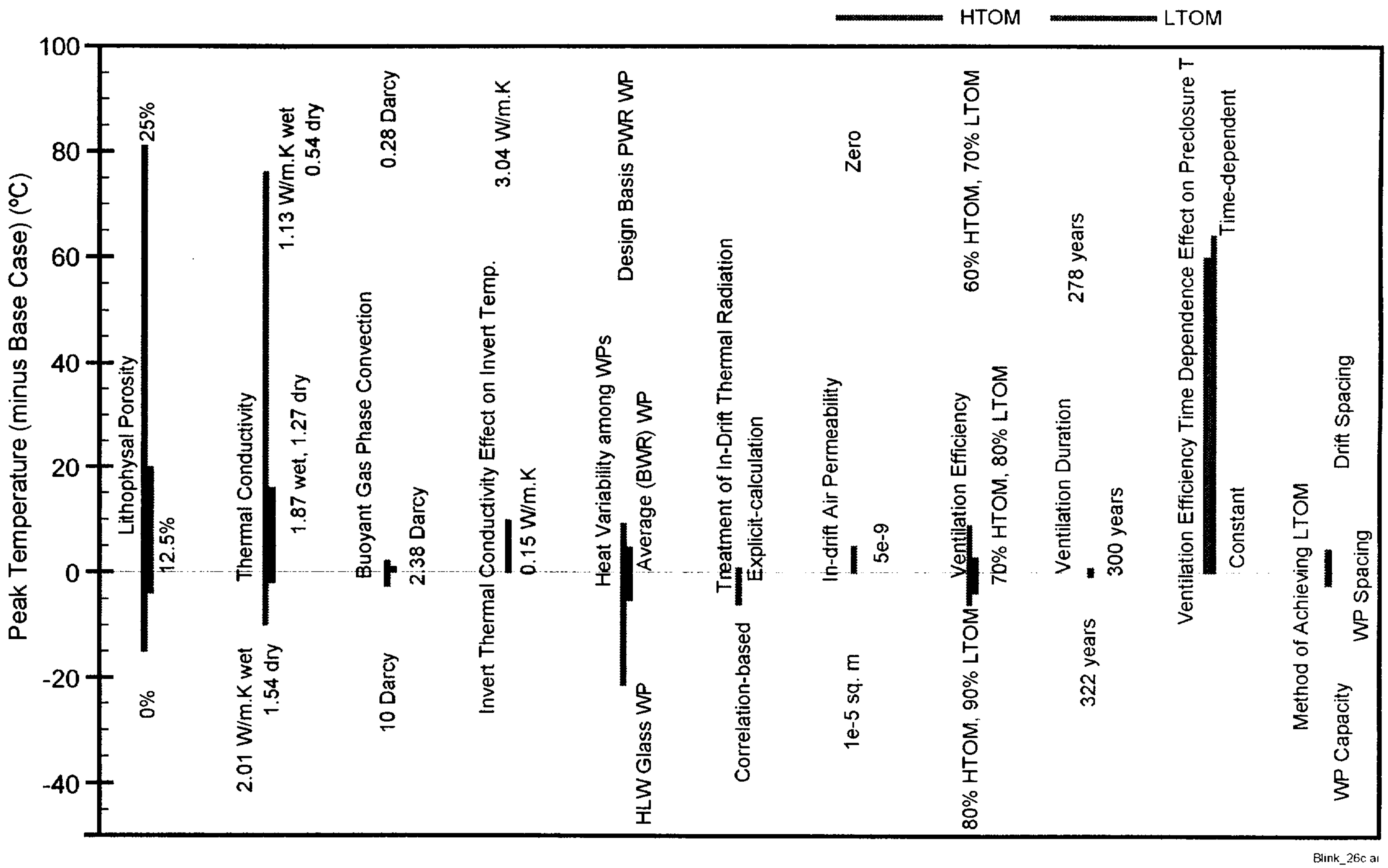
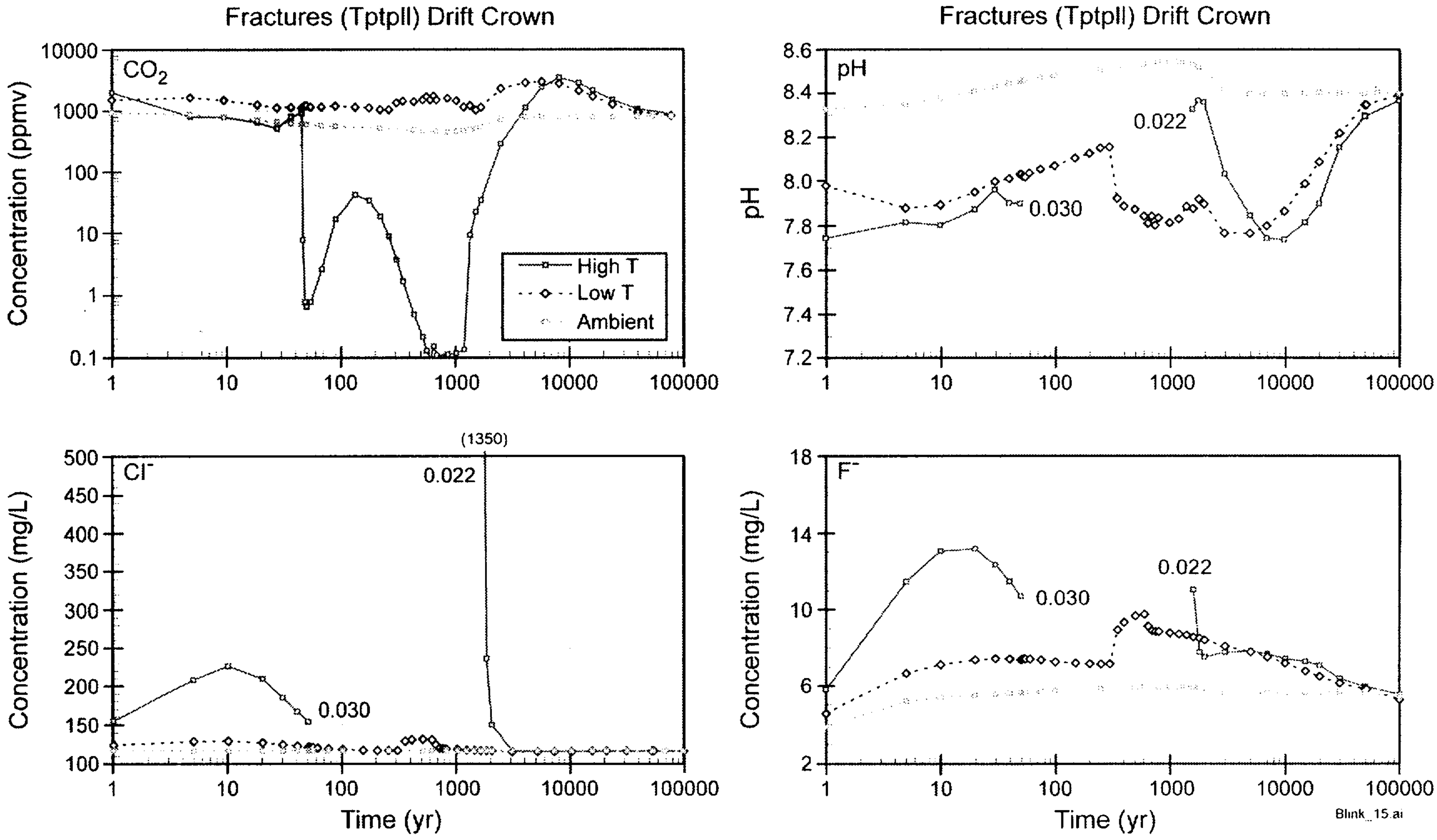
# Sensitivity of Peak Postclosure Temperature

