UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

Title: BRIEFING ON NRC HIGH-LEVEL RADIOACTIVE WASTE PERFORMANCE ASSESSMENT PROGRAM - PUBLIC MEETING

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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BRIEFING ON NRC HIGH-LEVEL RADIOACTIVE

WASTE PERFORMANCE ASSESSMENT PROGRAM

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PUBLIC MEETING

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United States Nuclear Regulatory
Commission
One White Flint North
Rockville, Maryland

Thursday, September 8, 1994

The above-entitled meeting convened, pursuant to notice, at 3:00 p.m., Ivan Selin, Chairman, presiding.

COMMISSIONERS PRESENT:

IVAN SELIN, Chairman of the Commission
KENNETH C. ROGERS, Commissioner
E. GAIL de PLANQUE, Commissioner

STAFF SEATED AT THE COMMISSION TABLE:

KAREN D. CYR, General Counsel

JOHN C. HOYLE, Acting Secretary

JAMES TAYLOR, Executive Director for Operations

ROBERT BERNERO, Director, NMSS

JOHN GREEVES, Deputy Director, Division of Waste Management, NMSS

MARGARET FEDERLINE, Chief, Performance Assessment and Hydrology Branch, NMSS

NORMAN EISENBERG, Section Leader, Performance Assessment and Hydrology Branch, NMSS

P R O C E E D I N G S

[3:00 p.m.]

CHAIRMAN SELIN: Hi, folks.

We're meeting today to get a briefing from the staff on the status and the activities of the High-Level Radioactive Waste Performance Assessment Program.

In line with Commissioner Rogers' remarks a couple of days ago, we wish to use probabilistic performance approaches across the board within the agency and the closest analog on the high-level issue is the performance assessment. So, we expect that there will be increasing dependence on these techniques. They're certainly going to be central to processing the Department of Energy's expected request for licensing at the high-level waste repository site in Nevada. So, we're interested in this from a generic basis and from a specific basis and just would really like to hear what you have to say.

Commissioner Rogers?

Mr. Taylor?

MR. TAYLOR: Good afternoon. With me at the table are Bob Bernero, John Greeves, Margaret Federline and Norm Eisenberg, all from NMSS.

This is an essential component of high-level waste regulatory program and it represents a joint effort of the Office of NMSS, the Office of Research and the Center for

Nuclear Waste Regulatory Analysis in San Antonio. We believe that this effort, as will be described today, is within the scope of and is consistent with our agency-wide PRA implementation plan on which you were recently briefed.

Here to begin the presentation, Margaret Federline.

MS. FEDERLINE: Thank you, Mr. Taylor.

Afternoon, Commissioner, Chairman.

Today I'll briefly describe the Performance Assessment Program and I'd like to begin by providing the basics of the development of our performance assessment and illustrate it with a discussion of a potential site at the Yucca Mountain. Then I'd like to discuss how performance assessment supports NRC's regulatory mission in the high-level waste program and identify some accomplishments in that regard. Next I'd like to highlight our required future work in this area and finally I'll offer some observations related to DOE's proposed program approach specifically related to performance assessment.

May I have slide 2?

[Slide.]

MS. FEDERLINE: Performance assessment is an essential component of high-level waste development both for the developers and the regulators in this country as well as internationally because it provides a systematic and

quantitative method for evaluating the safety of repository performance. Performance assessment provides a nexus between scientific and technical issues, modeling issues and regulatory standards. So, it really allows you to get to the bottom line. It answers the questions that I've listed here on the slide, what conditions and events could effect the repository, how likely they are to occur and what their impacts on repository performance are.

Now, a key attribute of performance assessment is that it allows you to integrate and couple data for many key scientific disciplines. The iterative nature of performance assessment allows you to relate repository estimates to site characterization and design. And finally, it provides a quantitative estimate of the potential releases and their probabilities.

May I have the next slide, please?

[Slide.]

MS. FEDERLINE: In the first few slides, I'd like to go through the step-wise development of a performance assessment which is common, whether you're a developer or a regulator. I've listed the steps on this slide. In the system description, the various important components of the repository system are described, including the waste form, the engineered barrier and the site. Next we must conduct a scenario analysis which predicts the range of future

conditions that might exist at the site as well as their probabilities. Next, the consequence analysis provides an estimate of repository performance for each given scenario. Next we combine the estimate of consequences with the corresponding probabilities of occurrence and next we consider uncertainty through sensitivity and uncertainty analysis. A sensitivity analysis allows us to understand the effect that parameters or assumptions might have on the analysis and the uncertainty analysis allows us to evaluate the source and the extent of the uncertainty. Finally, when we compare to a regulatory standard, the performance assessment really makes the analysis transparent so that we're understanding the interdependencies of processes that affect the performance at the site.

May I have slide 4, please?

[Slide.]

MS. FEDERLINE: On the next two slides I'd like to illustrate this step-wise development of a performance assessment by walking through a potential site at Yucca Mountain. Slide 4 discusses the undisturbed performance at a repository site. As I mentioned, it's first necessary to describe the repository system and, as you all know, the repository at the Yucca Mountain is located in an unsaturated fractured tuff. This places great significance on the infiltration rate into the repository and

infiltration in turn is affected by assumptions related to climate, the extent and duration of rainfall and fracture matrix flow.

So, once the water moves into the repository, then assumptions have to be considered regarding corrosion of the waste package as well as dissolution of the fuel and assumptions regarding thermal loading also are key to looking at liquid and gaseous transport, the carbon-14 issue having been very significant in the development of the EPA standard.

Now, below the repository, radionuclides in the liquid phase will be transported down to the water table and then through the saturated zone to the accessible environment where it's possible to calculate integrated releases or individual or population doses.

May I have slide 5?

[Slide.]

MS. FEDERLINE: Turning to slide 5, we must analyze scenarios to consider disruptions and future conditions at the site. For example, as we've depicted on this slide, a fault zone could provide a pathway for focused infiltration and seismic events could enhance the movement of moisture along that geologic feature.

May I have slide 6, please?

[Slide.]

MS. FEDERLINE: As you can see from this discussion, developing total systems models with a level of detail with realistic level of detail on each component would be very complex and computationally intensive. So, we have developed what we call a hierarchy of models using the abstraction process. The bottom level of the pyramid that I've reflected here provides detailed models of individual processes and this allows you to examine the influence of parameter variations in the individual processes.

Now, in the second level of the hierarchy we have simplified submodels which are coupled to some extent and which take into consideration site and design configurations. Finally, at the top of the hierarchy, all the component models are further simplified and coupled and this allows you to get a calculation of the total system. But as you may understand as we go through, certain significant processes, even at the top level, may have to be reflected in some level of detail so that we can actually capture the essence and their impact on the total system performance.

May I have slide 7, please?

[Slide.]

MS. FEDERLINE: Now, up to this point, I've been describing the approach for developing a PA, but clearly the application of performance assessment is very different

depending upon the mission of the organization and the Nuclear Waste Policy Act and the Energy Policy Act establish very different missions for the DOE and the NRC. DOE is clearly responsible for characterizing the site and determining suitability as well as for demonstrating compliance with the regulations.

PA has an important role in the NRC's High-Level Waste Program, both in the pre-licensing and licensing phases because we have a responsibility to ensure that the regulatory framework is appropriate, to provide guidance to DOE, to identify licensing issues early on so that a high quality license application can be delivered.

May I have the next slide, please?

[Slide.]

MS. FEDERLINE: Now, it's important to emphasize at this point that performance assessment is a joint activity between the Center for Nuclear Waste Regulatory Analysis and the Office of Research. We have established a joint management board which oversees these activities and Budhi Sagar and Bill Ott of the Office of Research and the Center are here in the audience and can assist me in answering any questions that you might have.

Now, the objectives that I've listed on this slide stem from a joint initiative between the Center and the NRC staff. We've been developing a performance assessment

strategy which essentially lays out all the goals, objectives and activities that we need to complete in performance assessment in order to be prepared to receive a license application. We're nearing the completion of that strategy now and that will be -- hope to publish it by the end of the year.

I'll go into detail on the objectives with some accomplishments in the next few slides.

Slide 9, please.

[Slide.]

MS. FEDERLINE: The first of the objectives that I wanted to highlight is the development of technical assessment capability because this really provides the essential core for all of the PA activities that are conducted. Now, the NRC Performance Assessment Program originated back in the mid-'70s when the Office of Research contracted Sandia National Labs to develop a methodology. This was really very pioneering work and it's been adapted by most of our international partners in their work.

Now, in 1988, we initiated an MOU between the Office of Research and the Office of NMSS in order to ensure that we had a staff capability in-house to be able to conduct reviews of DOE activities and we have completed two calculational activities. Phase 1 was completed in 1992 which was a very rudimentary effort and it was directed at

merely establishing a staff capability. IPA Phase 2, which we're completing right now, is more extensive. It has more enhanced capability and it is a joint activity between Research, NMSS and the Center, as I mentioned.

This is a point I wanted to emphasize because I feel this provides us with a joint reservoir of talent and it brings a lot of perspectives from many different disciplines that really enhance our capability to perform reviews with the Department of Energy.

Now, on this slide I've listed some insights that we've been able to gain from performance assessment. I wanted to caution because these first two phases were very directed at establishing capability and data was very limited and the models were simplified. So, we shouldn't put too much weight on the conclusions, but they really indicate the types of insights that we're able to gain and I'll just touch on one or two.

For instance, number two, the effect of drilling is expected to have small consequences relative to other releases, in part because drilling affects only a small number of waste packages and also because we're not operating in a pressurized environment as they are at WIPP. Also, the radionuclide transport and fractures appears to dominate as opposed to the matrix geochemistry for gas and liquid transport.

Let's turn to slide 10.

[Slide.]

MS. FEDERLINE: Now, for the second objective, I've listed three areas where accomplishments have really current applicability in the program. The first is our recommendations to the National Academy of Science. We've been providing feedback to the Commission on our interactions with the National Academy and I'm sure you're very familiar with those. We did take some positions with the National Academy back in May of 1993 and those were largely based on our experience that we had from our analysis. For example, the second item here, scenarios for individual protection, the staff supported an individual protection standard as a part of EPA's standard, although we cautioned that it needed to be a reasonable individual protection standard. We used as an illustration using a regional water supply that's accessed by a critical group rather than a maximally exposed individual at the site boundary. We really feel individual protection is appropriate, but it should be reasonably implemented. So, we used an example from our analyses.

Second here, we have been very active in providing comments to the EPA both on the Yucca Mountain -- or the early standards as well as the non-Yucca Mountain standards or WIPP standards as they're called, and the WIPP draft

compliance criteria. One example here that we used, our experience in the 10,000 year compliance period. Our experience shows us that there are such large uncertainties outside the 10,000 year post-closure period that it will be very difficult to project over long periods of time without using a stylized or some sort of referenced biosphere.

We're also developing guidance on model validation and expert elicitation. We're currently working with the Swedish Nuclear Power Inspectorate to develop a strategy on -- it's a regulatory strategy on model validation. We will be presenting this with the Swedes at the NEA Performance Assessment Group to get some peer review of that concept.

CHAIRMAN SELIN: Ms. Federline, on the question of standards, one of the things that's bothered a lot of people, including me, is the question of how robust the standards are. If you made small changes in the standards which don't seem intuitively to make a big difference, would that have a big impact on what's acceptable and what isn't? The carbon-14 is always the example that's brought up. Do you have any insights on that? Not on carbon-14, but on the robustness of the standard. In large part, that's why the National Academy of Sciences group --

MS. FEDERLINE: Did you want to --

MR. BERNERO: No. No. You go ahead.

MS. FEDERLINE: One thing that we have been urging

the National Academy to do, really the standard needs to convey an understanding of the repository processes. That's what the licensee needs to demonstrate. They need to demonstrate that they've adequately characterized a site that they understand the assumptions and that the assumptions can be demonstrated to be conservative. So, the standards should not be so restrictive in its characteristics that it would restrict the licensee from portraying the characteristics of any particular site.

