U.S. DEPARTMENT OF ENERGY

NUCLEAR WASTE TECHNICAL REVIEW BOARD

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PERFORMANCE ASSESSMENT BRIEFING

PUBLIC CONFERENCE

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VOLUME I

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U.S. DEPARTMENT OF ENERGY
Forrestal Building, Room 8E-089
1000 Independence Avenue, S.W.
Washington, D.C. 20585

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Tuesday, May 16, 1989

10:05 a.m.

COMMITTEE MEMBERS PRESENT:

DR. D. WARNER NORTH, CHAIRMAN
DR. DENNIS PRICE
DR. MELVIN CARTER
DR. DON U. DEERE
DR. DONALD LANGMUIR
DR. ELLIS D. VERINK
DR. JOHN CANTLON

DEPARTMENT OF ENERGY ATTENDEES:

MR. WILLIAM COONS, EXECUTIVE DIRECTOR, RELATIONS AND POLICY
MR. TOM ISACCS, ASSOCIATE DIRECTOR EXTERNAL RELATIONS AND POLICY
MR. RALPH STEIN, ASSOCIATE DIRECTOR, OFFICE OF SYSTEMS INTEGRATION AND REGULATIONS
MR. DONALD H. ALEXANDER, CHIEF, REGULATORY COMPLIANCE BRANCH, OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT

PRESENTERS FOR MAY 16, 1989

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DR. PAUL GNIRK
DR. DWIGHT MOXIE
DR. ABRAHAM E. VAN LUIK
DR. FELTON BINGHAM
DR. M.J. APTED
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C O N T E N T S

P R O C E E D I N G S

(On at 10:05 a.m.)

CHAIRMAN NORTH: Good morning and welcome to the Meeting of the Panel on Risk and Performance Analysis of the Nuclear Waste Technical Review Board.

I am Warner North and I am the Chairman of this panel and a member of the board. I would like to invite the other members of the board who are here to introduce ourselves and then we will go around the room very briefly and have each of you identify yourselves, name and affiliation.

So why don't we start.

I am Warner North with Decision Focus Incorporated.

DR. PRICE: I am Dennis Price, Virginia Tech.

DR. PRICE: I am Mel Carter, Consultant, Atlanta, Georgia and also a Member of the Board.

MR. COONS: I am Bill Coons, the Executive Director of the Board.

DR. DEERE: I am Don Deere, Chairman of the Board and private consultant.

DR. LANGMUIR: I am Don Langmuir, Colorado School of the Mines.

DR. VERINK: I am Ellis Verink, member of the Board, University of Florida.

DR. CANTLON: I am John Cantlon, member of the board, and Michigan State University.

MR. ISAACS: I am Tom Issacs, member of the board, Department of Energy.

MR. STEIN: I am Ralph Stein with the Department of Energy.

MR. ALEXANDER: I am Don Alexander, with the Department of Energy, University of Michigan.

(Other participant introductions are off the record and can be found on the title page.)

CHAIRMAN NORTH: Thank you and now I will turn it over to Tom Isaacs.

INTRODUCTION AND WELCOME: MR. ISAACS

MR. ISAACS: Thank you very much.

May I start by welcoming the panel and also saying that obviously Warner has put together a very provocative program here to draw 7/8 of the board to this gathering. And I think that this is a subject, that, in our minds is kind of at the apex of the mass pyramid here, to try to be successful, obviously performance and risk assessment and activities that go along with it, are central to demonstrating whether or not a repository is suitable and ought to be licensed and therefore, this is a very important subject and we are delighted to have all of you participating in it.

As you can see, we have, for those of you who are not there, this is the third meeting with members of the board. We had a general meeting in March, March 7th and 8th, and we had a meeting with a panel on Structural Geology in April and this meeting, of course, with the panel on Risk and Performance Assessment.

I think it is fair to say that we are very pleased so far with our interaction with the boards and the panels. We very much appreciate what we see is a very cooperative approach that is being taken here, and we think it is very helpful to us. I hope that you also see that we will continue, as is evidenced by the array of some very talented and dedicated people here, who will perform as part of the presentations that we are taking this very seriously and comprehensively ourselves. And we hope to continue to both present to you the kinds of things that we are doing in the variety of panel areas that you have registered interest in. And also to listen to you and interact with you in ways that will help the performance of the overall program.

I think it is also clear as we move forward that we are learning quite a bit about how to interact efficiently with both the board and the panels and we continue to learn. We had a set of interactions recently that taught us some things about how to most efficiently transmit information and communicate with the board.

And we are going to try and adapt what we have learned so far in a letter to you that will suggest how we think we ought to interact on a logistical basis with the board, and we would hope very much again that your executive director, Bill Coons and my lead liaison, Jim Carlson will get together and try and make that smooth functioning happen in a reasonable way.

Without further ado, let me simply say that Ralph Stein, the Associate Director for Systems Integration and Regulation will have the lead for participation and conducting the Department's presentations to you. I will be here for as much of the meetings as I can, and certainly retain my rights to kibbitz, and will do what we can, both substantively and administratively to make this meeting as successful as the past ones.

And with that, let me turn it over.

CHAIRMAN NORTH: Thank you, Tom.

MR. STEIN: Let me add my welcome to the board. It is always a pleasure to interact with you. The last two times that I had an opportunity to meet with you, I came away learning new things and new ideas and concepts and I hope that in turn, we were able to convey to you some of the thinking that had gone and has gone into our program.

I might start my just short talk by noting that recently we met with the NRC, who provided us with their initial staff comments on the site characterization plan. As I am sure you are all aware, we recently -- I shouldn't say recently -- at the beginning of this year, we submitted our site characterization plan to the NRC and they, in turn, have been working hard to evaluate it. And we have received their initial comments.

These comments are from the staff and don't necessarily represent management's position on the SEP. And for your information, the staff also presented their initial comments to the ACNW, Advisory Committee on Nuclear Waste.

So, they are also considering the staff's comments.

We have also recently initiated the final design for the exploratory shaft and the exploratory shaft facility, which is a key milestone, which indicates that enough elements of our program are in place, that we have confidence that we can proceed in development of those designs, or that design.

And this summer, or late fall, we are expecting to initiate surface-based testing at Yucca Mountain, assuming that we receive the necessary permits to do that. And once started, the data from site characterization will be collected over the next five to perhaps seven years.

I am sure, as Tom said, that we all recognize the importance of performance assessment as the primary vehicle to demonstrate compliance with the regulations. After all we are talking about 10,000 year regulation, that is, that it guides us for what we must be able to demonstrate for 10,000 years. And performance assessment obviously is the key to being able to demonstrate that we are, indeed, able to comply with those regulations.

So, it is very important that we use performance assessment to support the license application, which is scheduled for the 1995 period, to support the development of the environmental impact statement; to support the design, the license application design; and, of course, very important, near term, is to support and direct the site characterization activities.

I might mention, when I talk about site characterization, that in addition to the level of coverage of performance assessment in the site characterization plan, we are developing a number of other documents. These are detailed performance assessment documents including performance assessment management plan; a strategy plan for performance assessment and an implementation plan.

And, of course, we will make all of these documents available to the technical review board, as soon as they become available, which I might mention to you that they are sort of monthly starting in June -- June, July and September.

And I can give you the exact dates when we expect them to be available and we will be sure to transmit them to you for your use and review.

I would like to just mention the program's data base, as a follow-on to a telephone conversation that I had with Dr. North recently.

Basically, we developed a data base that was used in preparation of the environmental assessments which was issued in 1986. That data base that we used in that environmental assessment in 1986 for Yucca Mountain was basically the data base that we have today. We have some additional information, of course, but basically that is the information that we have today and we will be talking a little bit more about that later.

Primarily the data that we need and are expecting to collect in the field, is the data that will be required, as I noted earlier, to support the documents leading up to and including the license application. So, it is very important that we start to build on that data base that we already have. It is important that we get out there and start to collect information and start to develop some of our models and codes or bring it to a more mature state so that we can support the license application, ultimately.

I would like to quickly say, of course, that this does not mean that we have done no work on performance assessment or done little work since 1986. We really have done quite a bit. And you will hear more about that today and tomorrow.

We have, as I have noted earlier, we have used our performance assessment activites in the development of the environmental assessment, the comparative site evaluation assessment, the site characterization plan assessments. Particularly those assessments in the site characterization plan that analyze the impact of the exploratory shaft facility on the repository site.

We needed to be sure that what we were planning on doing was not going to impact a repository site, so that performance assessment played a very important role in our ability to make that determination.

Finally, I would like to note that relative to performance assessment that all of the analysis that we have done to date, and we will be talking more about that, indicate that the Yucca Mountain site will meet and we can demonstrate that it will meet the regulatory requirements.

So, we feel confident that, at this point in time, without the additional data that we need to collect to confirm that, that we think that we have a pretty solid indication of suitability for the Yucca Mountain site.

But that, again, is based on a data base that is not very broad, nor very deep. And so a lot needs to be done in order to be able to confirm or reject that premise that currently exists today.

I think, with that, I would like to turn the meeting over principally to Dr. Donald Alexander, who is the grants chief for the regulatory compliance branch.

Don's responsibility is to put together a regulatory program that will ultimately demonstrate that the licensing data base is sufficient to meet all the regulatory requirements and a key element of that is the performance risk assessment, which, for the program, is under Don's purview.

So, with that, I think I would like to turn the meeting over to Don, if it is all right with you, Dr. North?

CHAIRMAN NORTH: Fine, go ahead.

MR. STEIN: Thank you.

OVERVIEW OF PERFORMANCE ASSESSMENT BY DR. ALEXANDER

MR. ALEXANDER: What I would like to do first is to review the agenda, and see if it seems to be suitable, go through what it is that we intend to try to cover within each of the talks and see if there are any adjustments that the board would like to make.

And if it meets with your approval, then we will just move on through the sessions.

As you can see, there are five general sessions in your package. This one shows the two sessions that will be conducted today. The first session goes into an overview of the performance assessment program. We felt that it was very important to spend a little bit of time going through the regulatory background, the approach that we are taking in terms of the way that we are integrated, and the way that we are developing our program.

And we will go over a little bit about what we mean by performance assessment to make sure that we are all speaking the same language. A lot of people have different concepts as to what is meant by performance assessment.

As you know, it is not a discipline that is taught in any university of the United States. On the other hand, it is a discipline that is taught in every university in the United States.

The second seesion then, will give you an overview and I think that it will be more than just an overview of the major assessments that we have to conduct to demonstrate that we have compliance or meet compliance with the regulatory requirements.

And the second day -- if Bob could throw up that second slide -- on the second day, I think it is very important for all of you, here, to understand the relationship between the testing program that is laid out in the site characterization plan and our performance assessment plan.

And that is not clear in the site characterization plan for a number of reasons, which we will elaborate on today.

And then we will talk about some recent applications where performance assessment has been used by our program at the system level, the total system level. And then finally, we will go through a discussion of waste package model development as an example of how physical models and processes -- that we are going to try to understand when we get out on the site, and do more work in the laboratory -- are going to be folded into sub-system level models that will be used for performing the calculations to determine whether or not the requirements of the regulations are met.

And so that is the flow of the presentations and if you have any comments, we could take them now and rearrange them any way you would like. We are comfortable in doing that.

CHAIRMAN NORTH: The one comment that I have is that at 4:00 p.m. this afternoon, we are going to have a discussion among the panel on a different item. So that what I would like to ask is that we take discussion time on each presentation as we go, and try to hold to that schedule.

MR. ALEXANDER: That would be fine.

CHAIRMAN NORTH: Then to the extent that we need further discussion time, we are going to put that into tomorrow. And we might run slightly longer than the 2:20 summary shown on the slide.

MR. ALEXANDER: Okay, that is great.

Bob, if you will put up the first day's agenda and I will start with my first slide.

In the last time that we met, I gave you a short overview of performance assessment. A lot of what I talked about was given to you at a very summary level. The folks that are going to be making presentations today will go into much greater detail on many of those issues. And I am not going to spend much time on those, I just want to give you an introduction.

I am --

CHAIRMAN NORTH: There is one point that I would like to reiterate from the phone calls that we had, prior to this meeting, and that is, that we would like to get a sense of where you are and where you are going in terms of the specific results and insights that have come out of your analysis to date.

MR. ALEXANDER: Yes.

CHAIRMAN NORTH: So, I would urge that you tell us what results you have obtained, and specifically, what gaps you are filling in and some insights into why those gaps are important and need to be filled in, not simply the overview of the methodology.

MR. ALEXANDER: Yes.

We had definitely planned to do that and I think this afternoon, in particular, as we go through each of the different areas, we are going to be required to conduct some calculations. You will see that we review the calculations that have been done to date, and we review the deficiencies with respect to the data that are available. We will talk to you about some of the uncertainties and then we will talk about the near term directions that we intend to go in, in those areas.

So, I hope that is responsive. I think you will enjoy it.

Okay, I am going to go over -- I have just gone over the objectives of the briefing. I will cover them in a second and fill in any blanks that are left out.

Talk to you a little bit about what we mean by performance assessment, talk about performance assessment objectives, required assessments that we have to conduct, talk about some of the major technical concerns. I won't spend a lot of time on that now. I think that is a subject that we would like to get into in some depth at the end of the session on the second day. And then talk about our current plans for performance assessment activities.

I am going to talk about session one right now, and go over the objectives of our first session. The other two speakers in the session are Dr. Larry Rickertsen -- he might stand up -- and Dr. Paul Gnirk, our two gentlemen that are intrumental in helping me integrate the program.

What we would like to do is to establish the regulatory basis, establish the role of performance assessment in the reduction of uncertainties in our overall program, review the approach for our technical integration, and then review the timing and sequencing of the planned performance assessment activities both in the near term and in the long term.

(Next slide.)

MR. ALEXANDER: I would like to pass on this slide and we will pick this up in the front of each session, so that you might hold those two slides out.

(Next slide.)

MR. ALEXANDER: Performance assessment is a multi-faceted effort that involves a lot of different aspects of our program. It is integral to about all that we do. It involves data evaluation, model development, scenario development, co-development, probabilistic risk assessment, expert judgment, you name it.

It is a process that is central to issue resolution. You will hear a lot more about issue resolution or if you would like to think about it in other terms, it is instrumental in making findings against the regulatory requirements of Part 60 of the Act, and other guidelines that we have to follow.

It is a process of evaluating repository systems, subsystem and component performance; demonstrating compliance with numerical criteria that are in the regulations. And if you have reviewed those regulations, we will do a little bit of that for you this morning, you will find soon that there is a need to have greater definition in order to get to the point where you can do meaningful assessments.

By that, I mean that there are only several numerical criteria that are in the regulation, in Part 60, and what we have done in our planning for site characterization, is that we have identified a number of performance goals which we use to aid us in guiding our performance assessment program. We will be talking to you more about those. Larry Rickertsen will be talking to you about those in terms of what we refer to as performance measures.

Performance assessment, as you can tell from what Ralph was saying, is fundamental to the support for repository development and to guide our site characterization activities.

(Next slide.)

DR. ALEXANDER: Performance assessment is, on the first order, the method that will be used to evaluate the system and sub-system performance of the repository to demonstrate whether the site is suitable and whether it complies with the technical criteria of 10 CFR 60. It will also be used as a method for evaluating the environmental impacts at the site, and will be used extensively in the environmental impact statement.

We will be assessing the sensitivities and uncertainties in the performance assessment and by doing so, will be able to prioritize those parameters that we will be gathering to identify those that are most important in during our site investigation process. And by doing that, we will be able to guide our design of testing activities.

(Next slide.)

DR. ALEXANDER: We like to think of performance assessment in two categories -- pre and post closure. We are going to tell you about both of those this afternoon.

There are a series of pre-closure analyses that we need to perform. In the post-closure area, there is total system, engineered barrier system, and natural barrier assessments that we will be performing.

(Next slide.)

DR. ALEXANDER: The post-closure analyses that we have to perform are shown basically on this diagram. Dr. Felton Bingham will be telling you a lot about the performance assessment approach that we are taking to deal with post-closure performance assessments. Larry Rickertsen will go into greater detail on the regulatory requirements than I show here.

The major calculation, the fundamental calculation is the calculation of releases of radio-nucleids from the facility through the rock and across the boundary which we refer to as the accessible environment.

We have to calculate those cumulative releases in order to determine whether or not we are in compliance with Part 60, through the EPA standard as it is incorporated into Part 60.

(Next slide.)

DR. ALEXANDER: No, that is not the right slide.