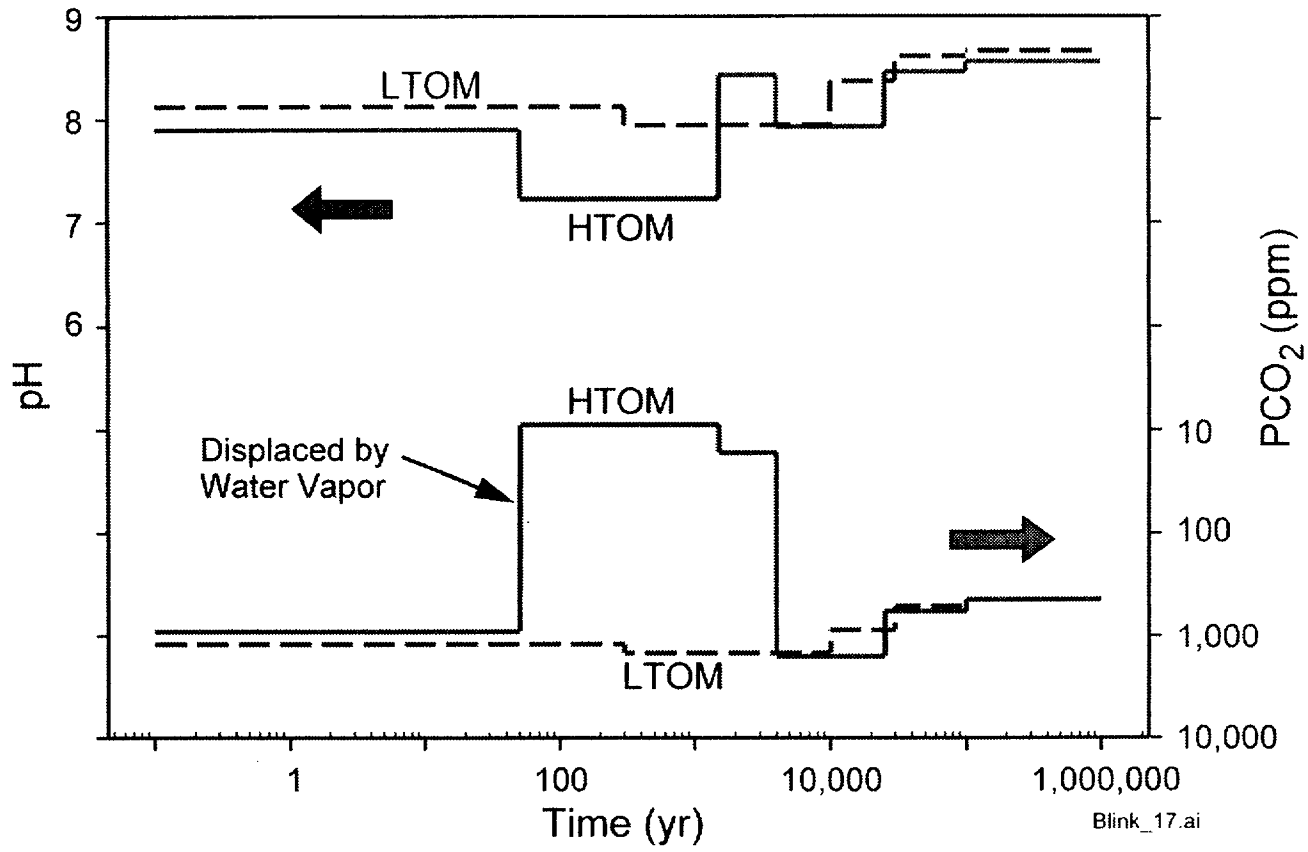


# Seepage Water Chemistry



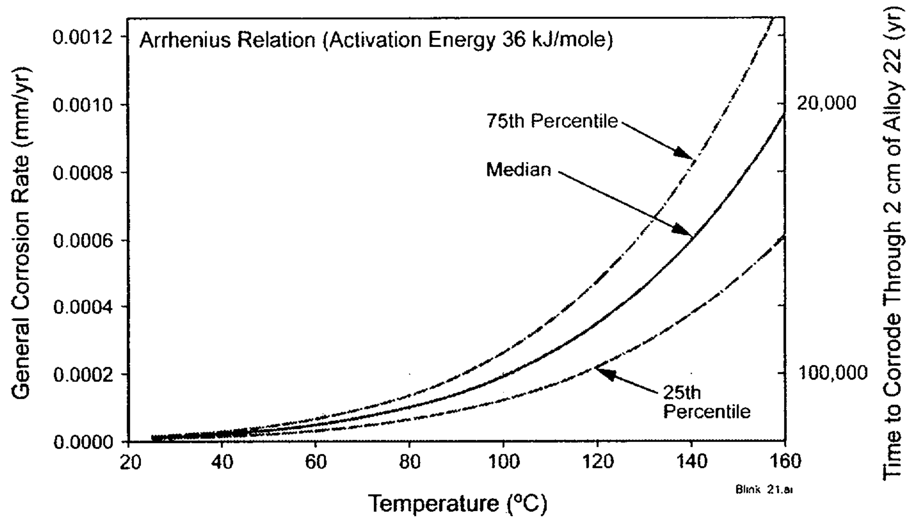

## *Low Temperature Operating Mode and High Temperature Operating Mode are similar after 2000 years*

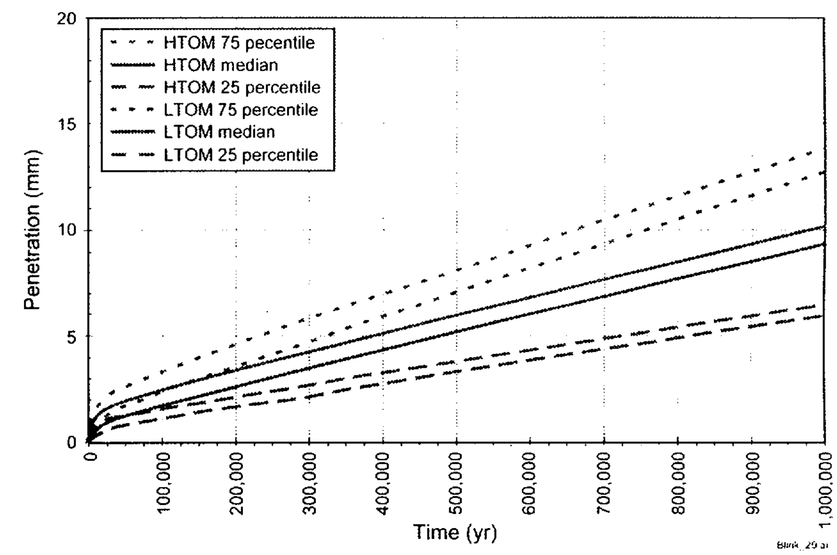
# In-Drift Water and Gas Chemistry
## (after temporal abstraction, prior to gas-liquid equilibration)




***High Temperature Operating Mode and Low Temperature Operating Mode are similar after a few 1000 years***

# Waste Package General Corrosion



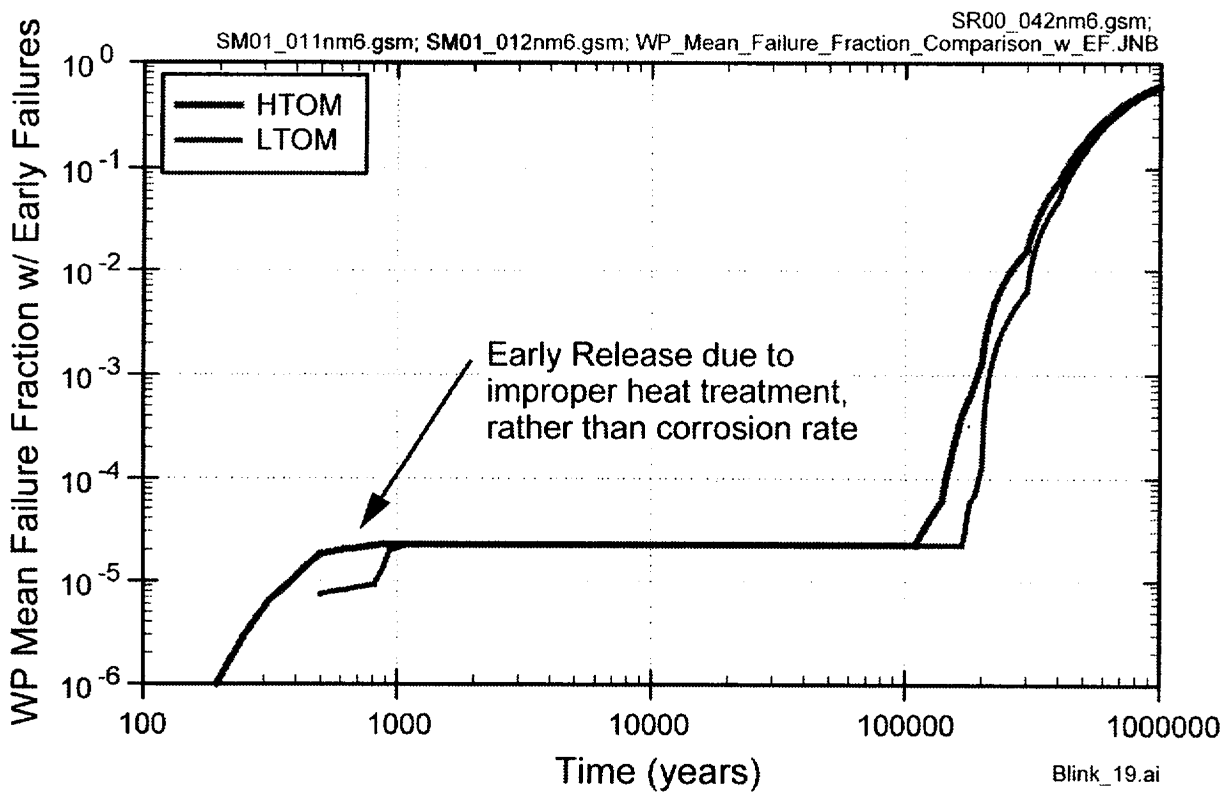




- **Potentiostatic polarization measurements determined Temperature-dependence**
  - **pH 2.75 and 7.75**
  - **LiCl, $Na_2SO_4$, $NaNO_3$ aqueous environment**
  - **Chloride to (Sulfate + Nitrate) ratios 10:1 and 100:1**

- **Supplemental Science and Performance Analyses Vol. 1, Rev 00 ICN01**
- **Average pressurized-water reactor, central location**
- **Assumes aggressive dust chemistry ⟶ corrosion initiation at closure**
- **No microbial induced corrosion enhancement**

***High Temperature Operating Mode has ~1 mm more general corrosion that Low Temperature Operating Mode due to the thermal pulse***