CHAIRMAN SELIN: I have no idea what that means. I'm sorry. I mean what does that answer mean in terms of what's going on that's good and what's going on that's not good?

MR. BERNERO: Let me try.

I'd like to portray it in a slightly different way. Take the Yucca Mountain standard which is, as you know, a collective dose standard. This is achievable, therefore it's acceptable. The Congress in the Energy Policy Act of '92 said, "How about a health-based or a health risk-based standard?" Now, it is widely spoken of that if you simply change the Yucca Mountain standard to four millirem a year, that Yucca Mountain wouldn't pass, it would be evidently unacceptable because after many, many, many thousands of years, the radioisotopes, the very long lived ones, would sooner or later get to the water and

sooner or later get to that hypothetical well that Margaret had on the earlier slides, and voilà, somebody would get more than 1 percent of average U.S. citizens' background.

The whole point is that the standards lack robustness in is that really necessary for safety and that four millirem a year issue illustrates the contrast between a dry site and a wet site. If you located the Yucca Mountain on a seashore, say the shore of Oregon or something, anything that comes out is massively diluted and you don't have that problem. But you are unable to discern in your standard setting the virtues of a dry site.

So, the standards -- and that's what the National Academy is facing right now. That's the issue they're facing right now, is is there a balance way to set a robust standard that can set requirements that are worthy of meeting without setting things that are really false, like the carbon-14 or this artificial farmer sipping out of a soda straw.

CHAIRMAN SELIN: Okay.

MS. FEDERLINE: The next objective is related to prelicensing interactions and these are extremely important because of the Nuclear Waste Policy Act's mandate for a three year licensing period. These prelicensing interactions are directed in ensuring that a high quality license application will be produced. One of the most

important things I believe happened are the NRC's comments on the site characterization plan urged DOE to conduct an early and iterative performance assessment program to focus on the adequacy of site characterization as well as to ensure that the right priority was given to the collection of site data. DOE has responded to this comment. I'm glad to say that they are now conducting a program of total system performance and we're watching carefully to see how it's integrated into their program.

We have reviewed four major DOE performance assessments and we've identified a number of concerns. One of the ones that I've raised here on this slide is the need for a broader range of infiltration. DOE was looking at a very narrow range of infiltration and our experience by conducting an independent performance assessment showed us that the data could support a much broader range of infiltration. So, we were able to get back to them and make that comment and they have, in fact, responded and now are considering a broader range of infiltration.

The technical exchanges are also extremely important. As we're both conducting our total system assessments, the opportunity to exchange and for us to be able to question DOE's assumptions are very important and we've conducted a number of these exchanges and the one I've highlighted here was on scenario analysis.

We're also working to close site characterization items based on the information that DOE presents to us. We've managed to close ten of those items. DOE has committed to display alternate conceptual models separately in addition to weighing these models. We were concerned that they were going to weight them with subjective probabilities and we would no longer be able to see the real impact of alternate conceptual models. So, we do have an agreement with them on that now.

May I have the next slide, please?

[Slide.]

MS. FEDERLINE: Now, the license application review plan --

CHAIRMAN SELIN: May I stop you for a second?

MS. FEDERLINE: Sorry.

CHAIRMAN SELIN: We're likely to get in the next year or two a number of requests for certification for multipurpose canisters. Relatively speaking, it's fairly straightforward to see how we would do the transport and storage characteristic. But would it be feasible to undertake some process somewhat analogous to what we've done in the repository itself, namely to try to identify the issues, to try to identify objections, to try to identify comments with the understanding that we certainly can't certify a design for disposal when we don't know either what

the waste form is or what the repository is, but that we could at least identify that these designs seem to be promising or these designs seem to have show stoppers in them.

I mean that sounds okay, but is it feasible to do or desirable to do something like that?

MR. BERNERO: Mr. Chairman, I believe you just got the letter from Dan Dreyfus responding to your question at their last briefing.

CHAIRMAN SELIN: I haven't seen that.

MR. BERNERO: You haven't seen that? I believe it just came in. I don't have a copy of it with me. But basically it is, in response to your question, "Here is the agenda for the multipurpose canister program." If you look at that letter, it has the transport casks, the topical report issues like burn-up credit and things like that all identified. A very ambitious, very difficult schedule.

But for disposal, they recognize and I think it was down the second from the bottom or something, they had a milestone there on doing this very thing, to identify the disposal aspects insofar as they can be treated now in order to perhaps close the issues that up to this point, this is as far as you can go and this would be sufficient to use in a license application for the repository, but to get issues on the table very early lest there be a development of a

multipurpose canister that's great for storage and transport and is wholly unacceptable for disposal.

So, their conscious of that, we're conscious of that and we're going to try very hard to do that.

CHAIRMAN SELIN: Do you believe it's possible to do performance analyses that are relevant when there's so much that's so ill defined about what the disposal application is?

MS. FEDERLINE: Well, if I could just follow-on, we have an effort planned in phase 3 to examine what are the critical aspects of a multiple purpose cask that we would need to call to DOE's attention. We think it's very important early on to, just from a conceptual standpoint, identify the issues even if we don't have the details.

CHAIRMAN SELIN: So, the answer to this letter which I haven't seen yet from Doctor Dreyfus, would be along the lines that I laid out?

MS. FEDERLINE: Yes.

MR. BERNERO: Yes, that that would be -- albeit dealing with the resource issues and the timing. Everything is next year or the year after. But nevertheless, getting on the table early on those parameters that can be analyzed. The easiest one to understand perhaps is thermal loading. As you know, a very significant aspect of the Yucca Mountain design is so many watts per cubic meter in order to control

the heat load and the temperature underground. That means that a small package is much easier to tailor to get so many watts per package. The larger the package and the fact that you go to utilities which vary widely in burn-up rate means you have less control or suffer greater variability in the thermal loading.

So, in your performance parameters, you can no longer guarantee a tightly held thermal control. You have suffer greater variation. So, we can analyze things like that, get a head start on them because they don't depend on the exact alloy of the package. What they depend on is thermal loading of that repository.

CHAIRMAN SELIN: Thank you.

MS. FEDERLINE: Next slide, please.

[Slide.]

MS. FEDERLINE: The license application review plan which provides staff guidance on review of DOE's license application is intended to ensure quality and uniformity of staff's review and to establish review priorities. So, we have been working as part of the staff to identify key technical uncertainties through the systematic regulatory analysis process. Five key technical uncertainties have been identified related to performance assessment and through our strategy we've identified goals and approaches that we intend to use to address these

uncertainties.

For instance, I'll just talk about the assumptions, the simplifications in mathematical models. Our goal is there to ensure that the abstracted models capture the essence of more detailed models to the extent that it's necessary to affect a performance prediction. So, our approach will be to review DOE's use of models and to develop our own independent models to compare against theirs to ascertain that the abstraction has been done effectively and is, in fact, correct.

Another one I'll just touch on is the future states. Our goal there is to identify an acceptable method for scenario selection to ensure completeness and to ensure that scenario classes have not been subdivided such that they artificially don't meet the screening criteria. We're working through an NEA working group on features, events and processes to develop a consensus internationally on what features, events and processes should be considered in a list of scenarios.

Turning to slide 13.

[Slide.]

MS. FEDERLINE: Finally, another important objective is coordination with other areas of the NRC's high-level waste program. I've touched upon the strategic plan. Let me just emphasize our international efforts here.

What we're trying to do with our international efforts is to follow new developments in PA technology and to understand and obtain peer review of new approaches and concepts, as well as to leverage our own staff resources in doing this. I've listed three examples here of how we feel we're doing that. We did participate in the development of a collective opinion on performance assessment which essentially established a consensus worldwide on an accepted methodology. We are, as I mentioned, working on a joint effort with the Swedes on a regulatory model validation and that is leveraging our resources and it's also getting us valuable peer review from another regulator.

Next we're only acting in an observer status on BIOMOVS. This is limiting our resource involvement, but we are positioning ourselves to be able to use the results of BIOMOVS which is developing a reference biosphere to implement any new EPA standard in this area. I've also provided several examples of our participation with the Nuclear Waste Technical Review Board and EPA's Science Advisory Board.

[Slide.]

MS. FEDERLINE: Turning to slide 14, the next two slides really touch on our required future work. We really feel with the completion of phase 2 that we have a mature and evolving staff capability that will have immediate

applicability in the review of DOE's proposed program approach as well as in reviewing the National Academy recommendations. As I know you're aware, the Energy Policy Act only gives EPA and NRC one year to put standards into place once the National Academy comes out. So, we really need to have our ducks in a row and be prepared to put into place an implementing standard.

Another priority I wanted to mention is with the reorganization of the Division of Waste Management, we want to make sure that our capability in high-level waste is made accessible to low-level waste decommissioning and SDMP. In fact, we're seeing a lot of synergism between the groups and finding some good feedback between the staff that are working on these.

I'll touch upon just -- in the technical assessment capability, we want to focus on key technical issues at this point in time and, Chairman, you mentioned the MPC that we have planned in phase 3. We're also planning and looking at the hot repository concept as well. So, we are focusing on programmatic issues.

I've touched upon the regulatory framework. I'll just mention that we also want to develop guidance in the areas of scenarios, biosphere transport and CCDF construction.

COMMISSIONER de PLANQUE: Margaret, what's the

latest timing estimate for the Academy recommendations?

MS. FEDERLINE: Well, Mr. Bernero has the latest.

MR. BERNERO: Yes. I was just talking to a member and their target was the end of this year, but it sounds like they're going to run a little over that. How much over it I don't know. I don't think they're certain, but they've got some pretty knotty issues they're trying to work out.

COMMISSIONER de PLANQUE: Okay.

MS. FEDERLINE: The next slide touches upon our future work in pre-licensing activities.

[Slide.]

MS. FEDERLINE: The DOE's proposed program approach provides performance assessments every 12 to 18 months. So, we'll be reviewing those and interacting with DOE. In fact, we have an upcoming technical exchange on September 27th and 28th and we'll also be reviewing the draft environmental impact statement. We'll be continuing to work on our key technical uncertainties as part of the license application review plan. We're participating in an effort right now to integrate the KTUs and to use performance assessment to somehow prioritize the KTUs, the significance of the KTUs. As we go through our independent analysis, of course, we may identify new KTUs as we go through the analysis.

In the area of coordination with other areas, I

wanted to touch on our international participation. The emphasis that we're placing there is to focus on immediate licensing needs. INTRAVAL has just been completed. It's a flow and transport project with about 28 international partners. The follow-on to that is GEOTRAP and we have been working with the organizing committee to influence that agenda. We believe there are concerns related to heterogeneity in modeling and we've been trying to direct the group and it looks like we've had some success to focus on those problems which will be directly applicable to our development of compliance determination methods.

I also wanted to touch on the research user needs. I know, Chairman, you just received a letter from ACNW on volcanism and tectonics research and they recommended that performance assessment be used to help prioritize research needs. I wanted to touch just a bit, not in great detail, about what we're doing. Phase 2, even though it had limitations because of the simplified models, it does come out with recommendations for research that is needed. It specifically focuses on the volcanism area, emphasizing that that's an area where there really is a need for an overall understanding of the basic processes. So, we really have to do some more research to understand the bounds of the consequences as well as the probabilities in that area.

We have both a formal and an informal process of

communicating with research. I mentioned that they're actually involved in conducting the performance assessment and in my view that's the best feedback mechanism when staff actually understands the problems. The second, we have a formal process where every year we revise the user needs and those are fed directly back to Research.

[Slide.]

MS. FEDERLINE: Turning to slide 16, I wanted to offer just a few observations on DOE's proposed program approach. As you're aware, we've sent two memos to the Commission on this and we've received very limited information. DOE is scheduled by the end of September to give us more indication about what their plans are for '95. But really at this point we have insufficient information to either support or object to the proposal. We do understand that the cornerstone of the program is going to be the high-level findings on site suitability. So, we've looked at this even though it's in some sketchy detail to provide you some indications of what we think from a performance assessment context. Based on the information we know, DOE will place greater reliance on bounding analysis and, of course, there's some questions in our mind about what bounding analysis really means and we need to have some discussions with DOE on that.