Yes.

When you consider the problem at source, the effort focuses in on the waste package itself, as I explained in our last meeting. There are three talks that will be devoted to this subject. Dr. Abe Van Luik will be giving a general talk this afternoon on that subject, and then tomorrow, Dr. Apted, and Dr. Pigford will be talking about the modeling details related to calculations with respect to two things -- waste package containment, and loss of containment, which, in this particular graphic, is indicated by release of gas -- presumably a carbon 14 gas, and then release rate through that container through time.

And so those are the two calculations that we have to deal with -- containment and release rate. And we will be talking a lot about those in the next two days.

(Next slide.)

DR. ALEXANDER: One of the major performance objectives that was debated heavily, as Part 60 was put together, was the calculation of ground-water travel time. It is referred to as pre-emplacement ground-water travel time.

It is supposed to be a measure of the suitability of the site in its unperturbed state. What you do in that particular calculation is that you estimate a boundary of disturbance near the repository, and from the edge of that disturbed zone, you calculate the time it takes for the front of water to move down through the system and then laterally out, again, to this accessible environment boundary.

And that is the calculation and Dwight Moxie will be telling you a lot more about that this afternoon.

(Next slide.)

DR. ALEXANDER: And then the final category of calculations involves preclosure requirements -- a series of preclosure requirements. They -- both the DOE and the NRC require a radiation protection of the workers and the general public during normal operations and during accidents. And they are defined in these requirements. And, again, Dave Michlewicz will be telling you a lot more about these.

(Next slide.)

DR. ALEXANDER: Now, at the onset, I thought that it would be a good idea to point out some of the problems that we are dealing with now, that are unresolved. Many of these will be unresolved for an extended period of time. As we go through the meeting, I would like to make notes of these kinds of concerns as they come up, and then during the summary period, on the second day, maybe go back through and talk about some of these you gentlemen.

One of the difficulties is simply the integration of the program. Because performance assessment involves model development, or I should say, the identification of the physical model, the alternative conceptual models, the scenarios operating in the system, etc., it is a very difficult program to integrate, because it comes from the bottom up -- from the scientists working at the survey, working on a hydrologic problem all the way on up to those people who are doing subsystem level performance assessments and system level performance assessments as I just presented.

There are a whole series of problems related to, or a whole series of uncertainties related to the identification of alternative conceptual models and the resolution of that problem -- namely the identification of the operative model that is working within the system.

It may be that when we get to licensing, we are going to have to carry with us several alternative conceptual models and fold those into our analyses. I think that many of us expect that that will be the case.

Another problem that many of us have talked about, that I would like to raise, is the question of scenario selection. We have used a certain approach to scenario selection. We have classified scenarios, grouped them together and we would like to talk to you a little bit about that problem.

We would also like to talk to you about the question of validation and what it means in this particular arena. It is very difficult to think about how one would conduct an experiment to validate the kinds of things that we are talking about, when we are talking about a 10,000-year period or more.

And there are ways to do that, but we need to talk about that problem.

And a big question that Warner raised over the phone is the question of representativeness of site data, adequacy of data, and where we are with respect to data.

And that lends a lot of uncertainty into the equations.

There are uncertainties in the models that we are going to be talking about tomorrow, namely the waste containment models and the release models. Many of you have been at meetings where we have spent a lot of time talking about the ability to extrapolate corrosion data out into time.

It lends a lot of uncertainty into the modeling process and we need to try to resolve approaches for dealing with that kind of problem.

In the preclosure area, there are two major concerns; the seismic environment that we are working in lends some uncertainties and we are still working to pin down the accident source term.

And you will hear a little bit about some of the activities that are going on in that area.

One of the big question marks in our minds is the question of the release of the carbon 14 from the waste package during the post-containment period. We need to talk about that.

And then finally, one of the biggest problems that we have had over the years, that adds a lot of uncertainty, at least into the discussion, or it leads to a lot of confusion into the discussion is the question of how people interpret the regulatory definitions that you find in Part 60.

And these are the four key ones that we will need to talk about.

(Next slide.)

DR. ALEXANDER: Performance assessment is an ongoing program, and it will extend well beyond the licensing phase. The licensing phase as it is shown here is in the post-'95 time frame. It will go on out into the performance confirmation period and presumably right on out until the repository is decommissioned. What I would like to focus on though, is those key phases that will lead us up to the license application.

Divided them up somewhat arbitrarily into a sculping phase, an EIS performance assessment phase, and an SAR performance assessment phase.

I want to point out that there are a number of key programmatic documents that are required for the license application -- the draft environmental impact statement, the final environmental impact statement, a safety analysis report -- all of which are rolled up into a license application.

There are two major design milestones -- the advanced conceptual design, and the license application design. And because of the role that we have in performance assessment, we interface extensively with the designers.

In testing, there are two key milestones that we can point out. The initiation of surface based testing and the initiation of insitu testing at the bottom of the facility.

So, along the bottom then, I show a number of key milestones that we will be focusing on over the next several years -- the preliminary performance assessment for the ACD design which should be completed around the early part of 1991, and also then the preliminary PA for the license application design. We will be completing the PA in '93 for the DEIS. We will be completing the PA for the SAR in about 1-'94.

(Next slide.)

DR. ALEXANDER: And so for purposes of planning, then, our strategy looks something like this.

At the end of last year, December of 1988, we completed the site characterization plan. That site characterization plan provided us a basis for the development of our performance assessment program.

We are currently completing our performance assessment work plans, which will be folded into three major documents that you need to know about -- a performance assessment management plan, a performance assessment strategy plan, and a performance assessment implementation plan.

Those will all be completed by the end of the clendar year and we expect to have drafts out in the late summer.

Next year then, we are going to initiate two key phases in our performance assessment program -- sensitivity studies to determine which parameters are key parameters that need to be really rigorously evaluated during site characterization. That will help guide our site characterization program. And then for the benefit of performance assessment we will be conducting what we call benchmarking exercises where we will be looking at problems and comparing the analytical capability of one code versus another.

Once that is completed then, we will get into a process or a period of verification and validation to make sure that the physical models that have been developed during the site characterization process are accurately reflected in the subsystem level models.

We will then begin to determine which of the codes we will go forward with into the licensing phase, and that will begin a long period of co-documentation for QA purposes.

As you can see, this is all necessary and needs to be conducted over the next couple of years in order to provide us with credible assessments for the DEIS and for the SAR. And so we are in this mode right now of getting into our sensitivity analyses and our problem solving within the next year. And you will hear a lot about that from the other speakers.

(Next slide.)

DR. ALEXANDER: I want to use this slide, and it is my last slide, to indicate what will happen with all of these assessments that we will be talking about today and tomorrow. I first want to indicate, again, and reinforce a point that I made earlier, that there is a site characterization plan which is complemented by two different sets of plans -- namely design plans and performance assessment plans.

The performance assessment that is in the site characterization plan is in there in sufficient detail, we believe, to guide the development of that plan, but it is not adequate to conduct performance assessment program -- that is housed in the performance assessment strategy plan and it is implemented through our performance assessment implementation plan.

The results of the performance assessments then, will be shown in technical support documents that will come out through the period of the next several years, with the objective of writing ultimately a safety analysis report and an environmental impact statement.

And that concludes my talk.

Are there any questions?

(No response.)

MR. ALEXANDER: Okay, the next speaker is Dr. Larry Rickertsen. Larry is going to be telling you a lot about the regulatory requirements that we have to deal with and their flow down into our performance assessment programs.

FLOWDOWN OF REGULATORY REQUIREMENTS TO PERFORMANCE ASSESSMENT PROGRAM BY DR. LARRY RICHERTSEN

DR. RICHERTSEN: Thank you.

The objective, I think, of this, at least for today's talk and I guess in the way that we will talk about some specific activities that have been conducted, tomorrow, is to show where we are at; what we have accomplished so far; give an outline or a brief description of some of the things that have been accomplished; indicate roughly what the problems are and where we are headed.

And to give you a direction to where we are headed, I need to provide a little bit of a framework for what our targets are. Don gave you a brief description of an introduction to some of those terms, and for the sake of completeness I am going to show you where in the reuglations, it leads us to think the way that we have been thinking.

I will go through that fairly fast. I know that almost all of you are familiar to one extent or another with what the regulations say. Let me skip that one also and go right to the next one.

But I want to give a little bit of a structure to what you will be hearing about today and show some of the general targets.

What you see is the kind of a breakup or a decomposition of what the performance assessments do. It is kind of arbitrary, and somewhat artificial breaking up things, but I think by and large you will recognize most of the elements, or the elements that generally have to be accomplished in doing performance assessments.

The specification of performance measures; that is, the things that gauge, the measure the performance of the system that you are evaluating, ad the things that you are actually going to calculate and do analysis on.

The development of physical models that you will need to calculate those performance measures. The calculational models that you will need, and then you do the analysis.

And we will go into each of those steps as we go along.

This is the performance structure that I will be talking to and that you will be hearing about as we go along, kind of language that we will be speaking.

This fits within a broader structure that if you will look it up, called the issue resolution strategy. Issue resolution strategy is a general strategy for resolving the issues, regulatory issues that we have identified and this general strategy is given in great detail in the site characterization plan and guides everything that we do in the program.

Part of that program is to analyze some results and performance assessment is part of those analyses. The main point that I want to make about that is that performance assessment is part of the overall structure. In the site characterization plan, you will see a general description of performance assessment suitable as a part of this entire structure, but it doesn't go into sufficient detail to in much detail about performance assessments themselves, other than the general objectives.

Go to the next slide.

This is a topological change of that last curve, if you like, to illustrate the general notion of the issue resolution strategy. You see on one side, descending from the regulatory requirements, a program of investigations, to obtain the information that you need, and also descending from the regulations, a set of performance measures that you then calculate, using the information that you have obtained.

And that's -- I guess it is not surprising that if the regulations are guiding the whole issue resolution strategy, they are also guiding the performance assessment program. And that is the main point that I want to make, is that our performance assessment program is focused on the technical criteria of the regulations. And it has been, I guess there has been an evolution in our thought -- we start off thinking that is what we are going to do, but as we have honed in on specifically what we do, we find that this is always the way to bring home the specific things that we are doing.

And you will see, as we go through, the specific structure of how it descends from the regulations.

(Next slide please.)

CHAIRMAN NORTH: I would like to stop and ask a question on this, and invite the board to comment.

It seems to me that some interesting questions might be asked as to what happens if the regulatory requirements were to change?

For example, I noticed that there was one that came from EPA involving how many bore holes might be sunk by future human activities? That one strikes me as an extremely soft number and it strikes me that on issues like that, it might be useful to have some sensitivity analysis to see what happens if future regulatory requirements were to be somewhat different? Would that be a major problem or a minor problem?

To what extent have you addressed questions like that? It might be something that we might want to look at as we go along.

MR. STEIN: We've -- I might just comment for a moment and react initially to your hypothesis.

To the applicant, it is very frightening to think about regulations that might change four or five years in the future from regulations that you are working on, at the present time.

I think that you could look at the utilities and get a sense of their consternation with regulations that change and they have complained greatly about it.

We have, for example, at this point, a regulation that we know is undergoing some further modification. Those are regulations that will flow from the EPA standard, 40 CFR 191 in which the court has remanded back to the EPA for further consideration -- consideration of the requirements of the Safety and Water Act.

We believe our program is broad enough and deep enough that we can -- that it will encompass any changes to that regulation, so that we could deal with it, and we think that we are dealing with it.

But what you are proposing, well, not proposing, but actually suggesting is that there may be some regulations changed downstream and what kind of contingencies should you have for those changes in the regulations?

CHAIRMAN NORTH: Well, it seems to me, from the board's perspective, our charter is very broad and if the regulations don't seem to us to be completely consistent with common sense, I think one of the things that we might want to do is to suggest that they be reexamined.

It wouldn't surprise me, as we hear from the various groups in the public, if we hear some comments to the effect that they have some concerns over the regulation.

So, it seems to me that it might be useful not to focus too narrowly on the regulations being given and indeed cast in concrete, that in the whole area of risk and performance analysis we also look at the question: does it all make sense, in terms of assuring the safety of the facilities in all of the dimensions that we might want to have such assurance.

DR. LANGMUIR: In the same vein, it might be worthwhile if the presenters over the next two days would suggest areas in which they might have some questions and doubts about complying with existing regulations.

MR. ALEXANDER: Well, as I pointed out in my talk, Don, there are areas of the regulations, in particular, where it is very difficult to interpret what is meant. There are those four definitions, in particular, that I posted -- substantially complete containment one that has been debated back and forth -- are areas where I think that there needs to be some clarification.

But on a broader plane, on a level that you are talking about, Warner, I think that you will see that our site characterization program is very comprehensive and very flexible and could deal with any logical changes in the regulations, you know, if it is not a logical change, then I can't tell you whether we could deal with it or not.

But I think, by and large, we are set to deal with most any change in the regulation, because our first and foremost objective is to determine the suitability of the site. And as you will hear from the speakers, you will see that it is almost done, that part is done almost irrespective of the regulations.

CHAIRMAN NORTH: I think that is reassuring. I think ultimately the test of the site has to meet is does it all make good sense from a safety point of view, not does it meet the regulations.

The assurance the public is going to want is a broader question rather than the narrower one. We have to deal with the narrower one as we go along and it certainly would be great if all the regulations were, in fact, just exactly what is needed to meet the broader objective.

MR. STEIN: I agree with Don's characterization of our site characterization plan. I don't think that I would have said that it was structured to take care of any logical change in regulations that might occur downstream because one can't really tell what is going to be logical three or four more years from now.

But I would hasten to say that as the applicant, we have a legal requirement to comply with the regulations, which we will, until such time or if the regulations are changed. So, I certainly, you know, would welcome any investigation that you would want to undertake and we, too, continually look at the regulations. But our path to work with the regulations and changes to them is with the regulator, in this case, the NRC.

So, I guess what I am saying is that as long as we have a set of regulations on the books, we need to work within the framework of those regulations. And any deviations from that, or changes are changes that are made in working through the regulator.

DR. CANTLON: Warner's comment though of doing a little sensitivity analysis on the "what if" the regulations going up or down, might, in fact, give you a feeling of security about your calculations.

And I think that it would be a very economic investment at this early stage.

MR. STEIN: I certainly agree. There is no argument about that at all. I think that is a very good point and it is one that I believe that we have, at least a sensitivity analysis scheduled for this coming fiscal year, isn't that right?

MR. ALEXANDER: Yes, as I showed in my plans, we want to focus, in fact, on that question of what is important and what is not important. We want to explore that next year.

A couple of years back, we did some very global sensitivity analyses where we looked at changes in, let's say, the release rate, for example. And Paul Verink is going to tell you a little bit about that later on tomorrow.

CHAIRMAN NORTH: Good.

MR. ALEXANDER: But we are committed to doing that, and I think that it is very important too.

DR. RICHERTSEN: Let's go on to the next slide.

(The next slide.)

DR. RICHERTSEN: That is an interesting thought. The way that I had structured the talk was around doing a different kind of sensitivity analysis but that is one to consider as well.

What I want to talk about here is the things that you calculate in the performance measures. It really is difficult to proceed without knowing what specifically your target is, and I want to say that the performance measures are those variables. The regulations are the criteria that would be placed on those measures.

And I am not too concerned at this stage, what those particular criteria are. I just want to know how to calculate those things which would then be compared against those criteria at a later point.

Don gave you this slide which showed you the overall objectives so to get the measure of the performance, I will need objective measures for each of these general objectives that we are trying to accomplish. The first one has to do with meeting technical criteria of Part 60, so we will look at the technical criteria of Part 60 to see what performance measures are defined there.

Also we will have to do an environmental impact statement which has a different set of requirements, will have a different set of requirements associated with it. And then there is work to support suppository development and we want to make sure that we define performance measures that are appropriate for those studies. So we will just move, first of all, to the licensing problem.

What I want to do, when I created this set of slides I want to make sure that we move through this fast. I want to go through all of the technical criteria, but basically it is to show that the technical criteria point you to a very small number of so-called performance measures. These are the measures that are specified in the preclosure performance objective.

There are requirements on the doses to repository workers and to the public from normal releases, that is, releases from routine operations. There are no criteria for doses from accidents, but it makes sense. It is a natural extension to consider doses from accidents as a performance measure.

And, in fact, there is a criterion for defining items important to safey in the regulation in terms of doses to the public from accidents. And, so, that is also specified here as a performance measure.

(Next slide please.)