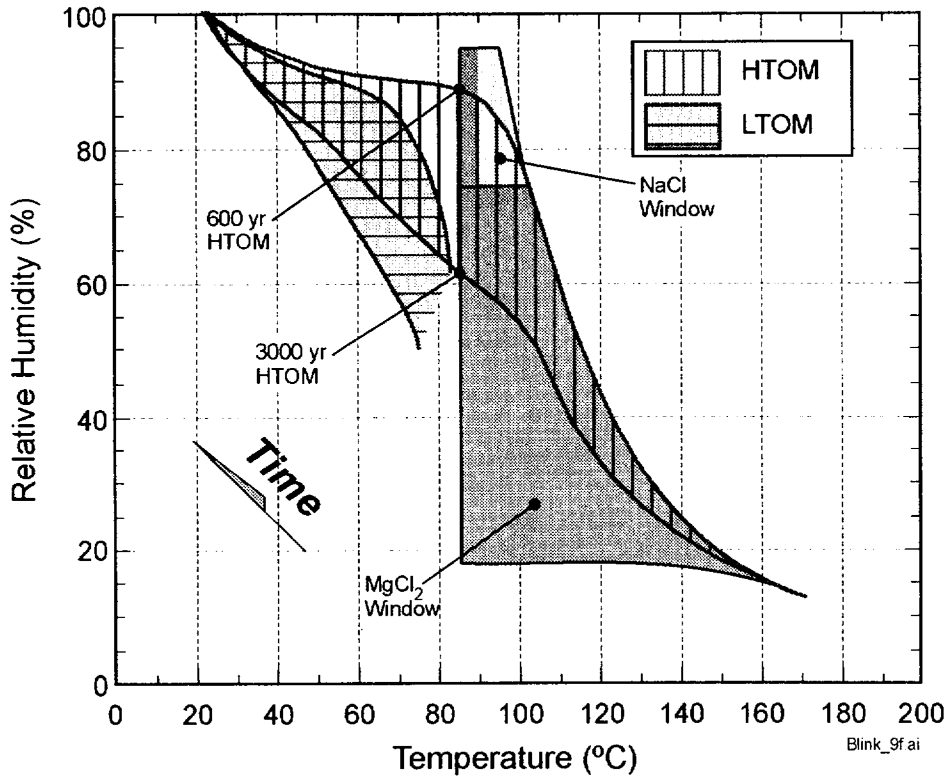
# Waste Package Failure, Including Early Failures




- **Includes general corrosion, local corrosion, and stress corrosion cracking**
- **General corrosion mode increased**
  - **by 1.0 to 2.0 for microbial induced corrosion**
  - **by 1.0 to 2.5 for aging (at closure weld)**

***Low Temperature Operating Mode and High Temperature Operating Mode are similar***

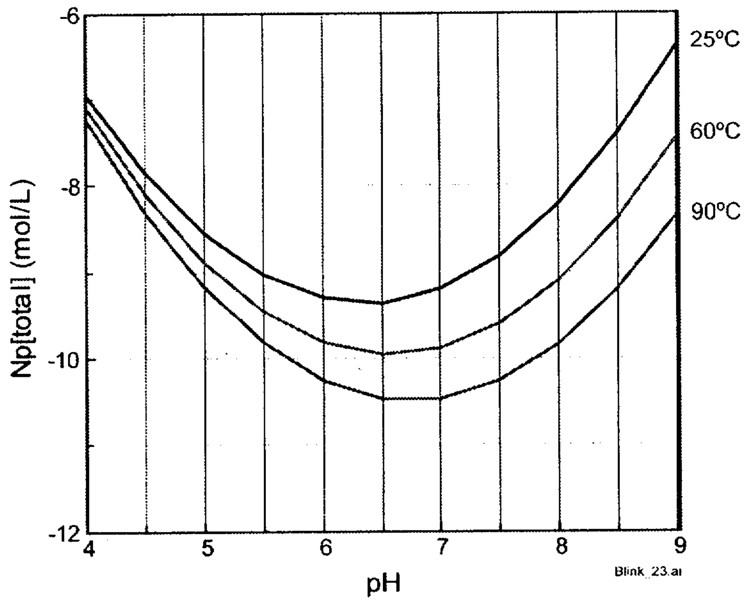
# Waste Package Temperature-Humidity Trajectories and the Crevice Corrosion Initiation Window of Susceptibility

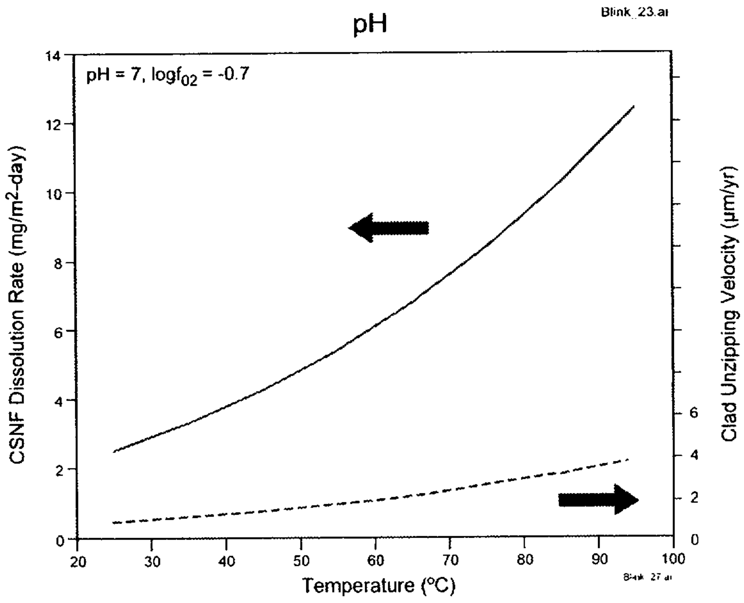



- **Crevice corrosion initiates by breaching the passive film**
- **The process model crevice corrosion initiation window includes T, [Cl⁻] and pH**
  - **The pH dependence dominates T and [Cl⁻]**
- **The Total System Performance Assessment crevice corrosion initiation is based on pH**

- ***Both Low Temperature Operating Mode and High Temperature Operating Mode avoid crevice corrosion***
  - **LTOM: Temperature criterion**
  - **HTOM: Chemistry (pH) criterion**