We have every indication that there will be a

compressed schedule with limited data and that the uncertainties are going to be larger than originally planned. So, we really feel that we're not quite clear how processes and events will be considered in combination as part of this process. We're concerned what the role of the total system performance assessment will be as they move forward with this program.

Now, the implications for our performance assessment program are that we need to have techniques to review bounding analysis and we need to really understand a broader range of uncertainties and a broader range of conceptual models to be able to probe DOE's assumptions as they come in with their submittals. So, this may, in fact, require an accelerated development of NRC's PA capability in certain critical areas.

[Slide.]

MS. FEDERLINE: Turning to the last slide, I just wanted to summarize by saying that staff has demonstrated an evolving PA capability which we believe is maturing in the right time frame. We have some immediate applications in looking at the PPA as well as in reviewing the National Academy recommendations and we're working towards developing that independent capability that will be necessary when the license application comes in.

MR. BERNERO: Mr. Chairman, I'd like to add a few

remarks to pick up on your opening comments and Commissioner Rogers' comments last year in the PRA discussion. In the course of it, perhaps I can give you a more satisfactory address of the question you had about standards and their robustness.

If you look at the history of performance assessment, and there was a little bit of it in the presentation here of what the performance assessment program is doing, it has been an agency-wide effort whose seed was planted in the Office of Research quite a few years ago. I remember with great satisfaction 14 years ago when I was head of the Probabilistic Analysis staff, we had vigorous activity to develop waste transport standards, to develop performance assessment and we held the contract that was granted to Sandia.

The one thing that is generally characteristic of PRA, performance assessment or PSA, whatever terminology you choose, its greatest virtue is the ability to systematically display what you know and to consider what you don't know. I recall in reactor PRA the briefing last week, there was one item made about safety goals and licensing and so forth.

PA, performance assessment, as a variant of PRA, is the best method we have to deal with both the standards, whether or not the standards make sense, whether or not they should be adopted and implemented, and also with the

licensing itself. It is the best systematic way to weigh the balance of good geology, bad geology, the role of engineered features and really making things better. And it has one other feature that is distinctly different from reactor PRA applications and that is given that the standard is a probabilistic safety goal, in essence, it can become and is expected to become a part of our regulations after the smelting process and we are licensing to that safety goal.

So, it is very important for us to have the capability and to use it wisely in the process of dealing with the standards, are they robust, in what ways are they not robust, how should they be modified if so, and also to be able to understand the processes well enough to sensibly apply those standards in a licensing case as the time comes.

The proposed program approach that has been talked about and will be talked about for many months to come that DOE is following now for Yucca Mountain has one fundamental characteristic that's evident from its evolution and that is that we will probably have less on the table in the way of data, analysis and what have you to make a decision than some of us would like because there is a tendency for the regulators to sit back and, "Show me some more rocks before I tell you they're nice rocks." That proposed program approach is evolving toward a more streamlined, actually

something more consistent with what the National Academy recommended four years ago, a more gradual or evolutionary approach to licensing and the PA capability, the performance assessment capability is going to be vital to our dealing with that.

We may not have enough information on the table to make a final decision for construction authorization, but we certainly will have to use performance assessment wisely in order to draw that conclusion.

MR. TAYLOR: That's all, sir.

COMMISSIONER ROGERS: Well, just following up a little bit on that, it seems to me that the concept of an iterative process is very important here, that you've mentioned I think. My understanding of the concept is that you will try to do a total system analysis and performance assessment with whatever knowledge you have and then continue to refine it as more and more knowledge develops, so that in a sense you -- if I'm not right, I'd like you to straighten me out on this because I think that is a very sensible way to go and that you always have a picture, you always have a total picture, although it's maybe not as clear as you would like, but it's there. It's like a negative developing in the developer bath. I mean you see a little bit at first but you got the whole thing and then more and more evolves as time goes on, as more and more data

understandings come in and as you can plug them in in the appropriate way, but you always have the whole thing.

It seems to me that in a sense that's really very important. It's one of the things that we've always been concerned about, that there might be something that has been totally overlooked until you get around to looking at it and then all of a sudden there it is, it's staring you in the face and everything else fades into the background as unimportant compared to that one thing.

On the other hand, if you're looking at the total system as you go, you have a sensitivity to that potential from the outset and it seems to me that that's very important.

I wonder if you could say a little bit more about the iterative nature of the performance assessment activities.

MR. BERNERO: Yes. I would like to take the floor from Margaret for this one.

I think you said it well. It's very important to get the iterative character and to understand that you don't have all the information yet. But in her comments on insights from performance assessment, she wisely spoke to the limitations that those who are doing it are also aware that their methodology has inherent weaknesses, it's as yet undeveloped in one aspect or another and that's equally

important to remember as well as the lack of full physical data.

But it does go back to the fundamental character of an iterative use of performance assessment or PRA. It is a systematic way to display what you know now and to assess it for, "What do I need to do? Do I have enough information to make a decision? Do I have enough methodology to understand? If not, what should I do?" In my view, it's the only game in town, as the idiom goes. It's the iterative character of it that makes it.

Five years ago in this high-level waste program it was almost scandalous. I took to saying to DOE every insulting phrase I could, "Where are your performance assessments?" In our comment letter in 1989 we chastised them, urged them, "Come on, get the performance assessment out. Otherwise, you don't know where you're going or what you're doing." Now, of course, as Margaret pointed out, we have reviewed four major activities of theirs.

MS. FEDERLINE: If I could just add one point, it's extremely important that we continue to conduct performance assessments. We've learned so much by doing our own independent analysis, even though we're only looking at small portions of what DOE -- DOE is doing a much bigger job. But the insights that we've learned from actually running the analyses themselves, truly some things are not

intuitive. As reviewers, if a performance assessment would have come in, we would have sat at our desks and thought one thing. But because we're conducting the analysis, we've really had some different views of the work that DOE is doing. So, it's been advantageous for us on an iterative basis as well.

COMMISSIONER ROGERS: Well, I think that raises the question of resources. How do we decide what the adequate resources are that ought to be directed towards performance assessment here at NRC? There are various points of view towards this, as you know. I think ACNW has not come to a conclusion on it, but sort of talked a little bit about, "Well, maybe the reviewer doesn't have to have the same kinds of capability that the practitioner has to have and the doer."

And obviously you don't need an army of people, but it does seem to me there's got to be some basic critical mass, if you want, of expertise to carry out performance assessments and it is very important to identify what that is and see that you have it because if you have an adequate collection of expertise to do the performance assessment, you can't do the performance assessment almost by definition. It's then just a sort of spot check, hit or miss kind of activity and you lose the capability that you've just described that has been so important in our own

learning how to ultimately look at a performance assessment when it is submitted to us.

So, I wonder what we're doing with respect to identifying, if you want, the critical size group or the critical talents and abilities that have to be available to NRC in some way or another? I know we have the Center activities which are very important, but I wonder how we see putting that whole thing together. Has that been done or were you still in the process of doing that?

MR. BERNERO: Well, that is done through the budgeting process also in an iterative way. It relates significantly to some of the discussion last week on PRA agency-wide. If you look at probabilistic risk analysis or probabilistic safety analysis in reactors, we have evolved to a more refined state. We have every licensee at a condition of analyzing their own plants and even into the IPEEE, into the seismic events which are very knotty problems. We have a nucleus, a core of experts who do review those works in the Office of Research and in NRR, but at the same time we see a need for a broader perspective in the other project managers and inspectors and so forth to understand the context of PRA, PRA insights, what is the significance of it.

In performance assessment, it has been because of what it is. In waste disposal, you have the source term and

the only thing you haggle about is how big is it or what is it. Is it soluble cesium or is it insoluble americium? You have the source term and you are assessing the transport or release of that source term. That's in stark contrast to PRA which is much more looking at what are the odds that you will have a source term.

What we really have is performance assessment has been practiced in perhaps call it a more deterministic way. It's what got to the groundwater. You know, groundwater releases, do they exceed four millirem a year or whatever. This is a pervasive part of the regulatory process of waste disposal or contamination movement. What we have done is from the very beginning, starting in the Office of Research, we have tried to develop the capability, transpose the technology not only to the regulatory staff itself but to the Center. As short a time ago as I'd say three or four years, I didn't feel that the Center was a center of expertise. Now it is.

So, what we have tried to do in the budget process up until now is to get the technology of full bore or full competence performance assessment not only in the Office of Research and NMSS, but also into the Center. Now we are in a position as we use it to take a look at how much training or expertise is appropriate for the other members of the staff.

As a historical matter, Margaret's branch is hydrology and performance assessment because historically if you're doing hydrology you are really doing performance assessment. It's the key transport mechanism for waste.

So, we are at that stage. We don't have any formal algorithm to say how many training courses we're going to have and that yet, but we're at that stage where we now have the expertise in place. And at this level, I don't intend to grow the expert level to any significant degree, but we do need to look at the broader understanding of it with the rest of the staff.

COMMISSIONER ROGERS: Fine. Thank you very much.

COMMISSIONER de PLANQUE: Just one detail, Margaret. You were on a roll, so I didn't want to interrupt you.

Back on slide 10 you talked about developing guidance for expert elicitation. Is that a new word for expert judgment?

MS. FEDERLINE: Yes.

MR. BERNERO: Yes.

COMMISSIONER de PLANQUE: Could you just tell me a little bit more about where you're headed and why did the terminology change?

MS. FEDERLINE: Well, it's actually not a terminology change. What we have done, phase 2.5 we

initiated with the Center. We wanted to gain some experience ourselves in conducting an expert elicitation and that is the term that is used to elicit the views of experts. So, that is the process that's used.

We went through an experience ourselves so that we could advise DOE on what we felt would be appropriate for the licensing process. So, we have completed phrase 2.5 which was focused on climate change, looking at the probability of changes in future climate. That gave us some experience. Now we're moving into an effort of developing guidance based on that as well as looking at a wider use of expert judgment in the community.

COMMISSIONER de PLANQUE: Any striking observations from this process?

MS. FEDERLINE: I think we're well prepared at this point to discuss what an appropriate elicitation process encompasses. This is the selection of the right experts encompassing a broad set of views, how elicitation is conducted, what the role of the normalization expert is. I think we're well prepared to provide that sort of guidance. How it should be used in performance assessment, I think we still have some questions in our mind about what issues perhaps are candidates for aggregating expert judgment. We have some real concerns. Our goal is to ensure that everything in the licensing process is as

transparent as possible for the licensing board and the Commission and we don't want to appear to endorse anything that would make views not transparent. That's one concern we have about the aggregation process. But we're still looking at that. The jury is still out.

COMMISSIONER de PLANQUE: Okay. Thank you.

COMMISSIONER ROGERS: Just on that, I assume that you're in close contact with ACNW on this because that's --

MS. FEDERLINE: Oh, yes.

COMMISSIONER ROGERS: -- a topic which they have been putting quite a bit of thought into and --

MS. FEDERLINE: They've been very helpful to us.

COMMISSIONER ROGERS: -- particularly since they've had a new member who's been very interested in that. They have some very interesting ideas and they're not entirely in agreement on all aspects of this. But I had a very interesting session with them a few weeks ago and it's very clear that they are giving a lot of thought to this question.

MS. FEDERLINE: Yes.

COMMISSIONER ROGERS: And I think it can be of real help here.

MS. FEDERLINE: Yes. We agree.

CHAIRMAN SELIN: Okay. Thank you very much for a

very interesting presentation. It was great. Thank you.

MS. FEDERLINE: Thank you.

[Whereupon, at 3:54 p.m., the above-entitled meeting was concluded.]