DR. RICKERTSEN: This is the postclosure system performance objective specified in the regulations. And it essentially implements the EPA standards. In the EPA standards, as they were before they were remanded, there are three numerical requirements; the others are qualitative requirements.

And the requirements are; one, on cumulative release to the accessible environment. It is actually a 10,000-year cumulative release. In fact, the performance measure is the probability of distribution, which is, as far as I know, the first time that a probability has been placed as a performance measure in the regulations.

It has created some new work for us to do, ones that we have not seen before. But cumulative release to the accessible environment is a fairly understandable concept and it is one that whatever the performance measure winds up being, if it is the same or it is changed slightly, we are going to have to have information to calculate this thing in any event.

Two other things that were specified in the regulations are annual dose to individuals in the first 1,000 years -- that time frame may change, but the performance measure is likely to be the same or close to it. And the third one is concentrations in special sources of ground water.

So these are things that we feel that we are going to have to calculate in any performance measure system, performance assessment.

In addition the regulations put additional requirements on particular barriers. This has put, these are put in specifically to put, to provide additional confidence. There is going to be a lot of uncertainty in the system performance assessments, and so additional requirements are put on.

We, it is difficult sometimes to sort out the treatment of the engineered and the natural barriers from the system performance, but it puts particular requirements on us. And, in particular, the two, the three performance measures of which there are numerical criteria specified by the regulations -- one is on the containment of waste within the waste packages -- and so performance measure is something related to the degree of containment or the time until failure of the waste packages.

And then the next one is the rate of release from the engineered barrier system or the waste packages in the engineered barriers that are around the waste packages, following that containment period.

And the last one is a requirement on the natural barriers. It is the only one, the only numerical criteria in place on the natural barriers in the regulations and it is on the ground-water travel time.

MR. STEIN: I might just point out that the first one where you see, substantially complete, that is substantially complete containment. That is in the regulations and that is one of the definitions that we are not quite certain and neither is the Commission, quite certain how one defines substantially complete containment.

We have defined it qualitatively and quantitatively and I think that there is general agreement on the qualitative, but not the quantitative definition and it is going to require some interactions with the NRC in order to reach agreement as to what the definition is.

But here is one of the examples that Don pointed out earlier of a definition that does need to be closed on prior to us going in for a license application.

DR. CARTER: Larry, let me ask you a question.

When you have a range in requirements, such as 300 or a 1,000 years, how do you approach that?

DR. RICHERTSEN: In this case, this range, what this means is that the Commission will specify a time, after looking at our information, they will specify a time between 300 and 1,000 years that we are to meet.

Suppose they choose a 1,000 years, then that means that we have to demonstrate that there is containment for 1,000 years. In other words, we don't get to pick the time, although in the analysis you do, you wind up predicting time of failure and so on. So that we will do distributions of time so that the NRC will have a chance to look at those and make up their mind about what is a meaningful time to pick as our requirement.

DR. CARTER: You almost have to make the assumption that it will be a 1,000 years.

DR. RICHERTSEN: Well, we will do both. We will look at the range. It depends on the conditions. For example, 300 years that is a cut off, for the temperature distribution in some sense. A 1,000 years has another physical meaning. So we will look at the range and we have.

CHAIRMAN NORTH: You intend to take a probabilistic approach to that question, is that correct?

DR. RICHERTSEN: We will do both. We have been doing some deterministic calculations, but we have been doing probabilistic ones also. Because the rate of failure from packages, obviously, because of uncertainties and rate of failure and so on is obviously probabilistic.

CHAIRMAN NORTH: Your interpretation of substantially complete, means there could be a small number of failures and still comply with it. That is what I mean by probabilistic.

DR. RICHERTSEN: That is our --

CHAIRMAN NORTH: Where small needs to be clarified.

DR. RICHERTSEN: That is correct.

MR. ALEXANDER: That is the hard problem.

DR. RICHERTSEN: It is a bone of contention between us and the NRC. We are actually, obviously going to try and design a waste package which will have absolute containment but the likelihood of that actually happening will depend on all of the uncertainties including the fact, whether we understand what failure of the waste package means 1,000 years in the future.

Okay, and what I just gave you were all the numerical criteria of Part 60. Now, I am going to keep going and what I want to show and I will go quickly, is I want to show you the rest of the criteria point to those same numerical criteria that I just mentioned.

These are the siting criteria and they say, if you will just breeze through the next two pages, you will see that there are 24 potentially adverse conditions that we are required to characterize, look at, and decide if they are present and then, for those that are present, decide if they show that they contribute or detract from the numerical criteria that we talked about already.

So, the performance measure, for each of these 24 items, is essentially the same numerical criteria we already looked at. So we will do a system performance assessment where we explicitly take into account those that are present perhaps and do a performance assessment looking at the releases to the accessible environment.

You can skip on past that. That was really meant to impress you with the large number of things that we have to look at, but it doesn't introduce any new performance measures for us.

(Next slide please.)

DR. RICKERTSEN: The next set of criteria are the design criteria and again, each of these design criteria, even though there are numerous requirements, the specific requirements with regard to performance refer you back to the performance objectives that I have already mentioned. They all reference you to limits that have been specified in the previous parts of the regulation. There is one that is slightly different for those of you that like subtleties and that has to do with the Seals requirements.

The first requirement is that it doesn't compromise the ability to meet the previous objectives, and so that refers to them, but it also says something about the seals will not create a preferential pathway. And as we think about what that means in terms of performance assessment, we think about that a preferential pathway has something to do with releases to the accessible environment again and so again, we would gauge the sensitivity to the performance measure in terms of release to the accessible environment, to the design of the seals in order to be able to understand this particular aspect.

So again, we feel that we are being focused to look back at those numerical criteria. Well, what I did is that I breezed as quickly as I could through the requirements of Part 60. And now, what I would like to do is to talk about EIS requirements.

EIS requirements, we don't know what the performance measures are going to be in particular, because that will be defined during scoping, which will commence in the future. But experience and what it says in the CEQ guidelines suggests that we will have things like dose or health effects to look at, environmental impacts measured in terms of dose or health effects.

So you will have to know releases to the accessible environment and then you will probably have to know something about what happens in the accessible environment. So, some biosphere transport types of analyses will have to be done and so on.

It is not clear yet, and that has yet to be defined.

Other things that are specified in the CEQ guidelines, I am sorry, is the fact that we are going to have to look at accidents and disruptions and so we will be looking at accident scenarios. Much like you would, have been defined that we will have to do for the 10 FCR 60, and experience suggests to us that we will have to look at long-term performance, maybe even longer than the 10,000 year requirement for Part 60.

For the site suitability analysis and analyses to support the design of the site characterization design programs, all of our analyses to date we have focused back on those regulations of Part 60 that I mentioned to you earlier.

And I guess the main point that I am trying to come to is that we boiled down to those very same technical criteria. As I mentioned, the EIS requirements may ask us to do something additional and at that point, we will add to our program as required.

What the -- if you will just -- this is a summary slide that just boils those things down and you will see that there really aren't those many things in that technical criteria. That does not mean that there is not a lot of work to do.

But there are a small number of things that we need to focus on and these are the things that we will calculate. Now, you will notice that they come into four basic areas: preclosure safety, postclosure total system performance, and engineered and natural barriers. Those are the four areas that Don talked to you about and you will see that all of our programs are structured essentially in those four areas.

There are subareas within each of those, but by and large, that is how our program is broken up, based on the way that the regulations take us.

It is interesting to note, and I think that I am going to upstage someone later, but that the work that you need for total system performance requires that you know about engineered systems behavior. And therefore, the work that you do here provides information that you need here. These are not done independently, and so there is a need to make sure that information provided for one area feeds the others, and so on.

Now, I just would mention for those of you that are familiar with what has been done in the past, that we have to use other performance measures other than the ones that I have mentioned here. But that has been for a couple of reasons. First of all, the data have been incomplete and so it is difficult to do a full fledged CCDF, probability distribution for the releases to the accessible environment.

So we have tried to use surrogates for that, but we have in mind those things, the variables that are most important to the CCDF or to the other performance measures. So if you see something different, for example, in the talks later, that doesn't look like specifically in terms of performance measures that I have mentioned, it is because we are doing the best that we can.

(Next slide please.)

DR. RICKERTSEN: Now, once I have the performance measures, I know what kind of physical models it is that I have to go after to calculate that, or at least I have an idea. It is just by physical models, we have a hard problem with the word models as you will rapidly determine.

By physical models, I mean those site conceptual models, scenarios of processes and events that would take place and lead to an effect on the performance measures and then models for those processes and the responses of the system in particular.

And let me just give you an example of a site conceptual model if you would like. There are many things about the site that we don't know yet, although we know quite a bit about this site. I just want to make sure that we know that. We have, there are a lot of aspects of this that perhaps I could discuss with you -- uncertainties in this and so on -- our problem is to define this well enough so that we can calculate the performance measures.

If, for example, I will just use this as an example, that we decided that our release to the accessible environment calculation is not going to be done out here, at a boundary out here some place, but down at the water table, releases to the water table, just as an approximation, just to speed up things.

Then that means that we don't need to know too much about -- we don't need to know a whole lot about this part of the system, other than that it feeds the analysis, provides boundary conditions for other things that you are going to do.

In fact, we will probably evaluate releases at the accessible environment, doing the best we can with the information down there. And once I have physical models, now I know the calculational tools, the codes, the analytic techniques that I am supposed to develop.

Now, I always say this and I know that the development of a code on its own -- sometimes you do that. You develop a thermal model to calculate temperatures in general and then you apply it to a conceptual model of the site or the waste package. But, in fact, many of the computational models are developed in concert with developing the physical model -- the model of flow in the unsaturated zone will be coupled strongly with the calculational model that is developed at the same time.

So you don't really separate them out, although I have separated them arbitrarily here. I want to talk about three levels of calculational models.

This is pretty simple-minded, but it is important to us because it influences the way that we think in the program. The lowest level or the bottom level or something, the level three I call here, are those calculational models that we used to calculate processes. So a temperature code or a code that calculates radiation effects or shielding, they are not pointed towards a performance measure directly, but to evaluate the process model.

And the next level is where you assemble a bunch of these into a system model or a subsystem model.

By and large the subsystem models, at this level, this level two, would be very complicated, having many modules associated with all the processes and models that you think are important, just on a survey kind of basis.

Those are intended to calculate performance measures and to do sensitivity analyses, to find out what is important in that system. From the level two, you would simplify, once you decide where you can simplify. Once you decide where you can simplify, you would simplify to the level one right away. You would find out those things that you don't need to take into account, whether you need to take into account all the range of every process that exists in the system or you can simplify.

Sometimes you can do that qualitatively, identifying things quickly and sometimes it has to be done through an explicit sensitivity analysis.

And then the next step is to do calculations with these models. And let me just go through and illustrate for you types of analyses that we will be doing in performance assessments.

I want to emphasize that the calculations of the performance measure is only one part of performance assessment. I don't know of any performance assessor who calculates things and leaves it there. There are other aspects of the performance assessment, the qualitative aspects, the level of -- the degree and the quality of information that goes into the performances all has to be evaluated quantitatively and qualitatively.

But this is an important one and it needs to be done right. You will notice that some of the performance measures are probabilistic and some are deterministic. Ground-water travel time, waste packeage lifetimes, so on, releases to the accessible environment will be calculated probabilistically, because that is what the requirement says or implies. So we will be doing probabilistic calculations. We will also be doing deterministic calculations, but by and large, they will always be a probabilistic stem on that to understand the uncertainties in that particular case.

We hope that our analyses will always be conservative. It is not, I mean, you have to understand the system pretty well to decide whether it is conservative or not. We have several -- there is a range of conservatism. There is what I call realistic conservatism where you try to stay on the conservative side of a variable, that is, the side that would lead to worst impacts but not be out of the range of reality for that variable.

On the other hand, it simplifies things a lot if you can do bounding analysis, where you really bound things. You use very simple approximations that bound the processes or you take a variable which clearly bounds the range of uncertainty on a particular parameter. And so we hope that there are places that we can use bounding analyses effectively because they really simplify the work and the effort that you have to put in.

Finally, I want to say that this is the final thing or the most important thing, I believe in the performance assessments, is to evaluate the sensitivity and uncertainty in the assessments that you have just completed, that is the calculations that you have just completed. There are many kinds of uncertainties that have to be addressed. I have just put up some cartoons to illustrate some types of uncertainties. You have uncertainties in the physical models and you are not sure about those. You will have to figure out ways to address those uncertainties, either by trying a model with one process, and trying -- for a given process trying one model and trying another model and seeing how that affects the performance measure.

The particular process may not be important and so it doesn't really matter which one you use. On the other hand, it may be very important and focus you on the kind of testing you need to do.

MR. ALEXANDER: You might want to tell what that illustrated, the last slide illustrated.

DR. RICHERTSEN: Oh, this is one that is just a model of the flow process and it is a cartoon and Dwight Hoxie will give you a much better discussion of this, I am sure, when his time comes this afternoon.

Even if I have a model, there are uncertainties in that particular model in terms of the parameters that define it, and there are a number of ways to handle such uncertainties -- one is the bounding analysis way I mentioned, where you just take a deterministic value beyond the range and another one is to do Monte Carlo type sampling. And create a probability distribution for the performance measure based on the probability for that particular variable.

And other types of uncertainty and these are the really hard ones to get to, is how to you extrapolate from the tests that you do to different regimes?

For example, if I do an analysis in one location of a site, how do I know that that extrapolates to other locations of the site? The heterogenity in the site needs to be taken into account. The extrapolation in time -- that is, we do tests over 50 years or five years, how do we know how those apply longer in time?

There are other extrapolations, of course, that we have to take into account in our analyses. In addition, then this is another hard one, how do you take into account unanticipated processes and events, such as moving along an undiscovered fault?

If I have not made a measurement or the probability of the thing happening at the site is very low, it is difficult -- one of the difficulties that we have had is to do analyses that properly integrate that into the assessment.

And we will talk a little bit about the ways that that has been done in the past through treatment of scenarios. If you will just skip over this next one?

CHAIRMAN NORTH: Getting to that point that was made earlier about the need for the program integration, now, where there are conclusions with regard to the importance of data that you might acquire from testing, I think we would very much like to hear you discuss those.

DR. RICHERTSEN: I hope, and it is our plan that there will be several discussions of that type particularly this afternoon.

CHAIRMAN NORTH: I think that this issue of the importance of faults was very much the focus of our discussion at our panel meeting in Las Vegas for example. I found it very interesting reading through the site characterization plan to see how often some of those phrases occurred about the need to have better understanding of the Ghost Dance Fault, in particular, and we certainly have learned a great deal about it as we have had our discussion with you and look forward to learning more as the work that you have now underway on the exploratory shaft facilities proceeds.

DR. RICHERTSEN: Okay.

This is just to show you that we have a strategy associated with addressing uncertainties, and these are the steps, several of the steps that we plan to do. I don't know -- I can go into several of these.

For, if we finish an assessment and we have decided that the analyses, the uncertainties have not been completely or adequately addressed, there are several ways to do it, to address them.

One is to repeat the calculations more conservatively, or to add additional scenarios to our analysis. That doesn't reduce uncertainty at all, but it just means that you take it into account in a way that you didn't before.

And but by and large the most important way to address uncertainties is by either reducing them or mitigating them in some way through testing. There are several kinds of testing that will be done that we will be talking about tomorrow and through design measures that may be possible, for example, to use more conservative designs to address some of the uncertainties.

To use multiple barriers, where one barrier compensates for uncertainties in another barrier and so on. There are strategies in the SEP that address that.

Now, this is the conclusion of my presentation and basically the point of this is that Don already made it and I will just mention it, but in the performance assessment data, in the site characterization plan, you see issue resolution strategies, in which there is a portion devoted to performance assessment. The performance assessments are described in a way to fit into that issue resolution strategy with general, high-level information needs associated with them.

They provide the general structure for the performance assessments we are doing but details of the performance assessment you won't find there. But you will find those in another document, details of this structure in two other documents, the performance assessment strategy plan, and the performance assessment implementation of the strategy which will be due out, will be out before the end of the calendar year.

MR. ALEXANDER: Any questions you might have for Larry?

(No response.)

MR. ALEXANDER: Then our next speaker is Dr. Paul Gnirk and Paul is going to be telling us a little bit about the integration effort that we have been conducting over the past year. At the point in time when we froze the text, so to speak, on a site characterization plan we initiated a fairly ambitious effort to integrate our performance assessment program around the needs of that particular plan. And so Paul is going to tell you a little bit about our plans.