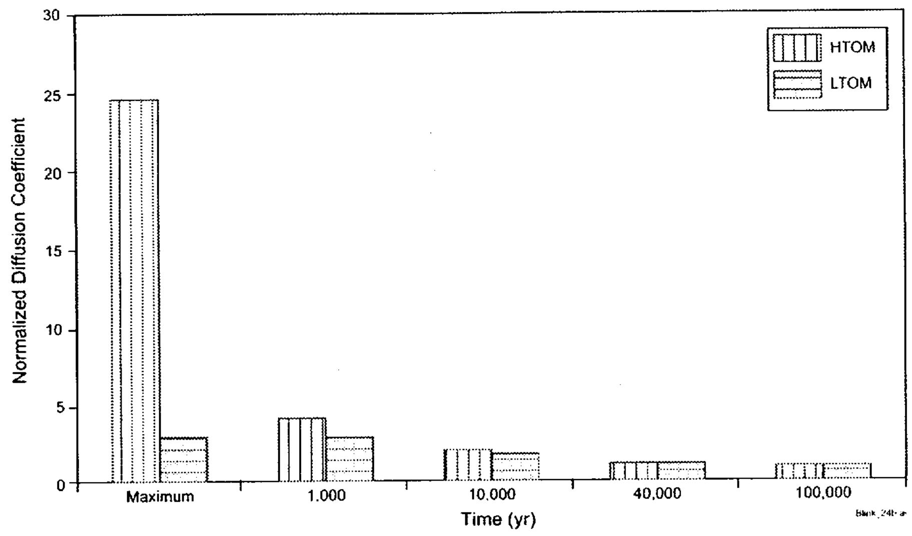
# Waste Form Mobilization

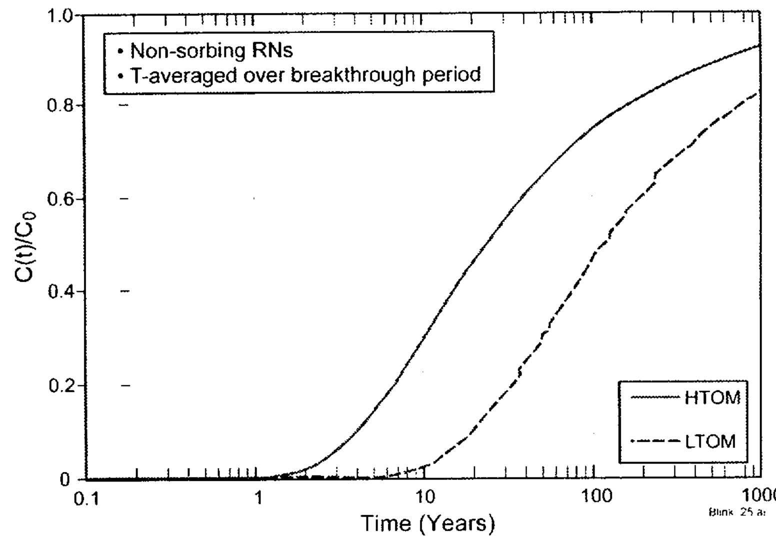



- **Other factors had little or no temperature-dependence**
  - **In-waste package pH: used 25°C-dominated database**
  - **Lower Pu solubility at high-temperature still too uncertain for Supplemental Science and Performance Analyses model**
  - **In-waste package diffusion coefficient not strongly temperature-dependent**
  - **In-waste package sorption temperature-dependence uncertain, higher sorption at higher-temperature is likely**
  - **Clad Creep is temperature-dependent, but negligible total creep**
  - **Little temperature-dependence for colloids**

# Engineered Barrier System Transport

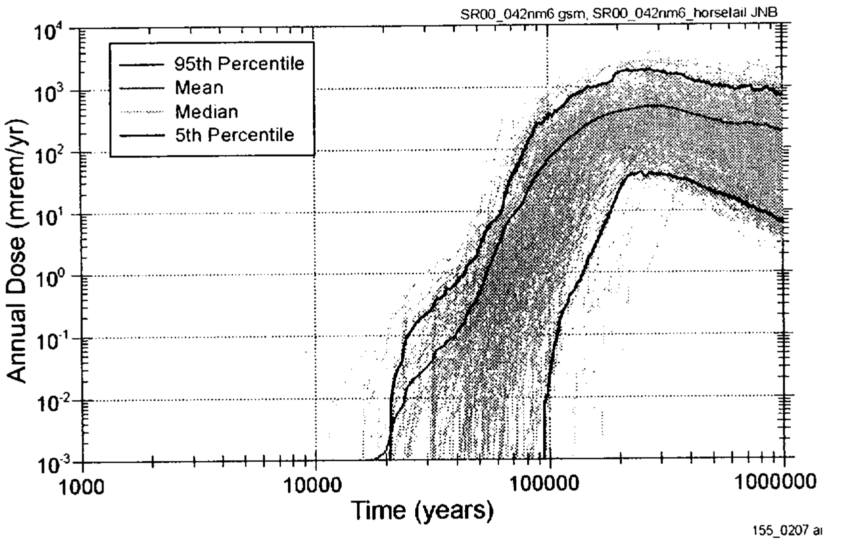


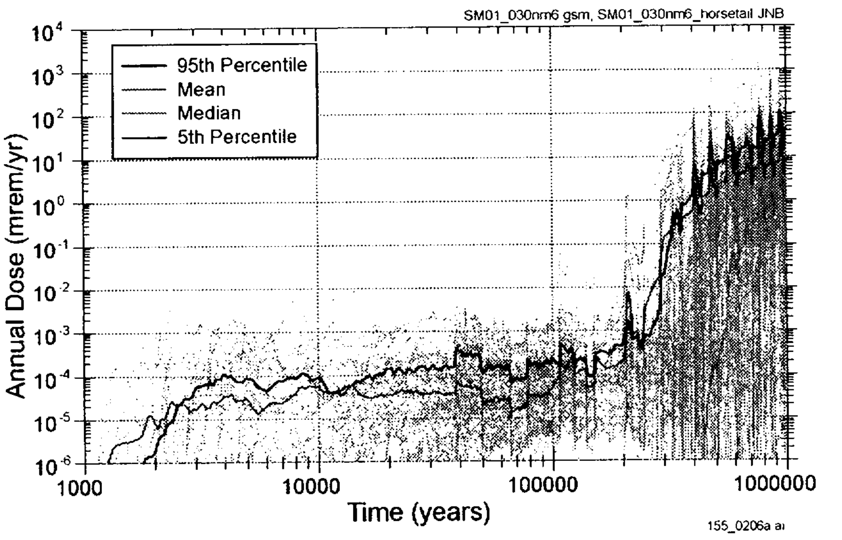




- **Parameters depend on temperature (T)**
  - **Diffusion coefficient is f(T, $S_{invert}$)**
  - **Absorption of water vapor (condensate thickness)**
  - **Evaporation/condensation fluxes**

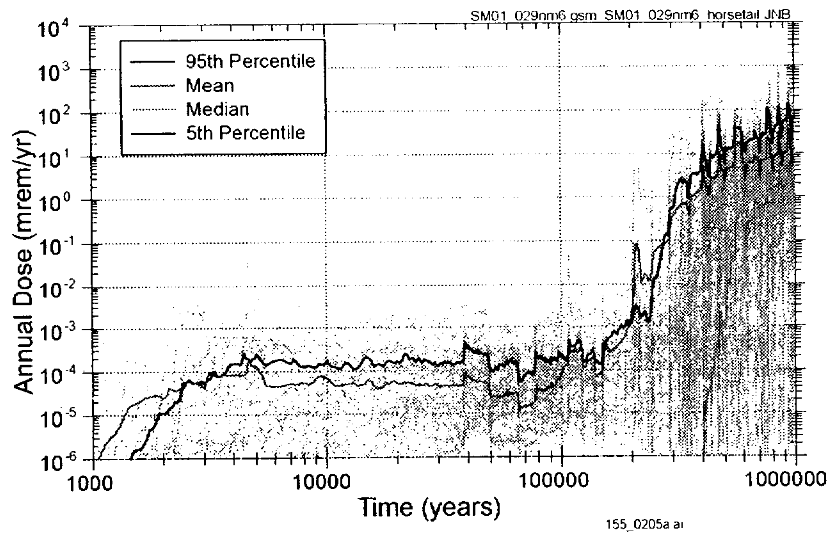
***Negligible difference between High Temperature Operating Mode and Low Temperature Operating Mode because very few waste packages fail when temperatures are different***