CERTIFICATE

This is to certify that the attached description of a meeting of the U.S. Nuclear Regulatory Commission entitled:

TITLE OF MEETING: BRIEFING ON NRC HIGH-LEVEL RADIOACTIVE WASTE PERFORMANCE ASSESSMENT PROGRAM - PUBLIC MEETING

PLACE OF MEETING: Rockville, Maryland

DATE OF MEETING: Thursday, September 8, 1994

was held as herein appears, is a true and accurate record of the meeting, and that this is the original transcript thereof taken stenographically by me, thereafter reduced to typewriting by me or under the direction of the court reporting company

Transcriber: Carol Lynch

Reporter: Peter Lynch

STAFF BRIEFING ON THE

HIGH-LEVEL RADIOACTIVE WASTE PERFORMANCE ASSESSMENT PROGRAM

September 8, 1994

Margaret V. Federline, NMSS

Contact: Margaret Federline
Phone: (301) 415-7208

OVERVIEW

- Background
- Program Objectives and Accomplishments
- Plans for Future Work
- Observations Regarding DOE's PPA
- Summary

WHAT IS PERFORMANCE ASSESSMENT (PA)?

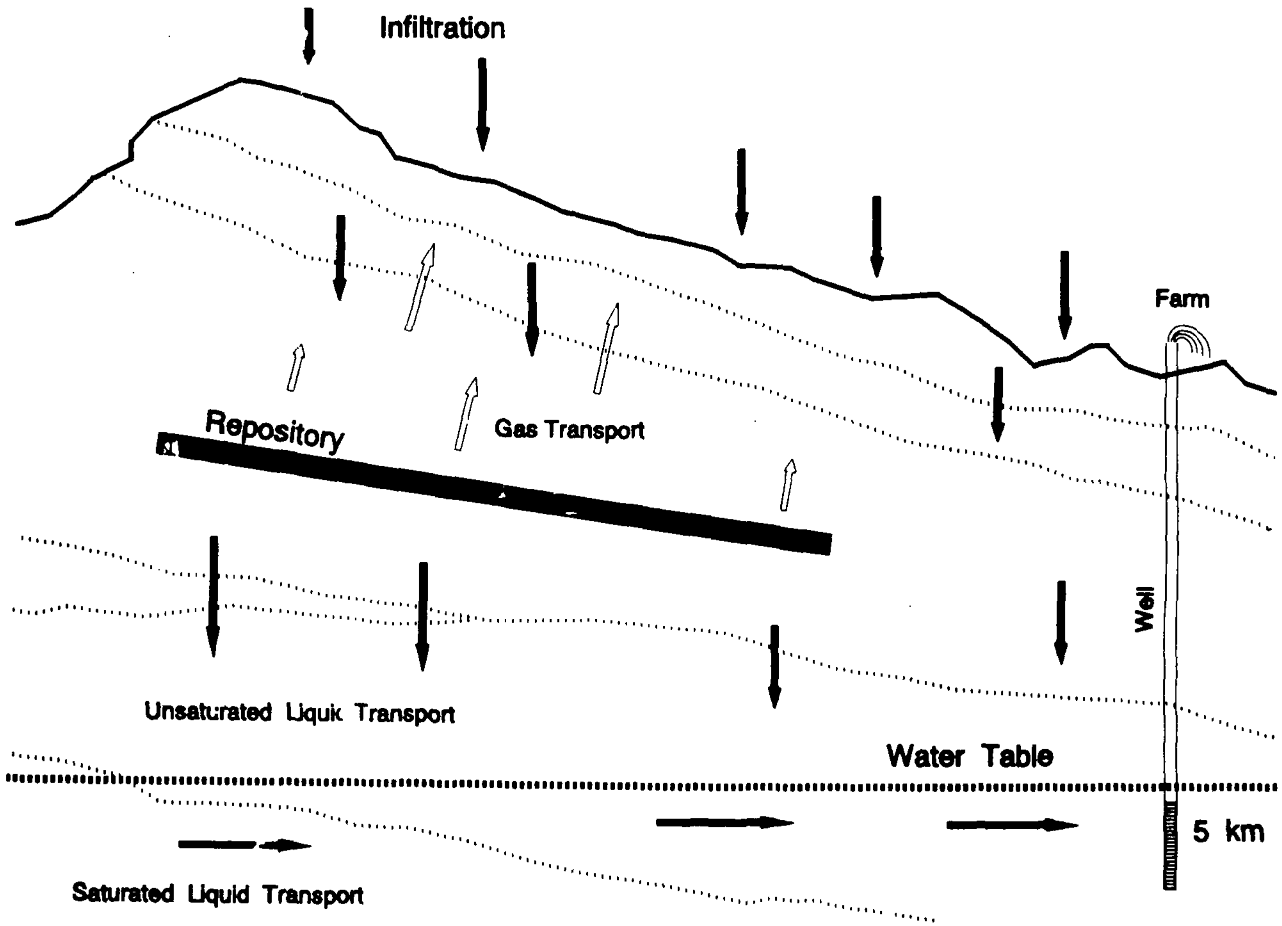
- Systematic Approach to Safety Analysis
  - What conditions and events could affect the repository?
  - How likely are they to occur?
  - What are their impacts on repository performance?

- Integrates and Couples Information

- Provides Quantitative Estimates

STEPWISE DEVELOPMENT OF A PERFORMANCE ASSESSMENT:

- System Description
- Scenario Analyses
- Consequence Analyses (Disturbed and Undisturbed)
- Combine Consequences with Probabilities
- Sensitivity and Uncertainty Analyses
- Compare to Regulatory Standards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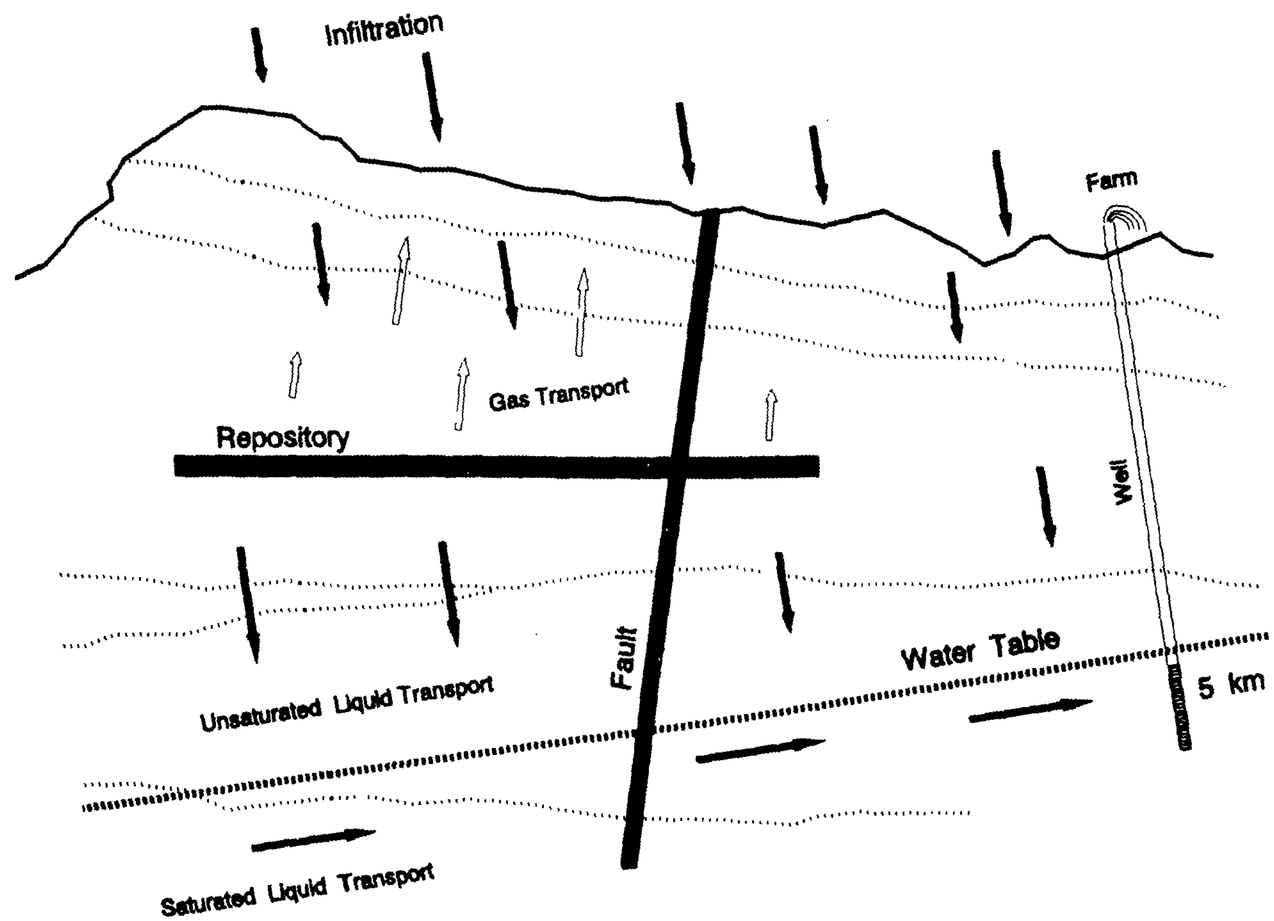
Saturated Liquid Transport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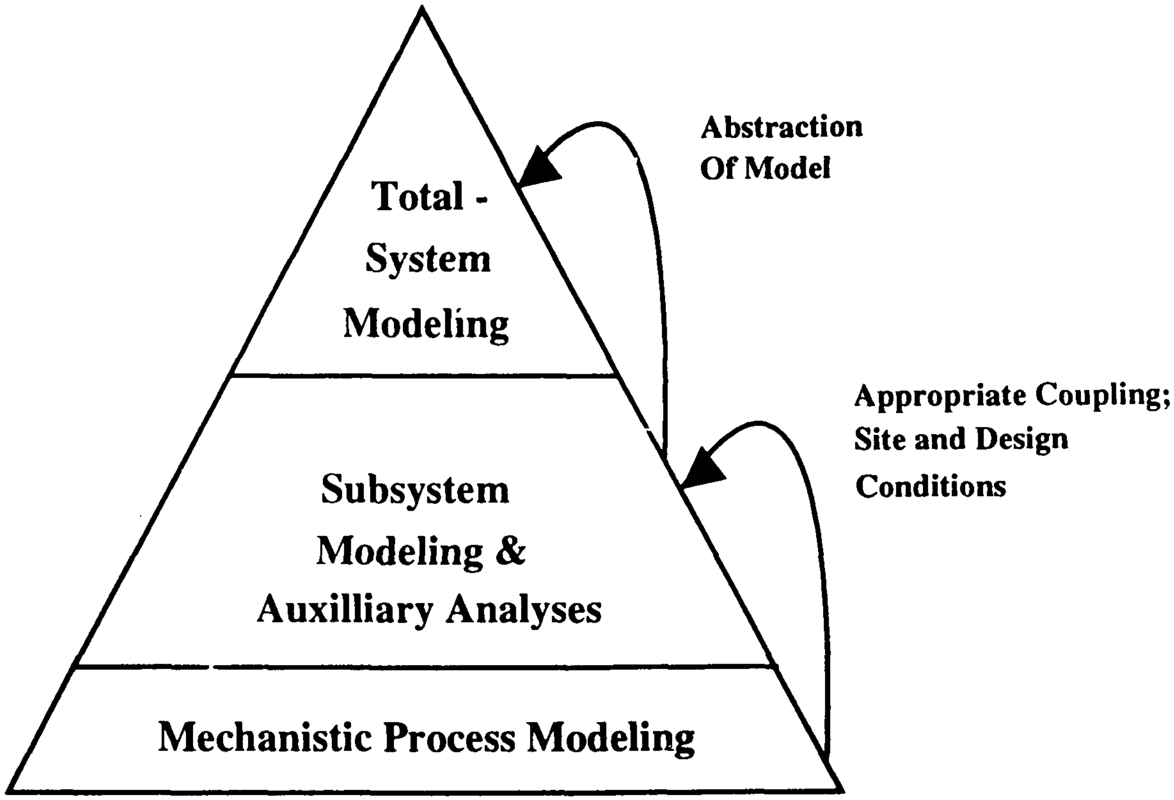
MODEL HIERARCHY