Paul?

TECHNICAL INTEGRATION OF PERFORMANCE ASSESSMENT PROGRAM BY DR. PAUL GNIRK

DR. GNIRK: Thank you, Don.

What I am going to talk about today is some of the things that we are doing and plan to do in the area of integrating the performance assessment effort. In particular, to talk about the purpose of why we are doing it, the organization and the people involved so that you can see the actual names and associate that with people that will speak today and tomorrow. And the functions of what we are doing and how they relate, the schedules and the products that have to come out. And the activities in this fiscal year and the next fiscal year and the following fiscal year in a sort of broad sense but with the notion of how all these pieces fit in, in relation to the schedules and so forth.

This integration effort was organized by the department at headquarters in November of this last year. About the time that the statutory SEP was nearing completion and, as Don says, we were freezing things, for the SEP and then we had to move forward into actually doing the characterization and doing the assessments.

So what is our purpose? The Department has two documents, two sets of documents, so to speak, that are extremely viable to the whole program. And those are the Safety Analysis Report which must go to support the license application. And the Environmental Impact Statement which must support the recommendation to the President.

In addition, the EIS that was developed and prepared by the department can be used or accepted, if practicable, by the NRC, for their EIS. We need that. We have to have a capability to ensure that that capability -- we have to have a capability to do those two documents. We need the methodology, we need the tools, the calculational tools, and we need the gray matter, the expertise that people who have had the experience over periods of time in doing these sorts of things and thinking it through.

That is essentially -- these three items are essentially the purpose of the integration function. The first capability being the strongest capability and secondly we need a separate capability to review our own assessments, an internal capability or internal review function, if you wish.

Thirdly, we have to have a capability to do the types of assessments that are required to support the repository design activities, to support those things in site characterization that deal with the characterization activities in so far as they may impact the isolation capability of the site, itself.

And these are the three central purposes. I just might mention, before I go on, as Don mentioned, in his first discussion, first presentation, the dates for the EIS and SAR are in the late '94, early '95 time frame. And however, the DEIS will have to be prepared in the mid-1992-3 time frame so that the calculations for that have to proceed the preparation of that particular document.

May I have the next slide, please?

(Next slide.)

DR. GNIRK: Thank you.

And here I would like to show what the management integration structure is, so that you can see how things flow.

Just to point this out, we have the center part here, being what we call DOE Headquarters. On the left is the project and then in a box down here is the integration function.

I want to call your attention to the fact that the solid lines indicate line authority, the dash lines indicate program policy guidance technical overview, and the dots indicate the integration aspects of things.

The top here is DOE Headquarters with the director of the OCRWM program and below that the office -- a number of offices, one of which is the office of systems integration and regulation -- of which Ralph

Stein is the associate director. And below Ralph, is a number of branches, one of which is the regulatory compliance branch of which Don Alexander is the chief.

And below that, that work for the department headquarters branch are a number of national laboratories and contractors that work with the DOE operations offices. These include Brookhaven, Oak Ridge, Argonne, Pacific Northwest Laboratories, and various organizational components -- Sandia, Livermore, and Los Alamos, that work, in effect, through various operations offices on performance assessment for the headquarters site.

The regulatory compliance branch is in charge of the performance assessment.

On the project side, you have the DOE Nevada manager and below that, the project manager for the Yucca Mountain project, which is Carl Kurtz.

That fades down to a number of divisions, one of which is a regulatory and site evaluation division of which Max Blanchard is the director. And below that, once again, of the national labs and the contractors, different organizational units in the national labs, including, in particular, Sandia, for the project side; Los Alamos National Laboratory, Lawrence Livermore

National Laboratory and the United States Geological Survey.

Okay, now, maybe a question as to how did this all come about and where did it come from and so forth? You keep in mind that up until the amendments to the National Waste Policy Act were passed in December of 1987 now, there were three projects, three of these units that related to the headquarters functions that were surrounding them.

And at that time, each one of the projects had their own performance assessment capability and headquarters people had to be able to review the work that was done in performance assessment for the purposes as an example of environmental assessment, had to review the performance assessment that was done by each of the projects.

As a consequence, the headquarters part had their own performance assessment group to do this; to be able to perform that independent review of three separate projects.

As a consequence of the Amendments Act, there is now only one site for characterization, but we still have a double system here in which we have people who work for the headquarters side, and people who work for the project side.

Once again, the program guidance and stuff closed from across the diagram to my left, as I point, the line authority is such. The integration function goes across in this fashion.

Now, I am going to talk about the integration function in more detail in subsequent graphs, but I want to point out a number of things as I will talk about this.

In this group, integration function, there is a program oversight group, a technical integration group, and working groups. Now, the program oversight group is all DOE people at the policy levels. The integration group has a broad focus of what goes on in performance assessment and the working groups have a more narrow focus.

The object is to look at what goes across in an attempt to integrate it. There is no line management that comes out of the integration function itself. It only operates in an advisory capacity and I will demonstrate or discuss various things that are involved with this as we go forth.

The next slide please.

(Next slide.)

DR. GNIRK: The integration structure, as I said before, has the oversight group, the integration group, the technical integration group, and it is then divided into seven working groups. The first three working groups at the far end of the screen from me, dealing with the total system performance, engineered barrier system and the natural barrier performance, all deal with postclosure, the postclosure aspects of performance assessment.

The fourth box, the fourth working group is a preclosure safety working group. The fifth is that working group that deals with the environmental assessment and environmental impact assessments. The sixth box of people, the working group deals with the repository and seal design, and exploratory shaft facility and so forth. And the last box, the seventh box, deals with site characteristics in so far as they go to support and complement the performance assessment aspects.

And in particular, the model validation work that will be talked about by Charles Voss later in the program is connected to the site characteristics working group.

So there are seven of these working groups across. Now, these working groups, as I will show on the next diagram, are composed of a mix of people. Mix in the sense that they represent DOE people from the headquarters side, DOE people from the project side, technical people from the headquarters side, and technical people from the project side.

So the notion in setting all of this up was to have the mix of both technical people, DOE people at this working group level in dealing with the various work activities that were done, that were underway by the participants of those people doing the work, that is, the national laboratories and the contractors in the program.

Just to show you these are some of the people involved. The program oversight group consists of Don Alexander; the headquarters, Max Blanchard from the project.

And the technical integration group, is myself, Larry Rickertsen, who you have heard from and Gene Younker from SAIC. Gene Younker was responsible, over the past years for managing the development and bringing together many, many parts of the environmental assessment and the site characterization plan. She has a very good in-depth knowledge of all these parts of the site characterization plan. They are important to performance assessment as well as to other aspects. Larry Rikertsen has been involved in reviewing the performance assessment parts of the environmental assessments when they were put out in '85-'86 and also the three site characterization plans, up until December of '87 for all three of the sites that were recommended for characterization and in more thoroughly the PA that was in the Yucca Mountain project, SEP.

Below that, are the seven working groups; the total systems performance, engineered barriers, natural barriers -- those three dealing with postclosure -- preclosure, repository design, environmental assessment, impact EIS and the site characteristics.

Now, today and tomorrow you will hear talks from a number of these people and the work that they do in their own particular areas, but they are part of the integration effort. You will hear from Abe Van Luik, PNL, Felton Bingham from Sandia, Mick Apted from PNL and Dwight Hoxie from USGS and Dave Michiewicz from Weston and Charles Voss from PNL, who will discuss various aspects of the work that is going on in their particular areas, as they are a part of the integration function.

Okay, next viewgraph, please?

(Next slide.)

DR. GNIRK: So what are we doing this year?

What are we going to do next year and how is this thing progressing?

One of the roles of the integration function is an ongoing review of the performance assessment program. Now, as I told you before, the integration group, the technical integration group is interested in a broad aspect, it takes a broad focus of the program. The working groups look at narrower focuses in particular areas of performance assessment. So we are hoping and we think that the review process is working by virture of an integration group, and the working groups.

In particular, some of the things that the technical integration group has done is to review all of the activities in the program in relation to the discussions with the working groups and the things that they have recommended. Secondly, they have made and will make more site visits to the individual contractors and laboratories, people that are doing the work. We have sat down in rooms and talked with the people who are actually developing the models, developing the code frameworks to handle the models and the discussions of their concerns, their feelings and how this all feeds together.

Another item that is taking place this year, as

Larry Rickertsen alluded to, is the development of the performance assessment strategy plan, the implementation plan, of course, and the management plan.

These are activities that are underway. The PASP should be completed some time this summer, along with the PAMP, the management plan, and the PAIP which is the implementation plan, which takes all of these activities and puts them into a structure that complements the strategy that is laid out and the strategy plan should be done some time by the end of this calendar year.

The implementation plan is a plan that will be reworked on a periodic basis, as new information becomes available from the characterization activities and perhaps, a methodology has to change in how we are approaching these assessments in relation to the regulations and the EIS.

Some other activities for this year, the methodology development for the model validation code certification, Charles Voss will talk about the model validation concept as they put together what is required in the methodology to approach that, and to look at a guide for methodology for identifying and screening preclosure initiating events. David Michlewicz will mention something in this regard. Termination to the extent of the disturbed zone. This is something that has to be discussed and considered this year with regard to the NRC.

And then, of course, we have the evaluation total system, waste package performance, so forth and then some notion, some investigation or thinking as to what is required for the assessments, the PA assessments that go into the DEIS.

Much of that has come out of scoping but we still have to have some thinking framework as to what those might entail.

(Next slide.)

DR. GNIRK: Another task or activity or role this year, is to guide the model co-development, including the documentation and benchmarking. And we have attempted to set up these systems in which groups of people to do benchmarkings of particular type of code against a similar code. The documentation that is required so that these codes can be used by other participants in the program outside the program.

And finally, a near term activity that is in the process of going on is the test problems or preliminary performance assessment of Yucca Mountain.

Some months ago, the technical integration group in a discussion with Tom Pigford, University of California at Berkeley, suggested that Pigford should put together some problems for particular reasons. One of which was to be able to come to grips with what all of our assumptions are in these performance assessment calculational techniques and the calculational problems and so forth, to look at the critical data and model needs once in some sort of integrated consistent fashion.

And secondly, to be able to assess if all of these participants can work together, contribute together towards the end product which is down the road. So, these problems have been submitted up to the working groups and they have evaluated these problems and next week, we will sit down and select those problems that will be looked at this year, by the different PA participants.

(Next slide.)

DR. GNIRK: In the long term, of course, in the '90-'91 time frame, the model validation and code certification activities have to be coordinated and go forth, and we have to establish and follow and keep working with the methodologies for the assessments for the safety analysis report and the DEIS and the EIS.

These methodologies must complement the strategy that is set out.

Secondly, we have to go through the process of identifying and screening quantification of these disruptive processes and events that have to be evaluated for the purpose of SAR and DEIS. And, more importantly, in the next two fiscal years, we intend to do some detailed calculational exercises for preliminary performance assessment purposes dealing with the expected site and repository condition, impacts of disruptive processes and events.

This is a follow-on from the test problems this year that will be looked at, but these things are being set up so that when the technology, the methodology, the expertise and the tools are needed in those years, to do the assessments for purposes of the DEIS, SAR, we will have gone through these processes a number of times.

The notion is to develop a well coordinated group of people who can do these things, with the expertise and the tools. In the '92 time frame, we have to conduct the assessments to support the preparation of the DEIS. And, of course, you could go out, according to the time frames that Don Alexander has talked about, to plug in all the different parts as we go forward.

Thank you, very much.

MR. ALEXANDER: Are there any questions for Paul?

CHAIRMAN NORTH: I have one reaction on the last couple of slides which is that I would have liked to have seen more detail as to the interaction with the site characterization activities as they evolved.

It seems to me that that is a very important aspect of the performance assessment, especially as you go through these calculational exercises is to define precisely what is it that we would like to know out of the testing that is going to go on over the next few years.

And getting into some of these specific examples like characteristics of faults or characteristics of ground-water flow through the matrix or other specific items that are going to be important in the performance assessment. When you go through these calculational exercises you learn that but then if you are going to get the data to resolve that uncertainty, it has to be translated into some detailed specifications for what experiment do you want the people out in the field to run?

MR. ALEXANDER: Yes, I could not agree with you more. In the first three talks, we all, you know, hedged our bets a little bit so that the speakers this afternoon could make their presentations directly at that. And I think in the four talks that you are going to hear, you are going to hear that they are going to identify some data needs or areas where there is uncertainty with regards to data and an understanding of the physical models and they will be talking about how they, at their level, directly integrate that kind of thinking you are talking about.

So, we are geared up to tell you that this afternoon for sure.

CHAIRMAN NORTH: Good.

Well, I think that we have had a very good introduction this morning. Are there any other comments from the board members?

(No response.)

CHAIRMAN NORTH: I have one request of our audience. If any of you have not signed the sign-in sheet, would you please do that before going off to lunch?

We are now going to take our lunch break and we will reconvene here at 1:00 p.m. And since we are slightly ahead of schedule, that means we can have a little bit longer lunch.

We have got an hour and 15 minutes.

(Whereupon, at 11:45 a.m., a lunch recess was taken, the above-entitled matter to reconvene at 1:00 p.m., on the same day.)

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

(On at 1:03 p.m.)

CHAIRMAN NORTH: We ask everybody to take their seats please.

If there are any members of the audience that have not signed on the sign-up sheet, please do so.

Now, let us continue.

MR. ALEXANDER: Okay, this afternoon we have four speakers -- I will be the leader of the discussion period as far as we carry that -- four speakers who are going to talk about the postclosure and preclosure assessments that we are going to be conducting over the next several years. Dwight Hoxie of the U.S. Geological Survey is going to be talking about the performance of natural barriers. Abe Van Luik will follow him and talk about the engineered barrier system with respect to containment and release and that will be summed up in a talk by Felton Bingham and Felton will be talking about the postclosure system in total, which includes both the natural and engineered barriers.

And then finally, Dave Michlewicz will be talking about our analyses in the area of preclosure safety assessment. The objectives of this session will be to review performance assessment calculations that have already been done from really those that were presented in the environmental assessment; to review the data status and needs; and then finally, to identify any near term activities that we are about to embark on.

And so, without further ado, I would like to invite Dwight Hoxie up to the podium and Dwight will be telling you about performance of natural barriers.

And I think you will find it very interesting.

Dwight?

PERFORMANCE OF NATURAL BARRIERS BY DR. DWIGHT HOXIE

DR. HOXIE: Thank you, Don.

One of the -- I have one as a matter of fact -- one of the very important aspects of the Yucca Mountain site is that we are going to rely very heavily on the so-called natural barrier system. And so, I would like to talk about that but one of the first things that I need to do -- well, let me, first of all, give you some idea of how I am going to go about approaching this.

If I might have the first slide?

(Next slide.)

DR. HOXIE: What I would like to do is to just very briefly talk about regulatory requirements for the natural barriers and this actually takes the form of the so-called ground-water travel time calculations.

I would like to go over the kind of information that we need for these calculations. I would like to address very briefly, summarize for you, the calculations that were made for the environmental assessment. And I would like then to kind of back-up a little bit and say okay, now that we have done that, what do we really need to do in order to get a handle on these kinds of calculations?

And so I would like to identify some additional informational needs that will be coming out of the site characterization program and to be defining the site characterization program with respect to this issue. And, finally, I would like to conclude with some of the current and future activities that are taking place.

May I have the next slide, please?

(Next slide.)

DR. HOXIE: I am not going to read this to you but this is the regulatory requirement from 10 CFR 60, 113(a)(2) that specifies what the ground-water travel time business is all about.

Basically what it says is that ground-water travel time from the disturbed zone to the accessible environment must be calculated along a path which is the fastest path for likely radio nucleid transport.

And this unfortunately leads to a number of ambiguities.

If I may have the next slide, please.

(Next slide.)

DR. HOXIE: Because it makes it very difficult to identify exactly what kind of information we need to make that kind of calculation.

CHAIRMAN NORTH: Could you review for us, again, what the definition of an accessible environment in this part of the law is?

DR. HOXIE: Okay.

The accessible environment essentially is -- I don't want to discard it -- it is the perimeter around a repository, okay, that it will extend out to a distance of at least five kilometers but will not exceed a 100 square kilometers. So it is some kind of region around the repository, itself.

CHAIRMAN NORTH: So, this boundary is not sharply defined at this point.

DR. HOXIE: I would say, no.

CHAIRMAN NORTH: It is defined more over a range of where, at some future time, its location within that range could be defined?