# 300 Realizations of Million-Year Annual Dose Histories for Nominal Performance



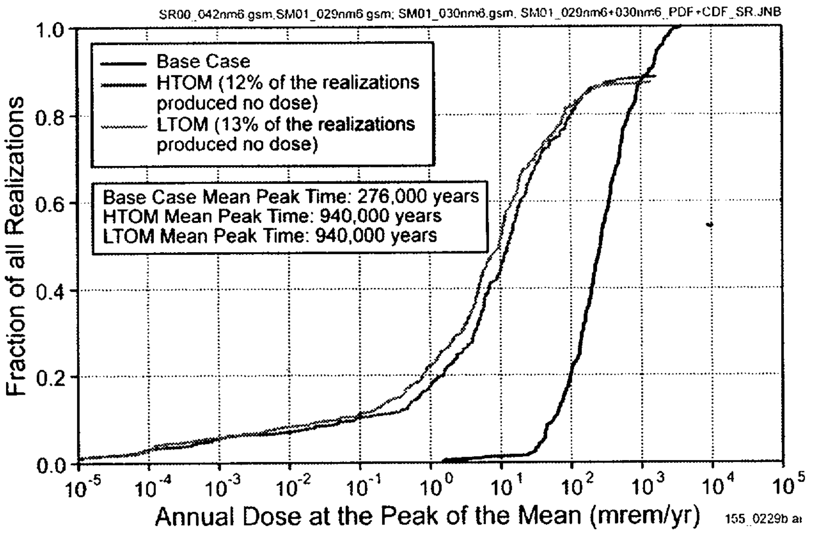

**Source: Supplemental Science and Performance Analyses, Volume 2, Figure 4.1-3.**



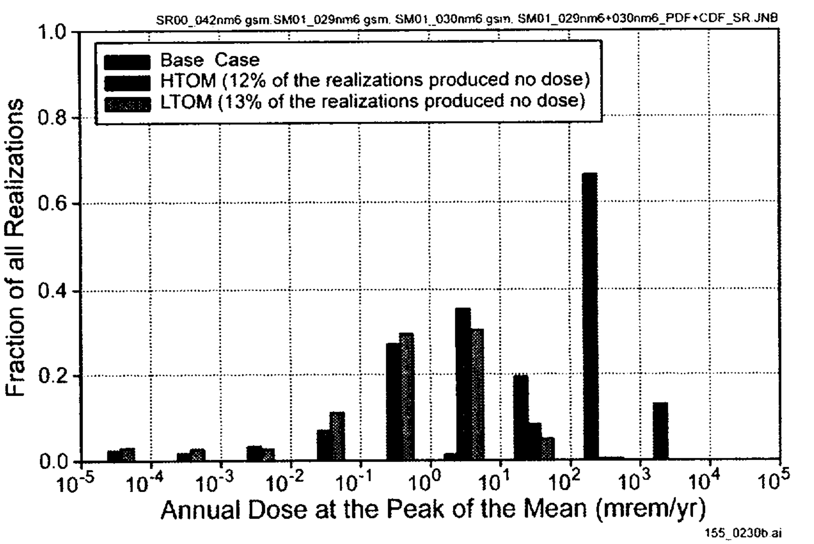

**Source: Supplemental Science and Performance Analyses, Volume 2, Figure 4.1-2.**

# Doses at Particular Times: Peak dose

**Cumulative distribution function of fraction of realizations**




**Histogram of fraction of realizations**

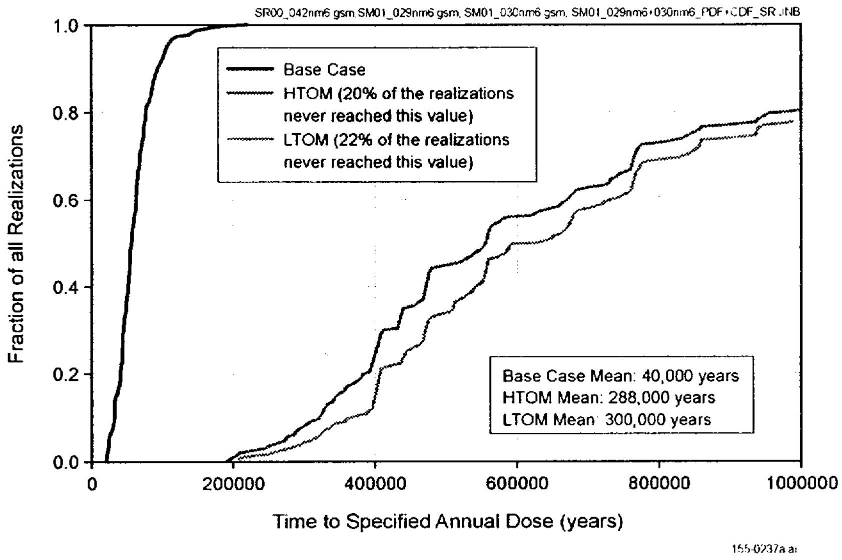



**Source: Supplemental Science and Performance Analyses, Volume 2, Figure 4.1-11(a) (b).**

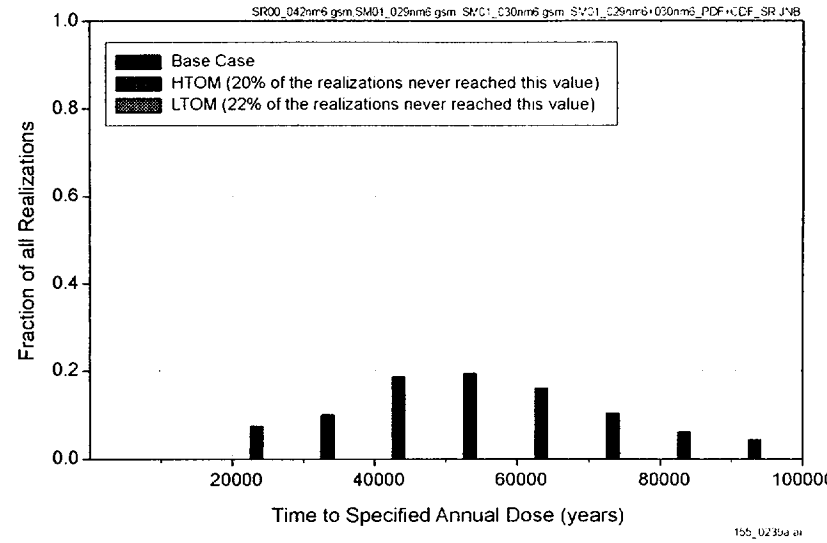
- **Peak dose occurs at about 275,00 yrs for base; about 1,000,000 yrs for supplemental model**
- **Median (50th percentile) and mean doses for supplemental model are about one order of magnitude less than base case**
- **Additional quantified uncertainties and updated models lead to a reduction in the peak dose at this time, but also a broader spread in the range of dose rates**
- **Differences due primarily to revised solubility models, which have lower mean solubility and broader range of uncertainty**

# Time to Particular Doses: 0.1 mrem/yr

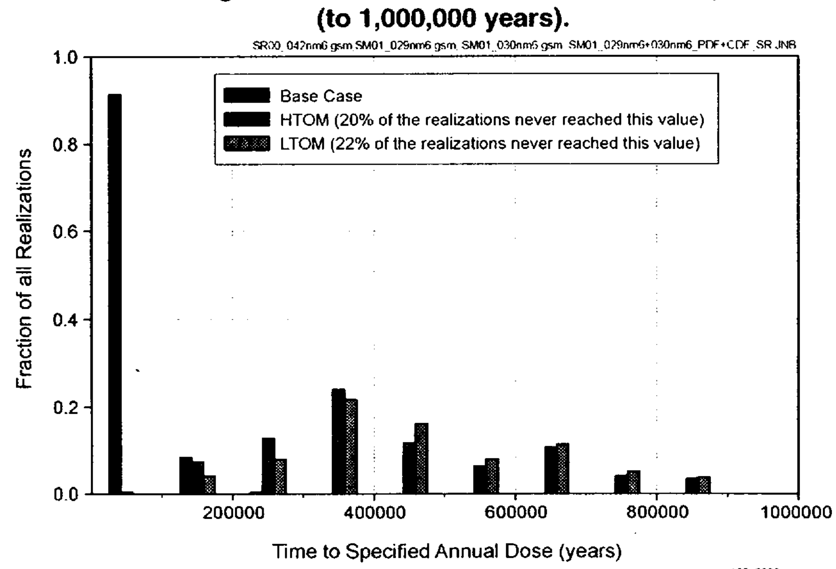
**Cumulative distribution function of time to dose rate of $10^{-1}$ mrem/yr.**




**Histogram of time to dose rate of $10^{-1}$ mrem/yr (to 100,000 years).**




**Histogram of time to dose rate of $10^{-1}$ mrem/yr (to 1,000,000 years).**




**Source: Supplemental Science and Performance Analyses, Volume 2, Figure 4.1-14 (a), (b), and (c).**

- **About one order of magnitude difference in time to reach 0.1 mrem/yr between base case and supplemental model at 50th percentile**
- **Broadening in timing due to additional quantified uncertainties**