NRC AND DOE USE OF PA REFLECT DIFFERENT AGENCY MISSIONS

- DOE
  - Characterize site and determine suitability
  - Demonstrate compliance with Part 60
  - Prepare EIS and LA using PA
- NRC
  - Conduct pre-licensing reviews
  - Revise technical criteria
  - Determine sufficiency of site characterization
  - Determine sufficiency of waste form proposal
  - Evaluate DOE's compliance with Part 60

OBJECTIVES OF NRC'S PA PROGRAM

- Develop Sufficient Technical Assessment Capability
- Ensure Sound Regulatory Framework
- Support Pre-licensing Interactions
- Prepare License Application Review Plan for PA
- Coordinate with Other HLW Activities

DEVELOP TECHNICAL ASSESSMENT CAPABILITY
Examples of Accomplishments

- **Preliminary Insights From Iterative Performance Assessment**

    - **^{14}C dominates releases; contributes little to individual dose**
    - **Lesser impact of human intrusion for Yucca Mountain**
    - **Radionuclide transport in fractures appears to dominate**
    - **Better source term model needed to evaluate thermal effects**

ENSURE SOUND REGULATORY FRAMEWORK
Examples of Accomplishments

- **Recommendations to National Academy of Sciences**
  - **Health-based standard**
  - **Scenarios for individual protection standard**
  - **Use of reference biosphere**

- **Comments on EPA Standards and Draft Compliance Criteria**
  - **10,000-year compliance period**
  - **Use of probability distribution functions**
  - **Number of samples to demonstrate compliance**

- **Developing Guidance on Model Validation and Expert Elicitation**

PRE-LICENSING INTERACTIONS
Examples of Accomplishments

- Reviewed 4 Major DOE PAs and Identified Need to Consider
  - Broader ranges of infiltration
  - Alternative flow concepts
- Technical Exchange Relayed Concerns Regarding Scenario Analyses
- Closed 10 Site Characterization Plan Open Items Including DOE's Inappropriate Weighting of Conceptual Models

DEVELOPMENT OF A LICENSE APPLICATION REVIEW PLAN
Examples of Accomplishments

- **Identified 5 Key Technical Uncertainties Related to PA**
  - **Conceptual models**
  - **Assumptions/simplification in mathematical models**
  - **Variability in input parameters**
  - **Future states**
  - **Model validation**

COORDINATION WITH OTHER AREAS OF NRC'S HLW PROGRAM
Examples of Accomplishments

- Strategic Plan
- International Efforts
  - Nuclear Energy Agency Collective Opinion on PA
  - Joint effort with Sweden on model validation strategy
  - Interact with BIOMOVS on reference biosphere development
- Presentations to Nuclear Waste Technical Review Board on PA and Use of Natural Analogues
- Presentation to EPA's Science Advisory Board on ^{14}C Releases

PLANS FOR FUTURE WORK

TECHNICAL ASSESSMENT CAPABILITY

- Focus PA on Key Technical Issues
- Coordinate HLW and LLW PA Programs

REGULATORY FRAMEWORK

- Evaluate NAS Recommendations
- Review and Conform Part 60 to Final EPA Standards
- Regulatory Guidance

PLANS FOR FUTURE WORK (CONTINUED)

PRE-LICENSING ACTIVITIES

- Review DOE's PAs
- Technical Exchanges
- Comment on DEIS

LICENSE APPLICATION REVIEW PLAN

- Identification and Prioritization of Uncertainties
- Compliance Determination Methods for PA Uncertainties

COORDINATION WITH HLW PROGRAM

- Complete PA Strategic Plan
- Focused International Participation
- Research User Needs

DOE'S PROPOSED PROGRAM APPROACH (PPA)
Observations and Implications

- Insufficient Information to Support or Object
- Greater Reliance on "Bounding Analyses"
- Compressed Schedule, Limited Data, Larger Uncertainties
- Combinations of Processes and Events Not Clearly Addressed
- Use of Total System PA Unclear
- Broader Range of Conceptual Models Will Need to Be Evaluated
- May Require Accelerated Development of NRC's PA Capability

SUMMARY

- PA Is Essential to Determination of Regulatory Compliance
- NRC Staff Has Demonstrated An Evolving PA Capability
- Future Activities Will Apply Staff's Capability to Important Technical and Programmatic Issues

UNITED STATES NUCLEAR REGULATORY COMMISSION

POLICY ISSUE
(Information)

August 29, 1994

SECY-94-228

FOR: The Commissioners

FROM: James M. Taylor
Executive Director for Operations

SUBJECT: STATUS OF THE HIGH-LEVEL WASTE PERFORMANCE ASSESSMENT PROGRAM

PURPOSE:

To inform the Commission of the current status of the staff's program for performance assessment (PA) of a high-level waste (HLW) repository.

SUMMARY:

PA is an essential component of the U.S. Nuclear Regulatory Commission's HLW regulatory program, because it affords a systematic, quantitative method for analyzing and evaluating the safety of a geologic repository. PA synthesizes information from a wide range of scientific and engineering disciplines to achieve quantitative estimates of repository performance and to obtain an essential understanding of key repository processes, their interactions, and their implications for safety. The PA capability of the NRC staff is a vital contributor to: (1) the fulfillment of NRC's legislative mandates; (2) the development of NRC's waste disposal regulations; (3) the provision of guidance to the U.S. Department of Energy (DOE) on the adequacy of site characterization; and, eventually, (4) the support of a Commission decision on whether to grant authorization for construction of a proposed repository. The NRC staff is developing its PA capability in a time frame appropriate to review DOE's total system performance assessments (TSPAs) during the characterization, development, and licensing of the proposed repository. In a

NOTE: TO BE MADE PUBLICLY AVAILABLE AT THE COMMISSION BRIEFING ON SEPTEMBER 8, 1994

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cooperative effort between Center for Nuclear Waste Regulatory Analyses (CNWRA) staff, and Office of Nuclear Material Safety and Safeguards (NMSS) and Office of Nuclear Regulatory Research (RES) staffs, NRC has recently completed the second iteration of conducting quantitative PAs and acquiring analytical tools, thereby enhancing the staffs' PA capability.

BACKGROUND:

Since its inception in the mid-1970's, the NRC's HLW repository program has relied on PA to accomplish several objectives. It has been applied to the formulation of the NRC's HLW regulations (10 CFR Part 60) as well as to the generation of formal and informal comments on the U.S. Environmental Protection Agency's (EPA's) HLW standards at various stages of development.

DOE is required, by regulation, to provide a comprehensive PA in its license application. NRC is obligated to ensure in its review of a license application that the proposed repository will adequately protect public health and safety. The NRC staff's strategy for conducting a licensing review of DOE's PA calls for an audit review of the assessment in its entirety, supplemented by more detailed reviews of those sections that are of greatest safety significance, for example, radionuclide transport through fractures and the effect of specific scenarios such as volcanism. As a part of its review process, the NRC staff will rely heavily on site data collected by DOE, but will perform independent estimates of the potential performance of the repository, as described in the license application. It will be necessary, therefore, for NRC to decide which portions of DOE's assessment require independent verification through more detailed quantitative analyses.

NRC's PA activities have also supported pre-licensing interchange with DOE concerning characterization of the Yucca Mountain site. In its 1989 Site Characterization Analysis, the NRC staff commented on DOE's Site Characterization Plan, as required under the Nuclear Waste Policy Act, and highlighted the need for TSPAs early in the site characterization program. The staff expressed concern that DOE needed to improve the technical integration of its site characterization program and emphasized the important role that PA should play to integrate data-gathering activities and to guide evaluations of those data. PA activities have also supported NRC staff's interactions with EPA and the National Academy of Sciences (NAS), as a part of the NAS reevaluation of EPA's HLW standards, as they will apply to a proposed repository at Yucca Mountain.

The NRC staff will continue to rely on its PA activities to: (1) support ongoing interactions; (2) provide a basis for judging the sufficiency of DOE's site characterization activities; (3) facilitate constructive review and comment on DOE's Draft Environmental Impact Statement (DEIS); and (4) prepare for an effective and efficient review of an eventual license application.

DISCUSSION:

What is PA?

PA is a systematic safety analysis, similar to probabilistic risk assessment (PRA), that is especially adapted to the issues and systems relevant to the geologic disposal of radioactive waste. A PA quantifies the safety of a waste repository by estimating the nature and probability of radionuclide releases to the accessible environment and the potential impacts on public health and safety and the environment. Additional measures of total system or subsystem performance may also be quantified, using PA techniques. A PA is a structured analysis that systematically addresses the following:

(a) What are the conditions and events that could impact the performance of the repository?
(b) What is the likelihood of occurrence of these conditions and events over the mission time of the repository?
(c) What are the potential impacts of these conditions and events on repository performance?

To address these questions and to provide quantitative estimates of performance, an assessment must integrate and couple information from many scientific and engineering disciplines, including: hydrology, geology, geochemistry, corrosion science, stress analysis, rock mechanics, thermo-fluid dynamics, mechanical engineering, and PRA. PA has many complicating factors, including conceptual model uncertainty, probabilistic aspects, a hierarchy of models, and natural and engineered components in the repository system.

Modeling for assessing performance, by necessity, must be closely tied to site characterization and repository design. Data from site characterization and design features are crucial, not only to the development of appropriate conceptual models, but also to extraction of parameter values that are employed to obtain numerical estimates of repository performance. Development of the conceptual model or models is the first step in PA modeling. For most natural and many engineered systems, formulation of a single, acceptable conceptual model is difficult, if not impossible, to achieve. In most cases, several classes of conceptual models are derived that satisfy the known constraints to varying degrees. Conceptual model development includes decisions on the governing equations, the geometry of the system, initial conditions, appropriate boundary conditions, and level of detail. Formulation of conceptual models for the natural system introduces problems that may not be encountered for engineered systems. Engineered systems, within limits, can be designed; geology can only be explored and characterized. Because tests may perturb the very properties being measured and because of the possibility that destructive testing could impair the barrier properties of the site, site testing is usually quite constrained. The site conceptual model, therefore, is based on considerable extrapolation of sparse quantitative data, which can give rise to large conceptual and parameter uncertainty. In view of this, it is especially important that NRC use its PA capability to analyze alternate site models to test the robustness of DOE's conclusions.

PAs are probabilistic because they must treat a variety of scenarios (potential future states) and broad ranges of parameter values. Although the use of PA, like PRA, was pioneered by the NRC staff, it is still an evolving discipline, with substantial challenges. Also, like PRA, it is unlikely that PA will become an "off-the-shelf" technique. Quantitative estimates of repository performance are primarily obtained from the execution of a sequence of linked computer codes, representing various components of the repository system or its environment. Variations of parameter values are usually treated by repetitive execution of these linked computer codes using sets of input parameter values drawn from distributions with a probability assigned to each set of values. Uncertainties due to scenarios are treated by altering the models or distributions based on the nature of the scenario and repeating the calculation of performance, weighting the result with the probability of the scenario, which is determined by a separate auxiliary analysis. Because a large number of repetitions is required to treat the full range of scenarios and parameter uncertainties, the computer codes representing the various components of the repository system must be rapidly executable, yet sufficiently complete and detailed. These efficient, fast representations of elements of the repository are "abstracted" from more detailed, but computationally intensive, computer codes, based on fundamental principles and the properties of the system. These computer codes, in turn, rest on even more fundamental analyses and experiments. This "abstraction process" is shown schematically in the figure shown on the next page.