DR. HOXIE: It could be defined, yes.

DR. CARTER: This is a vertical boundary?

DR. HOXIE: Well, this is a, essentially a vertical boundary and from the practical standpoint, it would represent the, you know, a region in which a person potentially could have access to a system and therefore, be endangered by any range of nucleids that might escape from the repository.

DR. CARTER: So, in this case, you have got to go from the disturbed zone out to this sort of imaginary boundary where the ground-water table intersects it?

DR. HOXIE: Well, the distrubed zone is essentially believed to be an envelope around the repository, itself, that will enclose the repository.

I will talk more about that.

DR. CARTER: Okay.

CHAIRMAN NORTH: The accessible environment could be underground?

DR. HOXIE: Yes.

CHAIRMAN NORTH: And it could be a distance of kilometers away whereas the disturbed zone, I gather, is in the order of meters away?

DR. HOXIE: Yes, I will talk about that. Probably not the accessible environment per se but certainly the disturbed zone.

DR. DEERE: A point of clarification.

I think, this morning, that I understood that this accessible environment could also be below us. Anything that is able to -- the ground-water level, for instance, wasn't this --

MR. ALEXANDER: Don, I think what Larry Rickertsen was saying when he made that point was, that we may arbitrarily choose to elect the accessible environment calculations to stop at the interface with the ground-water table.

But, you know, the option is open for us to do the continue the calculation all the way out to the cylinder that cuts down through the earth's surface around the repository which is out at a five-kilometer radius from the repository.

DR. CARTER: Yes, that was my question. Where the ground-water table intersected the accessible environment.

MR. ALEXANDER: Yes.

MR. STEIN: I think that you have to look at it as a cylinder. And the way that the regulations read, I think that Dwight said it correctly and that is that, you can't exceed a 100 square kilometers, but no one side of it can exceed five kilometers from the perimeter of the repository.

Now, we get to choose what that five kilometers is. In other words, it doesn't need to be a cylinder. You can have the accessible environment that or accessible boundary at one point hard up against the repository and shaped in an elliptical shape with five kilometer lane down through the water table.

DR. HOXIE: If I don't forget, I will emphasize Ralph's point here a little bit, as a matter of fact.

Okay, let's see, where were we?

Back to information duties. Well, first of all, of course, we need to understand the hydro-geologic system at the site.

So, this includes understanding what the geologic framework is; what the initial and boundary conditions might be; and what hydrologic and other kinds of processes are operating within the system, that determine the state of the system and the future state of the system.

We will then embody all of this into calculational models, and we have to have -- and this, again, is some point of unclearness, because we have to define the extent of the so-called disturbed zone -- and as we will define them for the environmental assessment calculations, the extent of the disturbed zone is said to be 15 meters below the mid-plane of the repository, itself.

DR. VERINK: Is that number 15 or 50?

DR. HOXIE: Five-0, 50 meters.

DR. VERINK: Fifty, okay.

DR. HOXIE: But the extent of the disturbed zone is something that is open for analysis. And again, another aspect of this requirement, which is open to various kinds of interpretation is, what exactly are the paths of likely radio nucleid travel?

Do we include diffusion? Do we allow for the fact that the radio nucleids are going to migrate through a coarse medium and therefore, be affected by dispersion -- geochemical kinds of activities? For our calculations, we say, no. That they are going to be chemically inert and that they simply will be advected with the water.

And so, what we are going to be doing then is to make calculations essentially of tracer particles that originate at the distrubed zone, and then travel as inert particles with the water towards the so-called accessible environment.

And then we have to go through and make some kind of an evaluation of what the ground-water travel time is actually going to be from the disturbed zone to whatever we define to be the accessible environment.

For the EA calculations, the conclusion was that the ground-water movement within the saturated zone is sufficiently rapid that the ground-water travel time associated with water moving through the saturated zone might be on the order of 50 years or so.

Consequently it was decided that all we needed to worry about was that portion of the system between the disturbed zone and the water table, itself. Effectively once a radio nucleid got to the water table it was essentially into the accessible environment already.

So, if I may have the next slide?

(Next slide.)

DR. HOXIE: This was a very, very simplified conceptual model for the calculations that were made for the environmental assessment. And I remind you that the site at Yucca Mountain consists of a sequence of TUFF's that alternate between being welded and non-welded. The distance from land surface to the water table ranges something on the order of 750 to 500 meters. So that is the thickness of what we would call the unsaturated zone.

It is planned to construct the repository in the so-called Topopah Spring welded unit. And it is a welded TUFF at a distance of approximately 200 meters, 300 meters below land surface and in a range of essentially 140 to about 260 meters above the water-table -- so well within the unsaturated zone.

So, this would be the repository location within the Topopah Spring. Lying below this, and parallel to the repository is the boundary of the disturbed zone, as I indicated, 50 meters below the repository.

Below the Topopah Spring is a unit called the Calico Hills nonwelded unit. We regard this to be the primary natural barrier, both because it has very, very low transmissive properties, over most of the -- beneath most of the repository block -- and it also has appropriate chemical properties that are likely to retard any kind of radio nucleid transport.

Below the Calico Hills is a group of TUFF's that make up the Crater Flat TUFF, the upper unit being the Prow Pass unit and in some places it is welded and in some places it is non-welded.

I might point out that the welded TUFF's tend to be less transmissive on the whole than the -- to water that is -- than the welded, non-welded TUFF's. And the welded TUFF's also tend to be more fractured than the non-welded TUFF's.

In fact, the difference between the welded and non-welded TUFF's, in terms of fracturing, is an order or magnitude or so.

And then beneath us, we have the Bullfrog unit. And then, finally, we get down to the water-table. Now, in the northeastern part of the repository area, the water-table intersects the Calico Hills non-welded unit. However, at the southwest corner, the southwest end of the proposed repository, the water-table actually is in the Bullfrog.

So, the water-table actually transects across these various -- what we would call hydro-geologic units.

(Next slide.)

DR. HOXIE: The physical assumptions that went into the environmental assessment calculations were very, very simple. First of all, we assumed that the hydrologic gradient is entirely vertical throughout the whole section from the disturbed zone to the water-table.

What this implies then, is that the liquid water flux -- and we were only concerned with liquid water -- is, itself, vertical and we made the further assumption that it is uniformly distributed in space and time -- that is, it is constant in space and time.

The effect of assuming a unit hyrdologic gradient then, is in the unsaturated zone, is that the effective matrix, hydraulic conductivity of the rocks, themselves, neglecting the fractures, is equal to the flux, itself.

So that makes the calculations that much more, makes them much simpler.

And the other things -- two parameters that we are going to need to make these calculations -- are the saturated hydraulic conductivity of the unit and the effective porosity of the unit. And the effective porosity is essentially the amount of pore space which is going to be available for transmitting liquid and therefore, depends on the saturation of the unit, itself.

So that means that you are only going to transmit water through that pore space which is actually occuppied by water. So we have to make a correction for that. We can't use just a total porosity.

That is not available, all of that porosity is not available for flow.

But we treat, in these calculations, we treat the saturated hydraulic conductivity and effective porosity as random variables. And the reason that we did so is that we have sufficient measurements on these properties for the various units that one could actually come up with classical statistical distributions for the two parameters.

And it was also assumed that they were independently distributed and there may be a bone of contention there because some people maintain that actually the saturated hydraulic conductivity does depend on or that there is a relationship between the saturated hydraulic conductivity and the porosity.

So this may not be --

CHAIRMAN NORTH: The assumption that you make about independence for various spatial locations -- you assume they are essentially independent samples from the distribution is a certain spacing?

DR. HOXIE: I am not sure I completely understand your question. But let's go just a little bit further and I think that I can answer it.

CHAIRMAN NORTH: Is there a correlation that you are assuming between let's say, adjacent samples?

DR. HOXIE: Yes.

Okay, there is. And I will explain that in just a minute.

You are anticipating me just slightly.

Okay, we don't -- again, in these calculations we had no idea of how to treat the fractures, so we simply say that if the flux exceeds .95, or 95 percent of the saturated hydraulic conductivity, within any unit, then the flow in that unit, or that portion of the unit is controlled solely by the fractures.

And we have assumed a fracture permeability, if you will, or hydraulic conductivity, of 10 to the fourth meters per second -- mili-meters per year, sorry.

Okay, and again I have talked about the disturbed zone.

(Next slide.)

DR. HOXIE: Okay.

DR. LANGMUIR: Before you go on, Dwight?

DR. HOXIE: Yes?

DR. LANGMUIR: The critical thing, it seems here, is are these assumptions all of them conservative, in some manner?

DR. HOXIE: Ah.

DR. LANGMUIR: Do you know where you are going to be plus or minus on them?

The most obvious thing that hits me is that there has been a lot of discussion over the last few years, as to the recharge rate. When you pick a single number for rainfall recharge, your value Q, which you have given here on the previous page, of .5 mili-meters per year, I don't recall if that is conservative or not.

There is quite a wide range, as I recall, of tenfold possible range of those values.

DR. HOXIE: All right, I would argue that the assumption of .5 mili-meters a year is a highly conservative assumption, okay.

The latest information that we have right now, is that -- we are getting a little ahead of the story -- but that the net infiltration averaged over the entire surface of the mountain has got to be less than 1 mili-meter per year. And so that would probably -- and this is probably also goes back historically -- we have to talk about that. I mean that is an unknown, of course.

Some other calculations that we have done -- again, these are very preliminary -- indicate that the actual flux, at the repository horizon is very, very much less than a tenth of a mili-meter per year.

And that these are crude and they are based on some approximations that may not be right and I am going to talk about that also. The whole notion is that if the -- my current understanding of the Topopah Spring unit right now, if the flux in the Topopah were to greatly exceed .5 mili-meters per year, we would probably induce, well, Topopah would probably be essentially saturated and therefore, we would probably induce, liquid water flow into the fractures.

Now, our only information on the actual saturation value for the Topopah Springs arise from a single well and the indication is that out of something like 11 samples, independently analyzed, is that the mean saturation in the Topopah Spring is about .65. And so, we know that it is in the matrix, at least at one point it is not saturated and so the flux must be less than the saturated hydraulic conductivity of the Topopah Spring, which we know to be on the order of a mili-meter per year.

So I think that that aspect is very conservative and another very conservative aspect is that we assume that the flow below the disturbed zone, to the water-table is entirely vertical.

And, of course, we realize that it is going to be highly -- . So that is another very conservative assumption.

And I will point out another one as we go along.

If I may have the next slide, please?

(Next slide.)

DR. HOXIE: I would like to explain. This is the way in which the calculations were performed. And what we have here is essentially the perimeter as it stands right now, of the repository.

The preimeter was divided up into 963 columns that were 250 feet on a side, square, and so looking down on it from a plane's view, and the columns, themselves, had a, were broken up into a thickness of 10 feet.

And these were essentially based on the assumption that these were the correlation lengths for properties within, representing the horizontal correlation lengths and the vertical correlation lengths.

So that these were greater than the appropriate correlation lengths so that parameters within a particular slab, would not be correlated with parameters in an adjacent slab, either vertically or horizontally.

CHAIRMAN NORTH: So you sampled independently both vertically and horizontally the parameters?

DR. HOXIE: That is right.

But what we would do then, is that we would come in with each unit now, had a distinct effective porosity and a distinct saturated hydraulic conductivity, and you have some kind of sample distribution for that.

And so the way that the calculations were actually made then is that we would calculate the flow, vertical flow, through a column and then using, taking values from these distributions and using those same values for each unit, in the horizontal direction. And then repeating this in a Monte Carlo kind of simulation.

And Monte Carlo simulations were run for 10, 50 and 100 different utilizations. So this is the way in which we then constructed the cumulative distribution function for a ground-water travel time.

CHAIRMAN NORTH: Now, the flow is constrained to be strictly vertical?

DR. HOXIE: That is correct.

And that is, I would say a very, very conservative assumption.

MR. ALEXANDER: Again, that is in the EA caluclations also?

DR. HOXIE: This is, yes, right.

Okay, may I have the next slide, please?

(Next slide.)

DR. HOXIE: And this will just give you the equations that essentially were used. I mean the ground-water travel time as it is subscript, say, in a particular column, column I, is nothing more than the sum of over all of the units, okay, or all of the vertical elements, having a thickness D, in this case, 10 feet, divided by the velocity of the water, within that particular element.

And the way that the velocity of the water was calculated, is to say that the actual, what we call the seepage velocity, which is the velocity effectively within the pore space, itself, not the so-called Darsian flux or so forth -- is equal to the flux of water, divided by the effective porosity, times a, if you will, a fudge factor, which depends upon the saturated hydraulic conductivity and the flux again. And it has a power law in here, that takes into account the fact that the pores are not completely saturated and so only water moving through the saturated or the water-filled portion of the pores is actually being conducted down vertically.

So we take that into account. And this is based on using the Brooks Quarry approximation for the relative hydraulic conductivity.

This is how we define the effective saturations, at least in this equation. It is equal to the effective porosity -- I am sorry, the effective porosity is equal to the bulk porosity times 1 minus the residual saturation.

And the residual saturation is the saturation within the pores of the unit that you would obtain, for example, after three covered and drying them for 24 hours. There would be that much water left over that you simply could not get out of the material.

And we don't have good information on that particular number, but we do have some information for a couple of the units.

MR. ALEXANDER: You don't mean bonded water, though, you mean absorbed water.

DR. HOXIE: Essentially absorbed water, right.

I then, for the fraction of these used a very, very simply model and that simply says that if the flux through a particular section or a particular slab, is greater than 95 percent of the saturated hydraulic conductivity, then the effective velocity of water is totally within the pores themselves and that will be equal to the difference between the flux and the saturated hydraulic conductivity times 10 to the fourth.

And so this means that the water would be moving rapidly in the fractures. Again, pointing out that we may have water moving through the fractures only through a single slab or something like that. It is not through the entire vertical column.

It would only be through that slab in which this condition were to hold.

Next slide, please.

(Next slide.)

DR. HOXIE: And this just gives you some of the information on the parameters that we actually used for these kinds of calculations.

So, up here, we have the hydro-geologic unit and we have the maximum thickness between the disturbed zone and the water-table for that particular unit. And this is the saturated hydraulic conductivity for the unit in mili-meters per year.

So, it gives you some idea of how effective these different units are in transmitting water. This would be the effective saturation or effective velocity for each of the units. And again, giving you some idea of the thickness between the units. And this is this power of Epsilon, which is in the fudge factor, taking into account the variable saturation points.

Next slide, please?

(Next slide.)

DR. HOXIE: This gives you some kind of comparison. So now, you can single in on a vertical flux of 25 mili-meters per year, and if we make all the other assumptions that we have made so far and use the physical properties, and we do these Monte Carlo simulations, and do obtaining 10 realizations, for 963 columns, so that is 9,630 different calculations, then we can develop a histogram showing the number of travel times for a column within a particular time interval. From that histogram, we can get the probability distribution function, which we then can integrate by summing, to get the cumulative distribution function, which is aligned here.

So essentially what we are saying is that if the ground-water -- if we picked some particular ground-water travel time, say, 30,000 years -- and the probability that the ground-water travel time is 30,000 years or less is simply going to be the vertical axis over here, so say something on the order of .18, the probability of .18.

DR. LANGMUIR: Dwight?

DR. HOXIE: Yes?

DR. LANGMUIR: I can picture a worst case that might or might not be within your envelope of uncertainties here and that would be -- I think that most of us know about desert type recharge, where you have a lot of runoff during a major storm that concentrates in a somewhat lower piece of topography and then all goes down right there, and it goes down fast, if you have got fracturing in a zone like that.

Is this sort of episodic or --

DR. HOXIE: Well, this kind of episodic thing, of course, we did not allow for. But the question is, is you also have to ask the question what happens to that water as it runs down?

And that is the second part of my tale.

So, I will get to your question, too.

Isn't it nice? I keep postponing all of these things, but we will get there.

Okay, so this is essentially a summary of what was done for the entire metal assessment.

Can we have the next slide, please?

(Next slide.)

DR. HOXIE: I think that as Dr. Langmuir has just pointed out and Dr. North, that we need to do a little more sophisticated kinds of analyses and we certainly agree with that.

So, now, I would kind of like to back up again, a little bit and look at it from the site characterization point of view. And so, at the risk of getting involved -- I don't want to get involved in an argument of what a conceptual model is -- but I will argue that if we have a conceptual model or want to develop a conceptual model for a hydrologic system, there are three very important elements that we have to consider: the geologic framework, the initial end boundary conditions that apply to the system, and the hydrologic and other physical processes that are going to be occurring in the system that will determine the present state of the system and the future states of the system.