- **Related to removal of conservatisms, particularly in Waste Package and solubility models**
- **Delay in reaching dose by lower temperature operating mode; due to temperature dependence in general corrosion rate**

# Conclusions Regarding Uncertainties and Conservatism at System Level

- **Supplemental model shows significantly wider ranges of doses at a given time and times to reach given doses**
  - Represented quantitatively by the distribution of realizations at particular dose rates and particular times
  - Broader range is a result of the additional uncertainties and updated models that have been incorporated into the supplemental model
  - Simplified or "bounding" models have been replaced with more physically representative models that include quantified uncertainties in their parameters
  - Examples are waste package degradation modes, diffusive pathways in Waste Package, Np solubility, and saturated zone transport
  - The low temperature and high temperature operating modes show similar effects of incorporation of uncertainties

# Conclusions Regarding Uncertainties and Conservatism at System Level
(Continued)

- **After the first 10,000 years, the base case model appears to be conservative with respect to the supplemental model:**
  - **The magnitude of the dose is less for the supplemental model and it occurs later in time**
  - **Mean estimates provide insight into the magnitude of the conservatism**
    - **At 30,000 years, the difference between the mean estimates of dose rate is about three orders of magnitude, and at time of peak mean dose the difference is about one order of magnitude**
    - **The mean delay in reaching 0.1 mrem/yr in the supplemental model is about 200,000 years, and in reaching 10 mrem/yr is over 400,000 years**

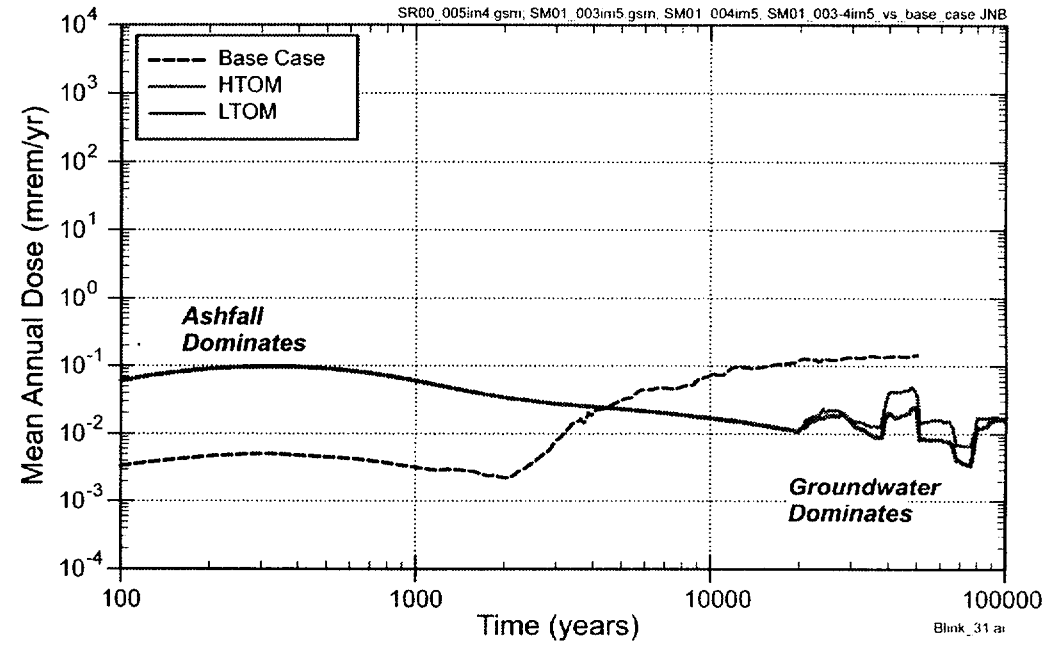
# Conclusions Regarding Uncertainties and Conservatism at System Level
(Continued)