Models and corresponding computer codes for the total system that include realistic details of all system components can become very complex and computationally onerous. This is generally the case for repository PA. Under such circumstances, it is logical and appropriate to perform modeling using a hierarchy of models. The very detailed, and more realistic, models of individual processes comprise the first level of this hierarchy and are useful for understanding the sensitivity of a process to parameter variations and external forces. These first-level models are also used to demonstrate the conservatism of assumptions and to provide a basis for second-level models in the hierarchy. In the second level, a limited number of the detailed models, with some simplifications, are coupled with one another, to gain some understanding of the interfaces among processes. In the third and final level, all component models are further simplified and coupled to formulate a "TSPA model." These are the fast, efficient models required for a probabilistic treatment of performance. It must be kept in mind, however, that if the coupling among the detailed models is strongly nonlinear, then it may not be easy to ascertain whether assumptions for conservatism made in one model remain conservative when this model is coupled to another. In addition, not all processes are reduced to the third level of simplicity for inclusion in the system model; some processes are so central to the final result that they must be included in full detail.

A further complication for PA is that natural components are an integral part of the repository system. PA attempts to predict the behavior of a repository system over a very long period of time, currently 10,000 years. Furthermore, a natural subsystem, the geosphere, is a major component of the repository,

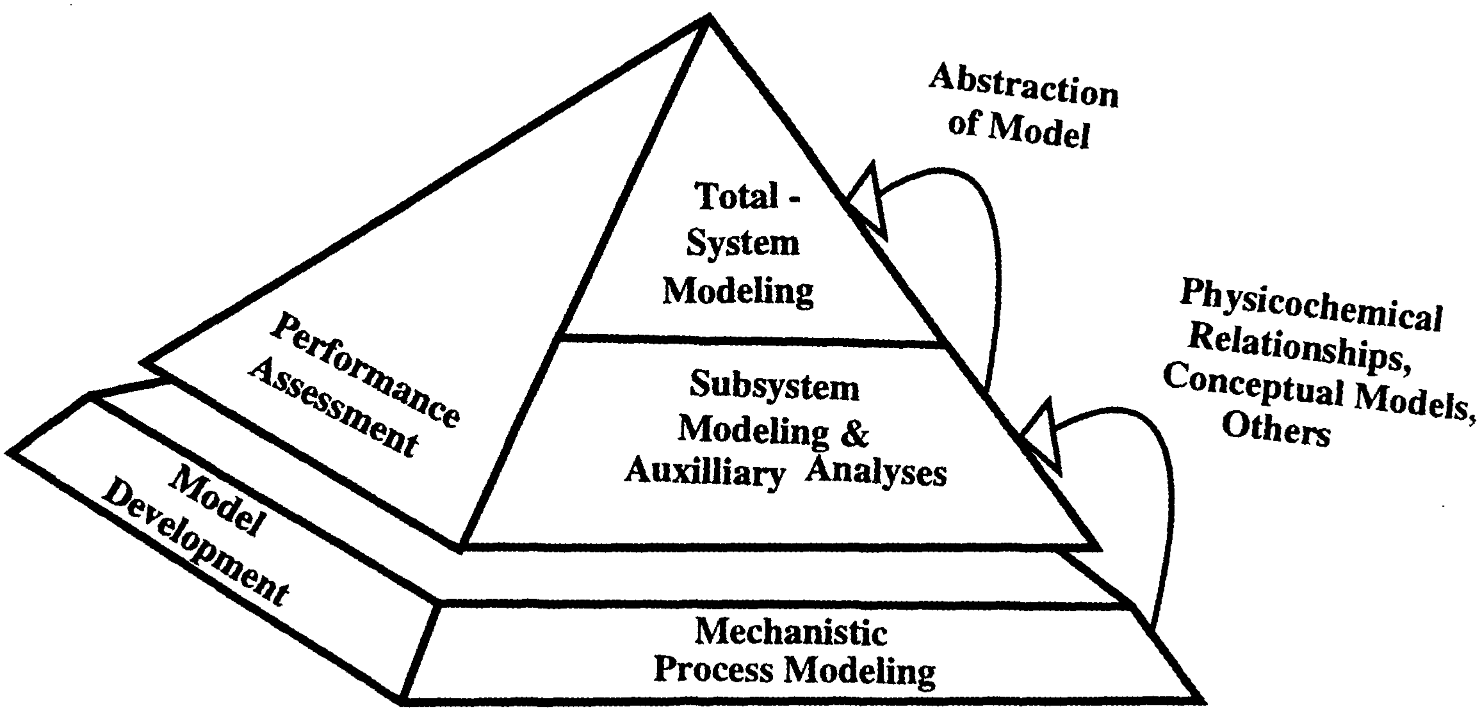

Figure: Model Hierarchy and Abstraction Process

playing a significant role in isolating the waste from the accessible environment, and interacting in complex ways with the engineered components of the repository. Because the geosphere itself functions as an integral part of the repository system, the natural system provides a barrier to isolate the waste, in addition to the engineered system. This is unlike other systems, such as a power reactor, where the natural system provides only the environment in which the reactor operates.

Validation of PA models is made difficult because: (1) the natural components can never be completely characterized; (2) the models for them are not unique; and (3) the long time period for performance precludes conventional testing of the models against experimental data. Because the repository system is expected to be robustly safe, there are many strategies that, conceivably, might be invoked to demonstrate compliance. For example, DOE could elect to take no credit for isolation of radionuclides by transport in the saturated zone at Yucca Mountain and rely solely on the isolation capability of the unsaturated zone at the site. Such a strategy could minimize the need for (and importance of) data about the saturated zone. The NRC staff must maintain a broad analytical capability to adjust to alternative compliance demonstration strategies as they are advanced and modified by DOE.

<u>The NRC PA Program</u>:

NRC's PA program offers both direct and indirect benefits to the HLW regulatory program. Direct benefits result because PA provides a basis for: (1) commenting on the adequacy of DOE's site characterization program and the assumptions made by DOE in its iterative total-system and subsystem PAs; (2) evaluating DOE's proposals for resolving specific technical issues during the pre-licensing period; (3) evaluating compliance determination methods to assist in the development of regulatory guidance; and (4) determining the feasibility of implementing existing regulatory requirements and the need for changes thereto. Indirect benefits include: (1) an improved understanding of the behavior of the mined geologic disposal system and the surrounding geologic medium; (2) improved translation of results obtained with quantitative models to support NRC pre-licensing and licensing review activities; (3) improved collaboration and coordination, among the HLW staff, of various technical and scientific specialties; and (4) development of information useful to identify and prioritize NRC-sponsored research.

PA activities are pursued in NRC's HLW regulatory program, to further specific objectives of the program. These objectives and supporting activities can be grouped into the following general categories: (1) fulfillment of NRC's statutory obligations; (2) continuing constructive pre-licensing interactions with DOE; (3) preparation of a license application review plan (LARP); (4) development of technical assessment capabilities; and (5) provision of general support to NRC's HLW regulatory program. A detailed discussion of these objectives and of the activities that support them is provided in the accompanying enclosure.

Accomplishments:

(1) Statutory Obligations

NRC has been an active participant in the recently-concluded public sessions of the NAS Committee on the Technical Bases for Yucca Mountain Standards. NRC staff relied heavily on its PA experience to formulate positions on various aspects of the EPA standard, including the specific questions raised by the Energy Policy Act of 1992. These views were presented to the committee at its opening session in May 1993. Over the course of the NAS Committee's public deliberations, the staff, assisted by the CNWRA, examined the NRC regulatory history of radiation protection standards related to waste disposal, reviewed all references in the regulatory history of Part 60 related to the persistence and effectiveness of institutional controls, and evaluated the written positions presented to the NAS Committee. Having completed these reviews, the NRC staff is satisfied that its formal views, presented to NAS in May 1993, continue to reflect staff's best judgment on the relevant issues, in light of its experience, to date. Staff's activities in support of the NAS Committee have been documented in a series of four memoranda from the Executive Director for Operations (EDO) to the Commission over the past 15 months.

In addition, NRC's PA experience has enabled the NRC staff to provide timely and detailed comments on EPA's final 40 CFR Part 191 environmental standards applicable to sites other than Yucca Mountain, as well as on draft Waste Isolation Pilot Plant (WIPP) compliance criteria (40 CFR Part 194) that EPA is developing and is expected to issue as a proposed rule in the Fall of 1994.

(2) Pre-licensing Interactions with DOE

The NRC staff conducts frequent and open interactions with DOE on issues related to PA. The staff has reviewed and commented on DOE TSPAs and subsystem PAs as they have become available. Since 1992, the NRC staff has conducted reviews of three major DOE PAs. From its interactions with DOE staff and reviews of ongoing DOE activities in PA, the staff has identified a number of areas related to PA, such as scenario methodology and use of expert judgment, for which NRC guidance is planned. Exercise of NRC staff's independent PA capability has enhanced NRC's participation in pre-licensing consultations with DOE on specific technical issues found to be important to repository performance and for which data are lacking.

(3) Development of a LARP

Based on staff's PA experience and using the Systematic Regulatory Analysis (SRA) process, the staff was able to identify five key technical uncertainties (KTUs) that directly pertain to PA. Staff's PA experience and activities are continuing to complement SRA by assisting in the identification, evaluation, and prioritization of KTUs, and by providing a means to focus NRC's limited resources on issues that are of greatest relevance to the determination of regulatory compliance. PA assists in focusing NRC's confirmatory research activities on the evaluation of the most significant KTUs.

(4) Technical Assessment Capability Development and Application

The NRC staff has applied its evolving PA capability through the conduct of two iterative performance assessment (IPA) exercises -- IPA Phase 1 and IPA Phase 2. Both exercises succeeded in demonstrating NRC's ability to conduct independent PA analyses and produced preliminary quantitative estimations of total repository system performance, using data available for Yucca Mountain, supplemented with numerous assumptions where data were not available. IPA Phase 2 expanded considerably on Phase 1, in that it incorporated better estimates of key geotechnical parameters, more scenarios and transport pathways, an improved uncertainty analysis and a dose assessment capability. This enhanced capability, developed in IPA Phase 2, includes a larger number of trained staff, more advanced models, and improved computer facility. This enhanced capability affords NRC increased flexibility to explore alternative interpretations and formulations of the repository system and to assess their impact on repository performance. Thus, NRC is better able to evaluate the assumptions made by DOE and to interact with DOE on those issues important to safety.

In addition to conducting total system IPA exercises, the staff has been developing and improving models and computer codes that contribute to a greater understanding of the geological, geochemical, hydrological, and corrosion phenomena that influence overall repository performance. The experience gained from this work has been directly applied to the evolution of staff's IPA system code, which provides a working platform from which staff can evaluate DOE's concepts and models.

(5) General Support of NRC's HLW Regulatory Program

Because the development of PA methodologies is being pursued vigorously in the international community of nations with ongoing repository programs, NRC staff participates in a number of international PA activities as actively as resource constraints allow. NRC participation in these international efforts thus far has allowed the NRC staff to stay abreast of new developments, obtain broad-based peer review of NRC's PA program and activities, and leverage limited staff resources to augment its technical capabilities.

In addition to participating in international HLW activities, the NRC staff frequently briefs the Advisory Committee on Nuclear Waste (ACNW) on selected PA topics of interest to the Committee and, periodically, on the staff's overall PA capabilities and activities. The NRC staff and the CNWRA participated in an all-day briefing of the ACNW on May 16, 1994, on the subject of NRC staff's capabilities in computer modeling and PA for the HLW regulatory program. Also, results from IPA Phase 2 specific to thermal effects have been presented to the Nuclear Waste Technical Review Board at its request.

Plans for Future Work:

To document the goals and required activities of NRC's HLW PA program, the staff is in the final stages of developing an initial Performance Assessment Strategic Plan (PASP). This planning document defines in detail the specific activities that support the staff's HLW regulatory program, as discussed for the five activity areas identified earlier in this paper, and that are discussed in more detail in the enclosure. The first version of the PASP will pertain to compliance with post-closure performance objectives and will be confined to activities planned up through the receipt of the DOE license application. Future versions will be modified to address compliance with pre-closure performance objectives and will include activities planned through repository closure. The goals and activities identified in this paper and in the PASP are consistent with, and are intended to complement, the NRC staff's overall review strategy, as presented in NUREG-1495. Near-term applications of PA planned in each of the activity areas are described more fully in the enclosure and are summarized below.