Okay, may I have the next slide, please?

(Next slide.)

DR. HOXIE: In terms of the geologic framework or the geometry of this system, of course, we are going to have the structural features, which at the Yucca Mountain site includes faults, folds and fractures. And I will get rid of the folds very quickly.

The Yucca Mountain system is in the Great Basin which is part of the basin and range physiographic province and consists of essentially mountains that are faulted on one side and tilted, tilted fault locks. And, indeed, Yucca Mountain is tilted to the east on the range of 5 to 8 degrees depending where you are.

So we have, not really a fold as such, but we do have dipping units, to the east and we certainly have faults and fractures.

And then we divide the system up into so-called hydrogeologic units. These do not necessarily correspond to what the geologist would define as rock stratographic units. These are units that have common hydrologic properties.

And at Yucca Mountain we have two major categories. We have the highly fractured welded TUFF's such as at Topopah Spring and we have the sparsely fractured non-welded TUFF's such as the Calico Hills, which we call our primary barrier.

(Next slide.)

DR. HOXIE: What I want to do right now is to talk about our conceptual model and try to answer some of the questions that have actually been raised.

This, again, is a cross-section through Yucca Mountain; it is the same one that Dr. Rickertsen showed this morning. It is essentially a cross-section from west to east over here and where it says, Yucca Mountain, you all can call this the Yucca Crest because beneath the Yucca Crest is where the repository, itself, is going to be located.

We are bounded on the west by something called the Solitary Canyon Fault which has a displacement. It is a fault that runs entirely along the Yucca Crest essentially. It defines a very large topographic escarpment. And it is a scissors fault; it is a normal fault in the first place. It dips at a steep angle and the west side has been displaced down relative to the east side. It is a scissors fault in the sense that the displacement at the south end of Yucca Mountain is on the order of 200 meters, whereas, at the north end, it is only about 70 meters. So it is slid like that.

On the east side of Yucca Mountain we have an intricate series of very, very small normal faults. By small, I mean small displacements on the order of two to three meters or so.

And cutting through the Yucca Mountain Crest, itself, and through the repository, we have something called the Ghost Dance Fault, which has maximum displacement of about 38 meters. And it essentially trends to the north and disappears at the north end of the repository.

I might point out that essentially all of these faults in here, are probably the result of quarternary collapse when these TUFF's were deposited from volcanoes located to the north.

And, so that the age of these faults is probably on the order of 12 million years or so. Only the Solitario Canyon Fault has any indication of any quaternary displacement on it, and that is very, very small that the faults show here that affect the --

DR. DEERE: Could your Ghost Dance Fault also be referred to as a scissors fault?

DR. HOXIE: Well, it is because --

DR. DEERE: Displacement --

DR. HOXIE: Disappears, yes, right.

DR. DEERE: Right.

DR. HOXIE: Okay, and I should point out that what is actually shown here vertically, on your diagram, are the indicated rock stratographic units as defined by geologists.

So what the T up here stands for Tiertary, and the P stands for the Paintbrush TUFF and C stands for here for this is the Tiva Canyon member of the Paintbrush TUFF.

And we then have a bedded TUFF down here and then we come down to the tiertary Paintbrush filoplus screen.

And that is how this symbolism is actually working. We have another nonwelded unit which is actually the Calico Hills and then we are coming down here into the greater flat TUFF, the Prow Pass, Bullfrog, the Tram unit and then a series of TUFF's well down into the water-table, the water-table being defined by the blue line across here.

I might also mention that -- well, okay, now.

The thing is that we now have the geometry of the system and we need boundary conditions and the lower boundary condition is defined by the water-table, which underneath Yucca Mountain is essentially very, very flat. It is at an altitude of about 730 meters. Although it does increase by about 300 meters or so, to the northeast, but underneath Yucca Mountain, itself, the water-table is actually quite flat.

But the point to remember is that even though the water-table forms a lower boundary, it is, in principle, a variable in space and in time. So it can change and this is something that we would have to allow for.

The upper boundary condition is land surfaced and we presume, at least one would, that the upper boundary is an infiltration boundary in the sense that water can percolate or rainfall, precipitation on Yucca Mountain could collect possibly and percolate into the interior of the mountain and therefore, provide water to the unsaturated zone and also provide flux that is moving down past the repository.

We do not know what the infiltration rate is. We do not know how it is distributed across the surface of Yucca Mountain. We don't know how it occurs in terms of space and time. We don't even know if it is actually a non-zero number; it might be zero.

But we have a large program that is ongoing to investigate the infiltration properties of at the surface of Yucca Mountain. And we are looking at various kinds of processes where you have water that perhaps, during the storm, collects in a drainage basin, runs down, enters into fracture systems in the Tiva Canyon unit or into a fault and then gains access to the unsaturated zones.

Well, one thing that is going to happen is that once it does, because the unsaturated zone is essentially dry or at a negative pressures, as we would call it, that water that would enter would tend to be dispersed throughout the unsaturated zones.

And so, as it moves downward, it is going to tend to spread. And there is the possibility, this is a hypothesis, is that by the time that we get down to the depth of the repository, the vertical flux tends to be nearly uniform and that we may, in fact, essentially have the steady state system, just because of the smoothing out of the episodic flux, episodic infiltration as it occurs across the surface.

DR. LANGMUIR: That is assuming though, a fracture level?

DR. HOXIE: That doesn't matter. What I think is going to happen is that if we have the flow of the fractures in the Tiva Canyon up here, that flow is going to come down, it is going to intersect these nonwelded units. The nonwelded units tend not to be fractured. So that but they also are essentially very porous, and have very high transmissive properties.

So, consequently, what will happen is that the waters that will intersect, say, the nonwelded would probably be absorbed by the nonwelded and redistributed laterally. And the various -- since these units are dipping to the east at 5 to 8 degrees, there is probably a tendency for the water to move down along the bedded TUFF units.

(Next slide.)

DR. HOXIE: We need the lateral boundaries on our site and these for the unsaturated zone are not well determined. We think right now, that a very good boundary is probably the Solitario Canyon Fault. We think the water probably enters the fault zone and it is very highly dredgiated (ph) so that the water will probably move down vertically to the water-table without actually entering into the unsaturated zone.

That is just a hypothesis and it is one that needs to be tested. Also we think that there is a very good likelihood that this system of intricate faults over here again, will act as a hydrologic boundary preventing water from moving into the repository area for two reasons. One, because the water would have to move across the faults and it would also have to move updip, so that we have some good argument there.

Next slide, please?

(Next slide.)

DR. HOXIE: This -- let's skip over, go up to the picture.

I have already done all of those so let's just go to the picture.

What I would like to do is to show you what things look like out there and this is a view of Yucca Crest, right along here, looking from essentially the southwest to the northeast. This is the drill hole UZ-6, as it was being drilled, unsaturated zone, and you are looking along the trace of the Solitario Canyon Fault here, which is defining this very large escarpment on the west side of Yucca Mountain.

This area over here is Crater Flats, and out here to the east, eventually, we get into Jackass Flats. And we are looking at a series of valleys over here which are delineated by faults to the northeast and what we are looking at here, right on the crest, this is the Tiva Canyon and the break on down here, these are the nonwelded units down in here.

And finally we get down to the Topopah Spring unit which is here. Now, there is a problem with a boundary condition on this side. So far we have assumed that only water is flowing within the system, but we know that the Topopah Spring is highly fractured. That means that there is the possibility that within the fractures we could have significant air flow and if we have air flow within the fractures, with the geothermal gradient or with barometric changes that lie on surface, we could have a forced convection either thermal or forced convection mechanism by which the pumped air, laden with water vapor out of the Topopah Spring or back into the Topopah Spring along an outcrop such as this.

And there is some circumstantial evidence that this effect may be taking place. For one thing, when we drilled the UZ-6, the bore hole stood open and air would blow in and out of the bore hole with considerable velocity. So that we know that we intersected some kind of air system, and it changed with direction and velocity with season and with the time of day and so forth.

So that we know that we have intersected something in the natural system but we don't know to what effect, to what extent it is the bore hole that is responsible for producing this disturbance. We don't really know that there is a natural air convection system within Yucca Mountain, itself.

So that is something that has to be tested.

Let me have the next slide.

DR. CARTER: Dwight, can I ask you a question?

DR. HOXIE: Surely.

DR. CARTER: I presume, as far as air flow and the movement of water vapor, that that is not considered ground-water flow, per se, is that true or not?

DR. HOXIE: Well, I wouldn't -- okay, you anticipated me again.

I will get there, let's go, next slide, please.

I am not putting you off.

(Next slide.)

DR. HOXIE: Okay, one of the things that we have to talk about now are the hydrologic -- just the hydrologic processes that might be occurring within Yucca Mountain and to answer your question, specifically, if we are going to consider the total moisture balance at any point within the system, we are going to have to account not only for the liquid water, but for the water vapor also.

And the two may not be in equilibrium if we have a lot of air flow, moving up, say, through the fractures.

And so that there may not be equilibrium, as thermal dynamic equilibrium, phase equilibrium between the liquid water that is being held by capillary forces within the unsaturated matrix and the water vapor that would be moving through the fractures add that along with any air that might be moving.

So this is something that we also are going to have to determine. And it could make a big difference on the liquid water flux, because we have to -- the total moisture balance has to include both of these.

DR. CARTER: What is the accessible environment in that case?

DR. HOXIE: In that case, that is --

DR. CARTER: You have got water vapor coming out vertically.

DR. HOXIE: Thank you.

The accessible environment, then, becomes possibly the edge of Solitario Canyon on the west side of the Yucca Crest, because if we have water vapor moving naturally out of or gas flow moving out of the Topopah Spring there and back in again, then any gaseous phase, radio nucleid also could be transported out through that avenue.

DR. CARTER: And that is a lot closer than five kilometers?

DR. HOXIE: Would be, wouldn't it, yes.

DR. CARTER: Yes.

DR. HOXIE: But that would have to be the -- I mean that is something that we have to look at; that is something that has to be considered. And, of course, I guess the real culprit would be carbon dioxide, carbon 14 dioxide.

DR. CARTER: Well, I presume that you are making measurements on looking to the west for this sort of thing.

Do you have a analytical program here?

DR. HOXIE: Well, there is a plan, and I am not even sure what the status of that is now, to drill a hole into the Solitario Canyon horizontal bore hole and that would give us a pretty good handle on what was going on.

And I think that we are going to learn a lot from all of our surface based bore holes where we are going to be doing not only looking for natural air, looking at the geochemistry of the air, but also doing air testing to find out what transmissive properties of the fracture system is to air.

(Next slide.)

DR. HOXIE: I wanted to -- let's put this one on the other one, and there is one other thing that I would like to point out. One of the things that we need to do is to emphasize the uncertainties that, try to emphasize the uncertainties that affect the system and I will try to hit this very, very quickly.

Neglect the Roman Numeral II please. One of the things that people do when they are working in the unsaturated zone is that you need an equation of motion for whatever fluid might be moving through the system and it is customary in soil science and in saturated zone hydrology to assume that if you have a porous medium that the appropriate equation of motion is Darcey's law.

And Darcey's law simply says, the notation is over here, but that if your flux of some kind of fluid F, say, this is in the unsaturated zone, then it is equal to a conductive term which is this term right here, times the gradient of a potential, that is defined an energy potential essentially, that is defined within the unsaturated porous medium.

The PF over here would just be the associated pressure. You are talking about liquid water, this is capillary pressure. You are talking about gas flow, air flow, then this just becomes the pressure of the air, itself.

But the thing is that in the saturated zone, we have a problem because the conductive term, over here, is actually a function of this saturation within the rock.

And so is the pressure term over here a function of the saturation, which makes this entire equation nonlinear, because saturation and -- if you change the saturation then you are going to change the pressure. If you change the pressure, you change the saturation and so we have that kind of problem.

And we cannot be sure, at the present time, for example, that Darcey's law is really appropriate to, especially the welded TUFF's; the welded TUFF's are very tight. Their hydraulic conductivity is on the order of something on the order of a mili-meter per year or so.

And this is getting down to the range where we cannot be sure that by going into the laboratory and trying to measure the parameters that would go into Darcey's law, are going to give us a correct set of parameters. And the one way that we are going to try to get a handle on that uncertainty is to collect lots of samples and do classical statistics.

So that is one area of uncertainty right there; is Darcey's law applicable, especially to the welded TUFF's.

(Next slide.)

DR. HOXIE: And I just want to show you very, very briefly here, this is for liquid water and this is for sand. This is the saturation which ranges from zero to one, so at one we are completely saturated sand. Over here is the capillary pressure, which is the pressure of the water that within the sand. And since we are talking about water that is being held under capillary tension, we always measure the pressure in negative units -- that is, less than atmospherics.

But this is the kind of relationship that one gets and there are two things to point out. First of all, we can see that the relationship between capillary pressure and saturation for sand is very highly nonlinear. And not only that, it exhibits historisus in the sense that if we take a sample that is already saturated and we dry it out, we go along a curve that looks like this.

On the other hand, if we take a sample and completely dry it out and then let it imbibe water, we get a curve that looks something like this. So that they do not retrace their paths.

And a real sample, which is partially saturated and so forth, is going to exhibit some kind of oscillations back and forth in here. So we have this historisus effect and that is another problem, another effect that we have no handle on for the rocks at Yucca Mountain.

And it may not be that important but it is something that we need to examine.

(Next slide.)

DR. HOXIE: The other thing that is very uncertain at Yucca Mountain is how do we go about handling the hydraulics of the fractures? Are the fractures barriers to flow or are they conduits for flow of liquid water? And can we have lateral flow across the fractures or can we have longitudinal flow within the fractures and when will these occur?

(Next slide.)

DR. HOXIE: I will try to show this pictorially. What I have here is the intersection of two fractures, located right here. Surrounding them is a porous medium. If you look the -- I don't think you can turn the lights down -- but in the -- what we have is essentially air is indicated in green, and brown indicates matrix particles of the rock. The blue indicates capillary water that is being held wiothin the pores of the rock. And if the fracture is very wide, then the capillary forces are very strong within the small pores of the rock and the water cannot enter into the fracture.

And so all we can have here, for example, as I have indicated, is the possibility that we have air flow through the fractures. On the other hand, over here, where we have an asperity in the fracture, or where the rocks come very close together, it is highly possible that the fracture will be narrow enough such that the aperture of the fracture will be equal to or less than the largest water-filled pore. And so the fracture can contain water in it; we can have lateral movement of water across the fracture, but not longitudinal movement of water along the fracture.

But we can have air moving in the fractures and air can be conveying water vapor. So my whole system with the fractures and the matrix could become quite complicated and whereas we realize this probably does occur, one thing that it accomplishes is that it increases the tortuosity of the path with which water is going to move.

So that if we have a fractured rock that is unsaturated then and we want to calculate ground-water travel time then the fact that we are going to have this kind of tortuosity, again, is going to aid us. Because the water paths are not going to be strictly vertical, they are going to be much more contorted.

But once the matrix, rock matrix becomes saturated, all of the pores become filled with water and then water now can drain into the fracture and presume we could flow down the fractures.

So, under those circumstances, one could have the fracture flow and we don't know all of the mechanics of that or when it will occur, or even how to account for it.

(Next slide.)

DR. HOXIE: So, in terms of information needs as we see them right now for the site characterization program, this is all going to be for pre-waste and placement kinds of activities. Our data acquisition -- we are going to get lots of data we hope, we presume, from the exploratory shaft facility.

We will also be getting great quantities of data on matrix properties, fracture properties from the 25 or so surface based bore holes that are planned to be drilled.

The hydrologic property data you must get from the rock matrix, we need velocity -- saturated hydraulic conductivities and those characteristic relations that I was showing you -- the relationship between capillary pressure and saturation, for example.

We need to understand what the fracture system looks like and how to go about handling it. Do we handle the fractures as discrete fractures, individually; do we handle them as some kind of network system; or perhaps, some kind of overlapping porous medium continuum?

We still have these kinds of decisions yet to make but that also means that we need to understand better what the interaction between the fractures and the rock matrix is.

The other thing we haven't really talked about are the faults. And the faults are special because the fractures are confined to a particular hydrogeologic unit, but the faults will transect all of the units. So they could, in principle, anyway, essentially be bus-bars through the entire system.