- At higher doses and later times, low temperature operating mode appears to show lower and delayed doses

- **During the period prior to 10,000 years, the base case model appears to be slightly non-conservative with respect to the supplemental model**
  - Base case model results in no dose and the supplemental model results in finite, but very low, dose (about 0.00006 mrem/yr for LTOM and 0.0002 mrem/yr for HTOM)

# Supplemental TSPA Model Results Igneous Disruption

- **Eruptive doses increase by ~20x, dominate for ~10 kyr**
  - **Changes in probability, biosphere dose conversion factors, wind speed, # of packages damaged**
- **Intrusive groundwater doses peak with 38 kyr climate change**




- **Overall peak probability-weighted dose is similar to base case, but dominant pathway shifts from groundwater to eruptive ashfall**

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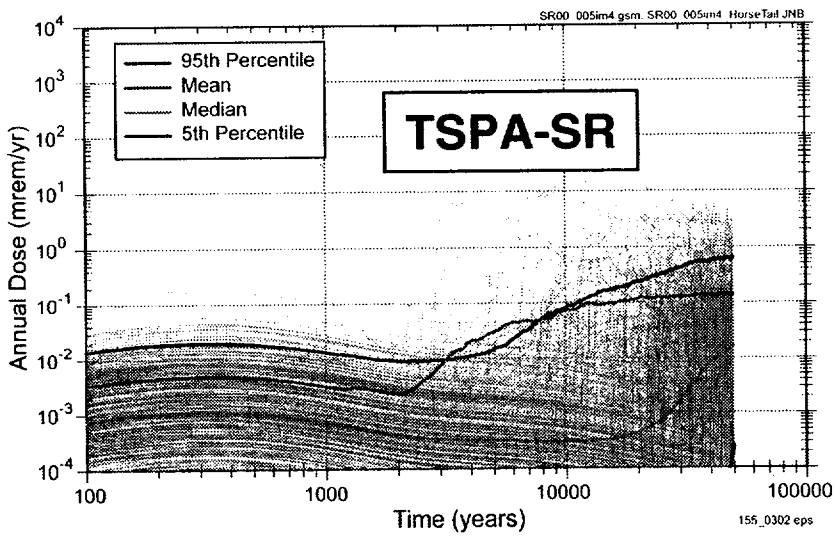
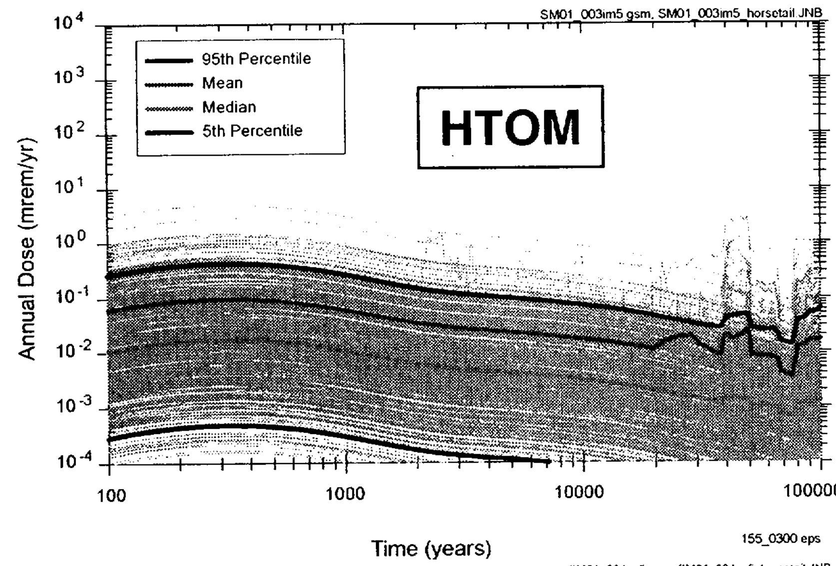
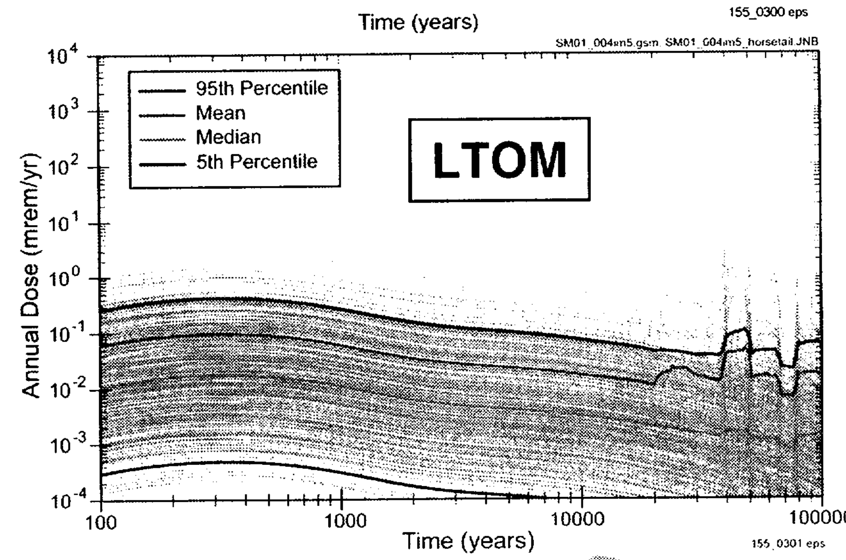
# Total Dose Uncertainty - Igneous Disruption Scenario




***Low Temperature Operating Mode and High Temperature Operating Mode results are similar***

# Process Model Effects on Dose

- Updated Np solubility - 10x peak dose decrease
- 1,000,000 year climate model - 10x dose variation
- Temperature-dependent general corrosion
  - 700,000 year delay in peak dose
  - ~350,000 year delay in 1 mrem/yr dose rate
- Early failure of a few waste packages - dose rate ~10-4 mrem/yr