(1) Statutory Obligations

NRC staff experience gained in PA will be brought to bear, as stated above, to evaluate the findings and recommendations of the NAS (expected in December 1994); to support NRC review of and comments on EPA standards that will be developed pursuant to those recommendations; and to assist in the determination of conforming amendments to Part 60. Staff will draw heavily on its PA experience, along with a more fully developed PA capability, as it prepares to review and comment on DOE's DEIS.

(2) Pre-licensing Interactions with DOE

DOE has committed to a program of IPA and the integration of PA with its design and site characterization activities. Following a preliminary publication in 1990, DOE has issued PAs in 1991 and 1993. The staff is currently reviewing the 1993 TSPA prepared by Sandia National Laboratory for DOE and a more limited PA prepared by TRW Environmental Safety Systems, Inc., the DOE Management and Operating Contractor. DOE projects that additional PAs will be issued in FY95. In the future, the staff expects PAs to be submitted periodically and to accompany other documents supporting design and site-suitability evaluations. The implications of major technical investigations, such as the thermal-loading experiments on a large block of tuff at Fran Ridge, are expected to be reflected in subsequent PAs.

(3) LARP

Insights from PA, and, in particular, the insights obtained from IPA Phase 2 and the review of recent DOE TSPAs, will be applied to the integration review of the LARP. At present, the LARP contains KTUs, which are identified at varying levels of detail, which may be duplicative, and which are not grouped in similar technical areas. PA will aid in the integration review intended to resolve these issues. In addition, PA will be useful to determine if additional KTUs are needed to address issues related to interdisciplinary

topics and interfaces, which may not have been previously identified.

(4) Technical Assessment Capability

As its PA model and code development work matures, the staff will shift from development toward applying this capability to resolution of technical, regulatory, and programmatic issues. In particular, the staff will be shifting their emphasis, in IPA Phase 3, toward applying methods and skills to the resolution of programmatic issues and the evaluation of additional site characterization data. Additional models and computer code development will be undertaken to the extent necessary to resolve new technical issues as they arise or to maintain a state-of-the-art capability as the technology continues to advance.

For example, alternative strategies for thermal loading of the repository have been advanced by DOE recently as a means to enhance repository performance. The "extended dry" repository design concept attempts to delay waste package corrosion and fuel dissolution in groundwater by using higher areal thermal loading densities to dry out the rock near the buried waste for a relatively long period of time. Although this strategy may be beneficial, it raises a number of technical issues, including:

(a) Will higher temperatures for a longer period of time enhance the flow of hot vapor past the waste packages, concentrating salts, and creating a corrosive environment that outweighs any advantages of drying?

(b) Will higher temperatures over longer times heat the host rock such that the rock is altered, thermal stresses are induced, and the waste packages are subjected to a disadvantageous mechanical and/or geochemical environment?

(c) Will the actual performance of the repository improve, but will the uncertainties in calculating the performance increase because of the higher operating temperature and the longer thermal period, so that licensing decisions become extremely difficult?

The NRC staff will apply its PA expertise to the evaluations of these and similar questions, as DOE's repository design evolves.

(5) General Support of NRC's HLW Regulatory Program

Staff will continue to participate in selected international PA activities, to leverage available staff resources, and to facilitate licensing by obtaining international acceptance of technical and regulatory approaches. In particular, NRC has gained great benefits from its participation in the Organization for Economic Cooperation and Development, Nuclear Energy Agency, Performance Assessment Advisory Group, and activities sponsored by that organization. Staff has also participated, on a limited basis, in the international study BIOMOVS, addressing issues in dose modeling related to waste management. PA staff will assist the Division of Waste Management (DWM) in communicating with the Commission, the ACNW, EPA, and other Federal

agencies. In particular, PA is expected to help set priorities across disciplines and to help integrate related technical activities.

Also, to realize the maximum efficiency and benefit from the newly reorganized DWM, the staff is exploring a number of ways to enhance the interaction between its HLW and low-level waste PA programs. Modeling experiences and, in some cases, modeling tools, may have direct applicability in more than one area. Furthermore, a larger group of analysts, all working in PA, provide a depth of coverage for the various disciplines needed in PA, to facilitate progress on critical activities.

Potential Impacts of DOE's Proposed Program Approach on NRC's PA Program:

DOE has recently articulated a Proposed Program Approach (PPA) that realigns the stated goals and schedules for its repository program. As indicated in a July 1, 1994, memorandum from the EDO to the Commission, the staff is carefully reviewing the PPA, but does not, at this time, have sufficient information to either object to, or support, DOE's new approach. The August 25, 1994 memorandum from the EDO to the Commission, which provides a more detailed analysis of the PPA, is consistent with this view. With respect to PA, staff has identified a number of potential concerns that could have significant impacts on NRC's program.

The PPA advanced by DOE essentially shifts the acquisition of a substantial amount of data from the pre-license application stage to the post-license application stage. In addition, it couples data collection to phased decision-making on site suitability, preparation of an environmental impact statement (EIS), and completion of a license application. According to the schedules indicated by DOE's approach, a decision on site suitability will be made in 1998, accompanied by the publication of a DEIS the same year; the final EIS will be published in 2000; and the license application will be submitted in 2001. Considering that DOE will need some time to process and review data before including data in these documents, time available for actual data collection can be expected to be somewhat shorter than the above dates suggest. This represents a significant change in DOE's strategy for licensing a HLW repository. It now appears clear that DOE expects to base its site suitability and licensing decisions on a much sparser database than was contemplated when the SCP was written. DOE proposes to reach decisions based on more limited data by relying on what is referred to as "bounding analyses" for many key technical issues.

NRC's review of a license application prepared under this approach will be based, of necessity, on the same sparse data. In response, the basic NRC strategy of subjecting the entire DOE submittal to audit reviews and selecting critical parts for detailed review and independent verification will become even more important, although independent verification of critical parts may become more difficult. With sparse data, NRC will have to assess a larger number of assumptions, more system conceptualizations, and larger parameter uncertainties. To determine whether DOE's bounding analyses are indeed bounding under such uncertainties may require NRC to perform (or ask DOE to perform) alternative analyses. For example, DOE appears to anticipate

resolving site-related issues one at a time, before total-system analyses are completed. However, the critical bounding levels for subsystems and components depend, to a great degree, on their interactions within the total system. Determining bounding values for infiltration rate, extent of fracturing and faulting, transport properties of fractures and faults, possible effects of heat on rock and contained fluids, probability of volcanism, and values of geochemical sorption will be problematic, because no system is robust enough to sustain values with very wide bounds. DOE selection of "realistic" bounds to get around these difficulties may be controversial at best, especially in the absence of reasonably complete total-system analyses that support DOE's bounding assumptions.

NRC may find it necessary, for example, under DOE's proposed approach, to redirect its SRA effort to focus on completing those compliance determination methods that relate to requirements of the 10 CFR 60.122 siting criteria, accelerate plans for reviewing Title I repository and Title II waste package designs, and more actively pursue rapid development of its PA capabilities so that the impact of differing or alternate assumptions on system performance can be evaluated in a timely manner.

James M. Taylor
Executive Director
for Operations

Enclosure:
Objectives and Activities of
NRC's HLW PA Program

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Enclosure

NRC's Part 60 requirements, including those revisions necessary to conform to final EPA standards, to resolve regulatory and technical uncertainties related to their implementation. Staff's activities in support of the NAS Committee have been documented in a series of four memoranda, from the EDO to the Commission, over the past 15 months.

2. PRE-LICENSING INTERACTIONS WITH DOE

Frequent and open interactions with DOE on issues related to PA are essential prerequisites to reaching agreement both on the PA methodology best suited to the Yucca Mountain site and on appropriate methods for demonstration of compliance with NRC's regulations. Staff activities supportive of such interactions with DOE fall into three general areas: (1) reviews of DOE's total-system and subsystem performance assessment, related topical reports generated by DOE, and DOE's license application annotated outline; (2) participation in PA-related technical exchange meetings, technical meetings, and quality assurance audits; and (3) development of appropriate regulatory guidance to address PA issues.

PA activities, both at NRC Headquarters and at the CNWRA, play an integral role in supporting the NRC staff's most important technical reviews. Among those technical reviews for which PA analyses will contribute heavily are: reviews of DOE site characterization plan (SCP) progress reports, SCP study plans, periodic Early Site Suitability Evaluation reports, repository and waste package designs, waste-form proposals, and site characterization analyses. Reviews of DOE's pre-licensing activities and documents focus on providing guidance to DOE on site characterization requirements, ongoing design work, and licensing issues important to DOE's development of a complete and high-quality license application. Staff members periodically take part in formal technical meetings with DOE, its contractors, and other interested stake holders, to review and consult on interpretations of data, to identify potential licensing issues, to discuss the sufficiency of available information and data, and to discuss methods and approaches for the acquisition of additional information and data.

Out of such interactions with DOE has emerged the recognition of a number of areas, related to PA, for which NRC regulatory guidance to DOE would be beneficial. To date, five areas have been identified in which the staff intends to develop guidance. These include: (1) the elicitation and use of expert judgment; (2) acceptable definition of scenarios and means for appropriately estimating their probability of occurrence; (3) the proper construction of complementary cumulative distribution functions (CCDFs) of radionuclide releases to the accessible environment over the 10,000 years, currently prescribed in the containment requirements of EPA's standards; (4) model validation strategy; and (5) transport of radionuclides through the biosphere. At present, staff is concentrating its guidance development activities on the first and fourth of these.

DOE is expected to make extensive use of expert judgment in developing its PAs. To be in a position to critically evaluate their use, the NRC staff has begun addressing the issues and techniques associated with the elicitation and use of expert judgment in PA. Staff is attempting to develop a foundation on

which it can provide guidance to DOE on the acceptable use of formal judgment elicitation techniques. The emphasis of such guidance will be on techniques for selection of experts, identification of topics for which expert elicitation is appropriate, structuring of the elicitation process, and documentation of the process. Recently, the CNWRA completed an expert judgment elicitation exercise for future climate scenarios in the Yucca Mountain region. As a result, NRC is now able to comment on specific aspects of DOE's use of expert judgment; has enhanced its own capability to elicit and use expert judgment; and has a better understanding of climate change at Yucca Mountain.

Scenario development is another area for which NRC guidance is necessary. In the staff's analysis of DOE's SCP, concerns were raised with regard to logical and mathematical inconsistencies in DOE's usage of the term "scenario" and in approaches used to decide on the inclusion or exclusion of scenarios in the demonstration of compliance with Part 60 requirements. Methods for determining the probabilities of plausible future states of the repository environment (e.g., faulting, climate change, volcanism) are not well-established, especially over long regulatory time frames. Guidance is needed to clarify NRC's expectations with respect to what constitutes acceptable procedures for defining relevant scenarios, for estimating their probabilities, and for conducting the scientific investigations necessary to support such estimates.

Depending on the ultimate form of the final EPA standards, the results of DOE's PA may be required to be displayed as CCDFs that indicate the probability of exceeding various levels of radionuclide release or of exceeding some specified health risk or dose limit. (The CCDF is a standard means to display probabilistic information and is likely to be used whether specifically mandated or not.) Thus, the CCDF is a fundamental indicator of whether compliance with the EPA standards and with NRC's implementing regulations has been demonstrated. The staff is quite concerned, therefore, with the process whereby DOE decides that a given condition, process, and/or scenario does not impact the performance of the system sufficiently to be considered in the construction of the CCDF. As a part of its Iterative Performance Assessment (IPA) effort, the staff will evaluate different means for generating the overall CCDF for cumulative releases, and can then provide guidance to DOE, to ensure that the approach DOE selects is scientifically defensible and allows for the construction of a CCDF that has meaning for protecting public health and safety.