And that is something that we also have to look at. Also faults tend to be much wider than fractures and they also tend to be rubble zones. And so they have different kinds of interior geometries than the fractures, themselves.

And this all leads us down to what we are doing is that we are going to have to consider a variety of hypotheses and go through a hypothesis-testing kind of routine; that is that we have to consider alternative conceptual models and that has gotten to be very important. I mean we can't close our eyes to any possibility at all.

The other thing is that we must go through and -- and this is something that was pointed out, a question that was raised and has been pointed out by the other speakers -- is that we definitely need to go through sensitivity studies. We have to find out which of those properties of the Yucca Mountain system really are important?

And which ones can we get by by neglecting? We can handle uncertainty in some cases, by doing purely classical statistics analogous to what we did with the environmental assessment type of calculations, using probability distribution functions, perhaps Monte Carlo simulations or something else.

And other tools that we can use to great advantage and that goes back to a question by Dr. North is by using geo-statistics, we now can examine the spatial correlation and the actual hetergeneity and we have 12 of our surface based bore holes are intended to do just that, with this kind of analysis.

Finally, we get down to the numerical modeling and we have to consider liquid water storage and flow. And we now realize that because of the possibility anyway of air, we have to consider air convective flow. The fracture systems, because we have a temperature gradient or geo-thermal gradient at Yucca Mountain, we also are going to have to be concerned about the invective water vapor transport -- this all assumes no waste emplacement as yet -- and we also then have to include the temperarture gradients and the geo-thermal heat flow. So our numerical modeling now becomes, in principle, a lot more complicated.

DR. DEERE: Before you leave that --

DR. HOXIE: Sure.

DR. DEERE: Wouldn't another complicating factor in your hydrologic property data be that the faults, themselves, might have variation in permeability or in characteristics depending on whether they were cutting through one of the softer TUFF's, versus a hard welded TUFF that would fracture and maybe give a very much different appearance?

DR. HOXIE: Our working hypothesis is that the faults are likely to be sealed in non-welded units, and open in the welded units and we do have some information on that.

Unfortunately, what we need is a bore hole that penetrates the Ghost Dance Fault and we have none. That would be the one to really look at.

DR. DEERE: Or shafts, or drifts?

DR. HOXIE: Or shafts or drifts, either one. That would be even better.

DR. LANGMUIR: Related question.

DR. HOXIE: Yes?

DR. LANGMUIR: You mentioned the Solitario Canyon Fault as being a potential sink for water directly into the water-table.

DR. HOXIE: Right.

DR. LANGMUIR: And the need to investigate it, and I am wondering other than going right to that fault and looking at it and playing with it, will you ever know that? You are going to have to get some measurements of that issue and also the breathe in the gas flow in the mountain issue requires direct measurements, perhaps the use of tracers in the gases.

Are those proposals that you are going to do?

DR. HOXIE: You probably know more about it than I do. Because I am not really sure, because this is the kind of thing that Rob Trouts and Dow Yang I would think would be -- I think that Rob is interested in that. And so, but I don't know what his plans really are, to tell you the truth.

DR. CARTER: Let me ask you a related question also. I wanted to know, have you taken any look at actual data out there, either nearby that already exists as far as checking the model against that? I would also ask you about the experimental program in measurements -- what sort of program do you have to actually measure ground-water movement?

DR. HOXIE: Well, the problem is that in the unsaturated zone, the fluxes are going to be so small that we will never be able to measure them directly and what we are going to have to do is to infer the fluxes by measuring the hydraulic gradient and the conductive properties of the rock, itself, which has a great deal of uncertainty in it.

DR. CARTER: Well, could you measure some of the long-live radio nucleids, like Chlorine 36?

DR. HOXIE: Well, that might help. We do have a program that, yes, for looking at the natural isotopes, and also at the radioactive isotopes and we have found, if I recall correctly, I think tridium at a depth of, it must have been in the Paintbrush non-welded unit, at about 200 feet.

So we have some hope there of -- and by using tracers, also -- the water moves so slowly, we cannot really use tracers in the water system.

DR. CARTER: Yes, I understand.

DR. HOXIE: And I am not sure how all of that is going to work out.

And my concluding slide is that I would like to indicate to you what some of the things are that we are doing. One thing I might just mention is that we have had a lot of talk about and a lot of uncertainty about how fractures work.

Last week, as part of the working group three, which Dr. Gnirk talked about this morning, we held a workshop of two days, where we got all of the fracture flow people together and talked nothing but fractured flow and how it interacts with the matrix and so forth.

And I think that was very profitable. And we need to do more of that kind of thing, only because we didn't allow enough time. We had about 30 people there and just all kinds of ideas were gleaned from that.

The other thing that we have in mind, and this again is being sponsored by working group three, is that what we would like to do is to take all of the data that we currently have, and try to get as much statistics as possible. We have a little bit more data than we had at the time of the environmental assessment. And we already have some work going on both with the classical and geostatistical analyses of these data.

So that we would like in the next fiscal year, get groups together and recalculate ground-water travel time using our best modeling techniques currently available, different kinds of hypotheses and perform sensitivity analyses and uncertainty analyses.

And with that, my tale is told.

Thank you. So I am concluded.

CHAIRMAN NORTH: Do we have further comments and questions from the board members?

MR. COONS: I have a question, did you perhaps used centrifuge modeling to assist you in this at all?

DR. HOXIE: We are using centrifuge techniques to get both, to get characteristic curves both for the hydraulic conductivity on small samples, and the separate hydraulic conductivity and the moisture retentions groups.

But, again, we have a problem because we are using very small, you know, one-inch cord. Now, how representative is a one-inch cord, you know, we have a scale problem. You know, a one-inch cord compared to a column that is within Yucca Mountain.

And that is something else that needs to be investigated.

DR. LANGMUIR: Just one last question, Dwight?

DR. HOXIE: Yes, sir.

DR. LANGMUIR: Looking at your schedule here, and Don Alexander presented this morning, you are going as far as you can go as far as I can tell, with the data that is currently available, characterizing the materials at the site, hydrology and so on.

And so, and you are trying to answer the regulations with respect to a very limited data base.

And clearly you are going to have a much bigger data base starting in '93, '92-'93, and it almost seems a little bit premature to be trying to push the data as far as you are going with it.

DR. HOXIE: No, I don't think so.

DR. LANGMUIR: What are your feelings about that?

DR. HOXIE: The kind of calculations I would make for the environmental assessment were simple one-column, one-dimensional kinds of models. And what we want to do is to expand and start using two- and possibly three-dimensional modeling techniques. I mean by using the larger models and what we really want to do is to be geared up so that as data becomes available, we can proceed, we can just start putting the data in.

So we want to go ahead and do these kinds of, what would be officially be scoping the boundary calculations and then -- okay, and then essentially I want to say, upgrade and update the models as more and more data become available.

DR. LANGMUIR: But you are confident that you are not going to make major conclusions in your conclusions is what you are telling me in spite of the lack of the kind of data you will have then?

DR. HOXIE: Well, I would not say that at all. Because we may change -- what I think is going to change probably is going to be much in terms of our conceptual models.

For example, we don't have the EA calculations neglecting any kind of air flow. And this kind of thing, and I think that, you know, that needs to be put in. It did not allow for any lateral flow of water or whatever.

That needs to be included in the calculations.

DR. LANGMUIR: Yes, and remember Don, that the calculations that we will be doing over the next couple of years are for the purpose of developing our codes that we are going to be using for license application and they are not really meant for final conclusions during that time frame.

On the other hand there are going to be aspects of the findings that will help us to rethink our site characterization program, rethink where we want to put our emphasis and I think that is going to be very important.

DR. HOXIE: The point is to look at them as exploratory ones.

DR. LANGMUIR: Exactly.

CHAIRMAN NORTH: Before we go on, Don, I have a couple of comments of my own that I would like to add here.

DR. LANGMUIR: Okay.

CHAIRMAN NORTH: The first will pick up from this same issue. I am looking at the site characterization plan, 8.3.5.12 page 51 and this is on the subject of analysis of unsaturated flow systems. And I am going to read the sentence from the bottom of this page, and if necessary to reach the necessary confidence and travel time predictions, a two-dimensional model of a single layer will be developed. A three-dimensional or quasi-three-dimensional modeling approach would be developed only if the two-dimensional models are shown to be inadequate.

I think you have given us some feel for what the issues are here, air flow being one of them. But it seems to me that it would be useful to go further in the performance assessment documents to describe for this issue, how are you going to make the decision between two-dimensional is adequate or is three-dimensional or quasi-three-dimensional and what data do you need in order to make that call?

Now, I am going to go to a much larger issue for my second comment, which is from the previous page,

page 50 of the same section. And where it notes, the facility location could be changed if necessary to ensure adequate thickness of specific hydrogeologic units to provide high confidence of 1,000 year travel times.

Now, this to me suggests this is going to be one of the most important design decisions in the repository design process; where do you put it?

And I gave, at a previous meeting, my suggestion that I thought it would be useful to have contingency plans. It seems to me that it would be extremely useful to start looking at this, where do we put it decision in the context of the hydrogeology.

Again, what data do you need to make the decision and what assurance can you give us that the appropriate data is being developed so that you will have it in time to make that decision in a timely way.

My third comment, backing up one more page is the page 49, and this is to highlight the issue of Ghost Dance Fault and again, I will read a couple of sentences from the site characterization plan. For example, transport and flow characteristics of fractures near Ghost Dance Fault will be evaluated. Similarly, the likelihood for a lateral diversion of the flow in the transport of radio nucleids and contacts with the hydrogeologic units will be evaluated.

So you promised to do it. The question is, where is the data going to come from and where are you going to get it and how will it be used to support the decisions?

I would like to underscore the discussion we had at Las Vegas at our meeting on the importance of getting not just one intersection with Ghost Dance Fall but perhaps two or three from the drifts?

Similarly, are there other ways that you might get the data that you will need to go through this evaluation on Ghost Dance Fault, given that right now, you don't have a single bore hole in it?

DR. HOXIE: Well, it goes beyond that, because if we are going to do it from the drifts, we are only going to be seeing it in the Topopah Spring and we need to characterize it above the Topopah Spring as well and that is probably that we need a bore hole or two that would intersect at say, in the non-welded unit, that would be something I would like to see.

CHAIRMAN NORTH: Well, again, I think that there are some very important points for integration between performance assessment and the rest of the program.

MR. STEIN: I think that you are raising some very good points and I think it is important to the program that we address these areas that you have raised, just as we are in the process of addressing the questions that were raised at the last time that we met and, as you know, we have a rather significant activity underway to try to address those questions that were raised at the last meeting.

And in regard to some of the questions raised here, they go to specifics relative to our site characterization program. And one of the members of our team has been very diligently writing down some of the questions that you are asking on site characterization activities and we plan to discuss these with you in greater depth when you meet in Las Vegas next month.

So, none of the questions are disappearing into air; they are all being very carefully monitored and we are --

CHAIRMAN NORTH: Good. We look forward to that.

MR. STEIN: -- looking forward to getting back with you and talking about them more.

CHAIRMAN NORTH: Of course, the lady on my left, is also recording this, so that we will have that record.

MR. STEIN: That, of course, is double then.

MR. ALEXANDER: Okay, the next talk is much less controversial and it only deals with two of the performance objectives and so I have asked Abe Van Luik to try and cut it back to 30 minutes and I know that Abe can do it and he promises he can do it in 15, if I would like him to and I said, no, don't go that far, but so anyway, Abe is going to be talking about where we are and where we were with respect to the calculations in the environmental assessment?

And I want to underscore that, we are reviewing what we did in the environmental assessment and we are looking at uncertainties and data needs as we go into the future, with respect in this particular talk to waste package containment and waste package release rate.

Abe?

ENGINEERED BARRIER SYSTEM PERFORMANCE BY DR. ABE VAN LUIK

DR. VAN LUIK: Thank you.

And one of the reasons that I think my talk will stay on schedule or get ahead of schedule is because tomorrow there are two talks on the topic of waste package release modeling and those talks will get into the actual nitty gritty of the modeling. So what I would like to talk about is to describe for you the waste package engineered barrier system. Everything in this talk almost comes out of chapters 8359 and 83510 of the SEP so if you have read those, you are way ahead of me.

I would like to review what was done in the EEA and then show how the SEP program addresses some of the problems that were raised in the EEA. And if we can go to the next -- oh, here it is. I am sorry, I told you to do that and then I am confusing myself.

The definition that we are using for the purposes of this talk is the engineered barrier system is the waste packages in the underground facility and for the purposes of performance assessment at this time, the edge of the engineered barrier system is the edge of the excavation.

Now, it is important to note that the waste package is the primary barrier of the engineered barrier system. So that if it looks to me, if it looks to you like I am talking primarily about the waste package system, that is for that reason.

We can go to the next viewgraph.

(Next slide.)

DR. VAN LUIK: This is just a little drawing from the conceptual design report which is included in the SEP and was done for the SEP. And it shows the containers that are going to be used. This is the pour cannister here for glass waste, high-level waste. And this is the container that is going to be used for spent fuel.

The barrier for containment is this barrier right here, and the pour cannister is not considered whatsoever. The barrier for containment purposes is this barrier right here, the edge of the container. And this gives some of the configurations that are being looked at for putting the spent fuel into this package.

And you can see that the weight of one of these packages is anywhere from nearly 7,000 to nearly 14,000 pounds, a very hefty package.

Next please?

(Next slide.)

DR. VAN LUIK: The two replacement options being considered are vertical in this kind of a configuration where you are looking at the drift here, the little shield plug one cannister per hole and in the SEP you will find this drawing of a horizontal emplacement with eight dummy containers in the front and either 14 or 18 spent fuel or high-level waste containers in the back.

Now, since the SEP has come out there has been a lot of work trying to evaluate these two options and this is the favorite option, I think probably because of its simplicity. But if there is horizontal emplacement and now they are thinking of one dummy that is a shielding container and then maybe up to three high-level or spent fuel containers.

So this is in a state of change; things are being evaluated as we speak.

DR. CARTER: I wonder if you can give us some of the advantages or disadvantage of either vertical or horizontal?

DR. VAN LUIK: I can only do that from the -- this is a problem that is being addressed by the engineering side of the house.

DR. CARTER: Is it just a matter of simplicity in actually the emplacement process?

DR. VAN LUIK: I think -- is there anyone here that can help me out on that? Felton?

DR. BINGHAM: The principal advantage of the horizontal emplacement is probably that it requires a great deal less drifting because, in a long hole with a lot of containers, you would save a good deal of money on the drifting process.

It is also true that in a horizontal emplacement, especially the way that it is shown there with the dummy containers, the heat producing containers, themselves, are farther away from the drifts so that the drifts don't get as hot and it helps reduce the need for ventilation and the drifts as well.

I think those are the two principal advantages of the horizontal over the vertical.

DR. VAN LUIK: From a performance assessment point of view, for example in the EA calculation, the area across, the area exposed to the downward flux was an important consideration. And there is, of course, much more area exposed in this sense than there would be here.

If we can go to the next sets?

(Next slide.)

DR. VAN LUIK: You changed two slides at the same time.

I want to talk now about the environmental assessment performance evaluations.

This is the, in a nutshell, the environmental assessment performance evaluationl. All containers were assumed, as we will consider in just a moment, to fail at the same time, so that containment was not really calculated. Mass loss from the container was calculated as a function of the flux of water and this is the same flux that Dwight showed you a minute ago, just in different units.

The container area normal to the flux, if you take the 25 centimeters that I showed a minute ago, calculate the area, it is .33 meters, squared. Solubility limit of the waste matrix. This is a UO2 solubility limit in the ground-water of the site.

Multiply all of these together and you get on the order of 10 to the minus-6 and 10 to the minus-5 kilograms per year for waste package; divide by the total weight of the waste package, total mass and then you come out with a release rate of about 10 to the minus 9 per year, which is a number that appears in the SEP.

Now, this is a very simple bounding calculation. The flux of water, we have already heard from Dwight, is a bounding number and this number here, is very noncontroversial and anyone can take a slide rule, if you still know how to use one and figure this number out.

And this number here, plus a conservatively chosen value for the solubility of the UO2 matrix.

DR. LANGMUIR: Was that U02 in oxidized water?

DR. VAN LUIK: That is a good question. I think so, I don't think that --

DR. LANGMUIR: That was a maximum

DR. VAN LUIK: Yes, it was a maximum.

These were done in the laboratory and I don't think that any particular --

MR. ALEXANDER: What is the value done, off hand, you remember? I thought it was like 10 to the minus-6 or something like that, for in grams.