Validation of models used in PA is likely to be a major issue, in the licensing of a repository, because demonstration of compliance will depend largely on results from the application of predictive models. The usual procedures for validation of predictive models with engineered systems (i.e., comparison of model predictions to experimental results) is precluded for the temporal and spatial scales of interest to repository performance. Consequently, a strategy that will provide an acceptable degree of validation (e.g., partial validation) is needed. The NRC staff is participating in a joint effort with the Swedish Nuclear Power Inspectorate (SKI) aimed at developing a regulatory perspective on validation of PA models. This activity will produce a White Paper discussing the regulatory issues related to

validation and potential strategies for the resolution of these issues specifically related to the evidence that could be used to demonstrate confidence in the models. In addition, NRC, through its own research-funded efforts and active participation in other multi-lateral validation activities such as INTRAVAL (INternational TRAnsport VALidation), is developing a basis for preparing the aforementioned guidance on model validation.

The NRC staff will need to be in a position to evaluate and employ models and codes that are used to estimate radionuclide migration in the biosphere, to predict health consequences from repository releases. Expertise in this area will be of even greater importance if final EPA standards are adopted that establish dose as the primary performance indicator. The NRC staff has long supported a health- or risk-based standard expressed, instead, as a limitation on a derived quantity, such as quantity or concentration of radioactive material released to the environment. A standard based on dose or risk to the individual could be made workable, in the staff's view, if such a standard could be applied in a reasonable manner and could be implemented using a reference biosphere. In the event that the NAS recommends, and EPA adopts, a health- or risk-based standard, expressed as a dose or risk limit, it may be necessary for the NRC staff to augment its PA methodology. To evaluate the potential impact of individual dose or risk as a performance indicator, a number of activities are planned to address the considerations peculiar to implementing such a criterion. First, the HLW PA program intends to tap expertise already resident in NRC's low-level waste program related to the assessment of exposure pathways for determining compliance with 10 CFR Part 61. Other sources of expertise on exposure pathways assessment include NRC staff involved with risk assessment studies for nuclear materials facilities, power plants, and decommissioning studies. Second, because the current NRC expertise on exposure pathways assessment has been applied primarily to short-term regulatory periods (e.g., operating facilities), the NRC staff is participating in international activities, such as the BIOsphere MOdel Validation Study (BIOMOVS), to take advantage of experiences in other radioactive waste disposal programs that are analyzing the level of confidence that can be placed on predictions of biosphere transport for radionuclides over thousands to hundreds of thousands of years. Information generated from these activities will allow the NRC staff to develop the models and codes necessary for estimating compliance with an individual dose performance measure, should it be included in a revised EPA standard.

3. DEVELOPMENT OF A LICENSE APPLICATION REVIEW PLAN (LARP)

NRC, working with the CNWRA, established the Systematic Regulatory Analysis (SRA) as the means to identify key technical uncertainties (KTUs), uncertainties that are significant to repository performance and that DOE should address during site characterization. Thorough identification and documentation of the KTUs are fundamental to the development of a LARP, as the NRC staff must pay particularly close attention to DOE's resolution of KTUs during the license application review. The SRA process was able to identify a number of KTUs that directly pertain to the conduct of PA. Among these are: (1) uncertainty in the conceptual models used to define or describe the repository system; (2) uncertainty with respect to the assumptions and simplifications adopted in the development of mathematical models and computer

codes; (3) uncertainty arising from the variability of input parameters; (4) uncertainty with regard to the prediction of future system states; and (5) uncertainty in the validity of PA models. PA is continuing to complement SRA by assisting in the identification, evaluation, and prioritization of KTUs, and by providing a means to focus NRC's limited resources on those issues of greatest relevance to the determination of compliance. PA also provides a basis for directing NRC's confirmatory research activities to the evaluation of the most significant KTUs.

PA methodology can and will be applied by the staff to evaluate the effectiveness and implementability of current regulations and to assess the need for additional rulemaking. Taken together, the results of SRA and staff's experience with PA are being used to support the development of regulatory guidance documents, review plans, staff technical positions, and, where necessary, rulemakings, all of which will contribute to the reduction in overall uncertainty in the pre-licensing and licensing processes.

4. TECHNICAL ASSESSMENT CAPABILITY

To critically evaluate DOE's analyses supporting compliance demonstration, it is essential that NRC develop and maintain an independent understanding of the processes and conditions significant to long-term repository performance. The NRC staff has undertaken two primary activities to cultivate, in-house, the necessary independent technical assessment capability: (1) IPA exercises conducted by the staff and the CNWRA; and (2) the generation and refinement of models and computational tools (i.e., computer codes) for specific components of the repository system (e.g., geology, hydrology, geochemistry, and the engineered barrier system).

IPA exercises are central to staff's efforts to develop its technical assessment capability efforts. Because knowledge of the repository system is incomplete, it is quite possible to arrive at multiple interpretations of what information is available. This can readily lead to alternative and conflicting conclusions about repository performance. IPA provides the NRC staff its only vehicle to develop independently the requisite understanding of the integrated repository system and, as such, permits staff to critically evaluate DOE's interpretation(s) of the site information, as well as to explore the impact of the staff's own interpretation(s) on repository performance.

NRC's first IPA exercise, IPA Phase 1, was completed in 1991 and was published as NUREG-1327. It was undertaken primarily to demonstrate NRC's ability to conduct a PA analysis and relied on very limited Yucca Mountain-related data, employed numerous simplifying assumptions, and evaluated only a small number of scenarios. The analysis produced a quantitative estimation of total-system performance, using available mathematical models and computer codes supplemented by a number of auxiliary analyses that supported and evaluated assumptions invoked in the total-system calculations. The focus of the calculations was the total-system performance measure as stipulated in the containment requirements of 40 CFR Part 191, as published by EPA in 1985. Virtually every aspect of the staff's HLW PA methodology developed for NRC at Sandia National Laboratories was exercised, including uncertainty and

sensitivity analyses. Uncertainty analysis was used to quantify the uncertainty in the performance measure caused by the uncertainty in the input parameters and in the future states that the disposal system could attain. The results of the analysis were used to construct the CCDF of total radionuclide discharges to the accessible environment over the 10,000-year regulatory period, as prescribed in the EPA standard. Sensitivity analysis was performed to identify those input parameters with the largest relative influence on the estimated performance measure and provided some insights regarding data needs and their relative priorities. By conducting IPA Phase 1, NRC was able to demonstrate its independent staff capability to: conduct PA analyses; evaluate the adequacy of existing tools and assess the need to further enhance these tools; and, most importantly, establish a basis for preliminary judgments regarding data needs and their respective priorities for DOE's SCP.

IPA Phase 2 used the same basic approach as Phase 1, but included significant enhancements as a result of implementing preliminary conclusions of Phase 1. These enhancements included: (1) use of a largely automated total-system code; (2) inclusion of a dose assessment capability; (3) evaluation of the SNL scenario-selection methodology; (4) analysis of a larger number of scenarios; (5) improved modeling of groundwater flow and radionuclide transport processes in unsaturated, fractured rock; (6) inclusion of a gaseous transport pathway; (7) inclusion of radionuclide transport in the saturated zone; (8) improved treatment of the radionuclide source term; (9) incorporation of additional methods for uncertainty analysis and sensitivity analysis; and (10) increased spatial resolution of the source term and transport modeling analyses.

The conduct of IPA Phase 2 has better prepared NRC to evaluate DOE Total System Performance Assessments and to engage in pre-licensing consultations with DOE on specific technical issues of importance to repository performance for which data are lacking. Applying the total-system code provided significant insights to NRC about the importance of the interactions between different components. Although the model for each one of these components can be exercised independently, the components of a repository system can interact in a complex fashion, and those interactions could have only been captured and examined in the context of the total-system code. As a result, NRC is now able to evaluate more meaningfully the assumptions made by DOE and to emphasize to DOE those issues of importance to safety. For example, this ability to incorporate more scenario classes and other potentially important radionuclide transport pathways (e.g., gas-phase transport) affords NRC increased flexibility to explore alternative interpretations and formulations of the repository system and assess their impact on repository performance. The results of Phase 2 allowed NRC, given the assumptions made in the analysis and the large data uncertainties, to identify the dominant radionuclides contributing to releases to the accessible environment, the primary pathways contributing to dose to man, and the effect of specific scenarios such as climate change and magmatism. Sensitivity analyses confirm staff's view that corrosion of the waste canister and infiltration are important processes that need to be more carefully investigated.

A necessary complement to IPA is the development and refinement of mathematical models and codes that assist the staff in establishing a sound

conceptual understanding of phenomena critical to the long-term performance of the repository system and their impact on estimates of relevant performance measures. Among these are the interactions between the natural and engineered components of the disposal system and their responses to changes in the environment; the causal relationships between the controlling physical and chemical processes; and the nature and propagation of uncertainties associated with these processes.

For example, risks associated with igneous activity are of considerable concern to the staff. Initial efforts to address the risks attributable to volcanism were incorporated into IPA Phase 2. However, staff analyses regarding probability derivations for future volcanism have shown that, for the Yucca Mountain region, the distribution of volcanic centers may not adequately be described by a homogeneous Poisson model that is favored by DOE. As a result, such derivations may not be adequate, as currently conducted. Additionally, modeling of the consequences resulting from volcanism conducted by DOE, to date, does not appear to appropriately incorporate all relevant processes and factors (e.g., the percentage of volatiles in the parent magma). The staff intends to explore the use of other models, for volcanic risk, in attempts to provide a technically-defensible approach for evaluating the risks and effect of volcanism on assessments of overall system performance.

In addition to developing greater understanding of the geologic and seismic phenomena affecting the repository, modeling and code development activities are underway to enhance staff's capability to assess the performance of the repository's geochemical, hydrological, and engineered barrier systems, as well. The experience gained from this model and code development is applied directly to the evolution of staff's IPA system code and provides a working platform from which staff can evaluate DOE's concepts and models.

5. GENERAL SUPPORT OF NRC's HLW REGULATORY PROGRAM

NRC's PA program also contributes to the overall HLW regulatory program in several general areas, such as providing support to NRC participation in international HLW activities, briefing the Advisory Committee on Nuclear Waste (ACNW), and supplying a basis for the preparation of research user needs.

The development of PA methodologies, and associated tools, procedures, and methods is vigorously being pursued in a number of other countries with ongoing geologic repository programs. NRC has a number of bi- and multi-lateral agreements with organizations participating in the HLW program in several of these countries. In addition, NRC actively participates in many activities, related to PA sponsored by the Organization for Economic Cooperation and Development's Nuclear Energy Agency (NEA). Participation in these international activities is motivated by the need to: stay abreast of new developments, obtain broad-based peer review of NRC's PA program and activities and leverage available resources by participating in activities of interest to NRC. At present, NRC is participating in six major international activities: (1) NEA's Performance Assessment Advisory Group; (2) NEA's Probabilistic Safety Assessment Group; (3) INTRAVAL model validation exercise; (4) NRC/SKI model validation study; (5) BIOMOVS, a biosphere exposure pathways modeling study; and (6) DECOVALEX, a coupled thermo-mechanical-hydrologic

validation study. The NRC staff strongly believes that frequent and visible participation in internationally-respected PA activities is important to maintaining NRC's credibility.

The NRC staff briefs the ACNW on select PA topics of interest to the committee, as well as, on the staff's overall PA capabilities and activities. NRC and the CNWRA staff participated in an all-day briefing of the ACNW on May 16, 1994, on the subject of NRC staff's capabilities in computer modeling and PA for the HLW regulatory program. In addition, results of IPA Phase 2, specific to thermal effects, have been presented to the Nuclear Waste Technical Review Board, at its request.

NRC's HLW research activities, conducted in coordination with the NRC Office of Nuclear Regulatory Research and the CNWRA, are supported, consistent with the Agency's licensing role and responsibilities. The focus of these research projects is: the development of the tools and technical bases necessary to judge the adequacy of DOE's license application; assurance of sufficient independent understanding of the basic physical processes taking place at the geologic repository; and maintenance of sufficient confirmatory research capability. The specific research projects are initiated on the basis of user needs identified by the Office of Nuclear Material Safety and Safeguards staff, and their respective priorities guided, in significant measure, by the needs identified by the staff's PA experience.