DR. LANGMUIR: In reduced?

MR. ALEXANDER: Yes.

DR. LANGMUIR: In a reduced ground-water, Don, it would be like 10 to the minue-6, but in an oxidized system, it is going to dissolve incongruently.

MR. ALEXANDER: Right.

DR. LANGMUIR: To something like uranial hydroxide or uranial carbon or something of that sort.

MR. ALEXANDER: Right.

DR. LANGMUIR: Which is much more soluable and comparable to the numbers given there. So that is presumably an oxidized --

DR. VAN LUIK: Yes, it is.

If we can go go the next viewgraph?

(Next slide.)

DR. VAN LUIK: The environmental assessments recognize the limitations and shortcomings of its own assessements and none of the things that I am telling you here are not contained in the environmental assessment.

The scenario was that no release occurs if no liquid water contacted the waste package and we have heard from Dwight that, of course, we need to consider gas fluxes.

A bounding flux was assumed to be effective over an area contacting each waste package and as I said, that is really a conservative assumption when you look at the physics of the situation. But it also points out that you need to look at the conceptual hydrologic models to find the flux and Dwight has covered this very well and the amount of liquid water that may contact any given waste package. It is not going to be this righ here.

And then I have already talked about the gaseous release so that we can go to the next one.

(Next slide.)

DR. VAN LUIK: Look at container degradation. A single failure time was used for all the containers and that was 3,000 years. And 3,000 years was an estimate based on experimental results of degradation rates of the one container metal, a stainless steel and one failure mode which was just general corrosion.

No other modes were observed, that is why there is no numbers for any of the others.

DR. LANGMUIR: Abe, has it been decided firmly that stainless steel will be the cannister of choice?

DR. VAN LUIK: No, sir.

One of the things that I will show in the later viewgraph is that there is a large program for deciding on a reference and an alternate metal and the results of that particular program are supposed to be, according to the SEP, done later this year.

DR. LANGMUIR: How does a 3,000-year life-time apply to the other materials that are still being considered?

DR. VAN LUIK: I really don't know the answer to that question, because the failure modes would be completely different. Some of these materials would not be susceptible to general corrosion so --

DR. LANGMUIR: And episodic corrosion or rupture is also a possibility for any of these materials.

DR. VAN LUIK: Yes, it would be, I think.

But in order to answer those kinds of questions, first we have to decide what the reference metal is going to be. And we need to define the environments in which these metals are going to be exist over the next, up to 1,000 years. We need to look at the degradation modes that are possible for those environments. And we need to define the degradation rates after we have decided what the modes are. And then, and only then, can we model containment failure times.

Next, please?

(Next slide.)

DR. VAN LUIK: When we look at the release rates, a concrude dissolution rate was used, which means that other release processes were neglected, such as any incongruities from the gap or rain bound and in the talks that you are going to hear tomorrow from Dr. Pigford and Dr. Apted, this particular aspect is going to be discussed in great detail to show you the equations that are going to be used for the different scenarios, etc.

We have already covered this one and there is some uncertainty. We assumed a continuous hydrologic pathway and I will show you in just a moment that that is a conservative assumption. And elevated temperature and radiation flux was neglected which we could do as an artefact of the 3,000 year containment time. But if you have early failures, of course, you cannot ignore that particular aspect of things.

So if we can go on to the next topic.

The EA, itself, recognized all of these shortcomings and said that we need a comprehensive program for adrressing each of these and the site characterization plan is our next subject.

It is going to address all of these needs. Now, the site characterization program, I will go by this real quick and you are going to hear from some speakers tomorrow to talk in more detail about this.

But the basic structure of the SEP is issues, information needs to answer these issues, and studies to provide information for the information needs, and of course, uncertainty analyses and sensitivity analyses. This is an editerative loop right here.

We can go to the next viewgraph.

(Next slide.)

DR. VAN LUIK: The site characterization plan, itself, if you look in 8359 and 83510 for the waste package system, it talks about a performance calculation hierarchy and could we put that hierarchy slide up on the second one?

(Next slide.)

DR. VAN LUIK: When you are given a large job, as any engineer will tell you, you try to cut it down into units that are manageable. And if you look at this level here, this is what we call a system level modeling and the next lower level is the subsystem level modeling or actually the submodels for waste form release, etc., that make up the waste package model and then below that, all of those boxes are called the process models.

And it is at the process level that the question that Dr. North asked a while ago, or right at the beginning, it is at that level that all of these models, if you look at water quality, water quantity, over there, gas release, all the things that define the environment that you are working in, that is specifically linked to laboratory and site's characterization in the SEP.

This diagram comes out of the SEP and in the SEP in each little box, and I have whited them out, because it was confusing, in each little box, it tells you what section to go to, to look for the actual plans for doing the work and providing the information for each of these little boxes.

So, this is a carefully thought out program and this calculation hierarchy is intimately linked at the process level to the site characterization plan. And what we contemplate is an interative process using data to first create a model; other data to test the model and uncertainty sensitivity analyses to define further data gathering prioritites. And the whole effort is focused on reduction of uncertainties over time.

CHAIRMAN NORTH: If I could make a comment, I really liked on 8.3.5.9 page 18, your discussion based on the Nuclear Energy Agency's workshop on uncertainty analysis in 1987, the seven steps for how you are going to do this?

I think what we would like to see is some detail as to how those steps are going to be implemented with specific emphasis on how data needs might be filled?

DR. VAN LUIK: That is being taken down as a request for future action.

The little green box on that particular thing shows -- I just want to pick a couple of things from this modeling hierarchy. The first thing is scenarios, which have a lot to do with what you are actually going to model.

The expected case is a dry case. It doesn't mean that there is no water present; it means that liquid water is not likely to contact the waste package and there are some good reasons for that. You have got unsaturated neo-filled rock, and you have got the likelihood that matrix flow predominates. Waste package temperatures exceeding ambiance by any significant degree will keep water moving away from the package. And you have a very important item here, an engineered air gap that breaks hydrologic continuity.

Now, an unexpected but credible case is the wet case where the air gap is filled or is liquid water dripping on to the waste package. And I will illustrate these with the next couple of viewgraphs.

Now, I have no idea how, but if a container is breached in the dry case, we expect carbon 14 to be released as C02, and if the cladding is there after breach, or some cladding is no doubt breached already, we would have gaseous radio nucleid releases. That is the no liquid water case.

And those are the things that would be modeled for that case. Now, if the site characterization plan, you can see a discussion of the wet and the dry case, and there is probably an expectation that some small fraction of the waste packages would be contacted by liquid water. There it is a very similar scenario except when the cladding is breached, besides having the gaseous releases, you would also have actinides and other soluable species released, at a rate consistent with the amount of water available and the solubility of those species.

If we can go to the next viewgraph?

(Next slide.)

DR. VAN LUIK: Here I want to show you what the air gap is all about. In the vertical emplacement, the cannister would be carefully emplaced so that there would be an air gap all the way around the container, and likewise on the horizontal emplacement, there would be air here.

Now, one of the questions that was raised a minute ago about the simplicity, if you look at this, it is very simple. It is an open hole, a support plate, and you drop in the cannister. Drop in, is a euphemism. But in the horizontal case, because you need to use a dolly to shove it back in, you have to have a seal liner, some grout underneath it, and it is a more complicated system to work.

So I am sure that is all part of the equation that is being used to work out whether one is better than the other.

DR. DEERE: Is the support plate the same material as the container?

DR. VAN LUIK: That I do not know. I would expect so, that would make a lot of sense, otherwise, you might set up some kind of a spaulding in the rock, the thing would self-destruct over time.

But I don't really know the answer to that question. And I have not looked into that.

Next, please?

(Next slide.)

DR. VAN LUIK: And when I said that there is a failed air gap scenario that might allow water to get to it, Dr. Pigford discusses these at length tomorrow and will show you the different types of formulas that might be used to calculate the releases from the scenarios.

Dripping water, no implications whatsoever for the vertical and horizontal. This could happen in either way. Dripping water, bringing liquid releases down and a compromised air gap might be from spaulding in the rock although that is not likely either. But over time, this can't be ruled out and so there is a different way that you would address this problem.

And I like I said, these will be discussed at length with Dr. Pigford tomorrow, unless he has taken all of his viewgraphs out in the meantime.

Talking very quickly about container degradation. There is a large program that is doing this: systematic laboratory testing. Like I said a minute ago, you have got to identify for each metal that you are going to work with degradation modes that are possible, phenomenology for those degradation modes, parametric dependencies -- otherwise you can't model it -- and hopefully, mechanisms.

The modeling that you do based on this information here, preliminary models -- and this is just the basic modeling approach you would use for any problem -- define tests for the models, consider alternates, because a lot of times two phenomena can be explained by two different paths and then compare predictions to experiments and refined models.

When you get past this, you go to the system modeling and you combine all your most specific models into one model for all modes, predict the behavior and the ranges of the expected repository conditions, and perform sensitivity and uncertainty analysis to see if you are done yet.

So in a nutshell this is a very lengthy description, a very short description of a lengthy part of the SEP and if we can go on to the next two viewgraphs?

(Next slide.)

DR. VAN LUIK: Waste form release. Luckily I am followed tomorrow by two very capable speakers talking on this subject and I will very quickly say that the release modeling that needs to be done is for both the liquid and the gaseous pathway release.

For the liquid release, the -- we seem to be going in the direction now of assuming that gap and drain boundary radio nucleid inventories are released very quickly. It is only a few percent of the total.

And then the releases from the matrix, I calculate as a function of all of these things and I won't read you this complete list. You can do that at your leisure, but each one of these things, of course, implies that you are going to get data to define these things for a number of conditions, etc.

So this is quite a comprehensive program of study. And if the ground-water flux is very low, diffusion, controlled envrionments, the list of things that you need to know is a little bit smaller, but still it is comprehensive.

And the probability is that we need to do both of these, not either or. And so if we can go to the next viewgraph and talk very quickly about gas pathway release modeling.

(Next slide.)

DR. VAN LUIK: It is also described in the SEP and here again is a list of things that you need to know in order to do the modeling for this. And the production life, for example, for carbon 14, and here is the bugaboo, you need to have a container filler rates and perhaps also a cladding degradation rates to get the gas productivity for carbon 14, so that this shows that you can't model releases without knowing something about container failure.

And for my last subject, I want to just quickly tell you something that I think you will find pretty obvious and that is that the system level modeling for the waste package or the engineered barrier systems, rolls up all of the things that I have just discussed. You have got to know your waste package environments. You have got to have submodels, these are the submodels shown here, that define that environment so that you can calculate the conditions.

And you have to know something about how container degradation works, given the conditions that you have calculated, so that you can predict failure rates, and when you project failure rates, you are answering the question raised by issue 1.4.

If we can go go the next viewgraph?

(Next slide.)

DR. VAN LUIK: The release rate modeling, you will hear a lot about tomorrow, and it gives you the answer to issue 1.5 and then there is the important aspect also of the total system performance -- total system performance, as you will find out from Felton Bingham, in just a few minutes, needs a source term. And not only that, but issue 1.1 needs to incorporate disruptive processes and event scenarios.

And, so, just because 10 CFR 60 does not require you to address disruptive processes and events for issue 1.4 and issue 1.5, doesn't mean that you don't need to know what the impacts of these processes and events are on the engineered barrier system.

You need, as Larry Rickertsen said a while ago, you need a simplified model especially if you are going to use it in a simulation mode, where you are going to make many thousands of runs. Your system model should not be a huge complicated thing that would take forever to crank through.

And then the source term is usually a time dependent concentration at the host rock, engineered barrier system interface. And that, in a nutshell, I did not quite make it in 15 minutes, but I tried.

MR. ALEXANDER: You have two more slides.

DR. VAN LUIK: Oh, I have two more slides.

Okay.

Another nutshell, the modeling hierarchy and this is the same thing I was saying a while ago -- system level, process level mechanistic and what I have given you is just a couple of EG's here. Pandora is a deterministic model being built by Livermore and AREST is a probabilistic model, at the system level being built at PNL and there is a whole host -- I could have put probably 50 or 60 in this thing here, but the idea is that you need to have some idea of what is in your waste package in terms of heat and radiation output also.

And you need to do heat and mass transfer calculations. You need to know your geochemistry and you need to know whether your rock is going to be stable. And these are the kinds of processes that feed either as data input, or as actual sub-routines to the system level model.

And then for the mechanistic modeling, we have talked about this at length -- you need to have container failure mode models, waste form degradation models at the mechanistic level of detail if possible. Now, it may not be possible. We may have to settle for semi-emphirical models, that are conservative in bounding.

DR. APTED: Dave?

DR. VAN LUIK: Sir?

DR. APTED: Just a slight acknowledgement really, both Pandora and AREST contain elements of both determinisitic and probabilistic modes. It is not either or really.

DR. VAN LUIK: Okay, that is from the author of AREST, so thank you.

What are we going to do in 1989 and 1990? We are already working on defining some problems for benchmarking as was mentioned a minute ago. And PNL did a preliminary analysis back in '88 and we have two other organizations trying to duplicate it. And Mik Apted, tomorrow, will talk about the recently completed comparison of the AREST versus the SIVAC vault model.

We are going to do ambitious things in sensitivity analysis to help guide the testing program. And, of course, model development is ongoing as you will hear tomorrow, there is a whole session on model developments.

And there is also a preliminary analysis of glass waste form performance going on which is a parallel effort to the spent fuel waste form performance effort of a couple of years ago.

So, this took me a whole half hour.

CHAIRMAN NORTH: You did pretty good.

DR. VAN LUIK: Thank you.

CHAIRMAN NORTH: I would like to emphasize again the importance of your second point there. The sensitivity and uncertainty analysis to help guide testing and I think it would help us if we could get an idea precisely what are your plans in this time period to develop those insights to guide testing?

DR. VAN LUIK: As far as I know, we are very much committed to this model. And, in fact, I should have put that one first, because all of these other things are secondary.

MR. ALEXANDER: Are there any other questions of Abe, before we let him get away?

(No response.)

MR. ALEXANDER: Okay, at this time, we are 20 minutes behind, and we have scheduled a break. Do you want to take a break?

CHAIRMAN NORTH: We need the break and let us try to hold it to 10 minutes and no more.

I would like to ask again, for members of the audience if you haven't signed the sign-in sheet, please sign the sign-in sheet.

(A brief recess was taken.)

MR. ALEXANDER: As everyone is moving back into their seats, let me just give Felton Bingham a little intro.

Felton is going to be talking to us about the total system performance assessment. And we planned this talk to follow the engineered barrier system talk and the site system talk, and it is in this effort that Felton will be describing that we bring it all together and he will touch on aspects of the talks presented by Abe Van Luik and by Dwight Hoxie showing how we are going to, or have, at least in the past, pulled together a total system analysis.

Felton?

POSTCLOSURE TOTAL SYSTEM PERFORMANCE ASSESSMENT

BY FELTON BINGHAM

DR. BINGHAM: Thank you, Dave.

It may not be obvious from this listing of scope just what it is that I am trying to do, so let me point out that what I would like this talk to do is to answer the kinds of questions that I have heard asked several times today.

And they are questions like these: what have you done so far? What is the status? In this case, what total system assessments have you done?

Then why aren't they adequate? What more needs to be done to them? Why don't they fill all the needs for a total system assessment? And then last, what are you doing about the need to make them more adequate?

Well, it is going to be easy to review the previous calculations because none of them makes any pretense of being a full total system assessment.

And, in fact, to answer what should go into a total system assessment, I think it is easiest to make a brief review of just what a total system assessment is.

Now, that is not intended to tell you things that you already know, but it will answer that question about what one is supposed to do. It will let you understand what the words I use mean because I have noticed in many exchanges of information like this, people falter over using words to mean different things. And we will also set the stage for the things that we need to do in the future.

Continuing on with what an assessment must do I am going to talk about the reliance that it makes on information that comes from other parts of the program. And then because there are several pieces that are peculiar to the total system assessment and not to much else in the program, that are very important, I would like to talk a little bit about each of them, pointing the way to a few examples of something that we can do with one total system model we have now.

And then last, to talk even more briefly about what happens in the future.

Bob, if you would like to leave that one on the other viewgraph, people can keep track of where we are.

(Next slide.)

DR. BINGHAM: In the past, there have been, I can think of three, total system assessments. There is an old one, the Sennin, Lan and Browning paper made in '84 and in the environmental assessment, there is one that goes by the name of Preliminary System Performance Analysis. That, of course, first was done around '84, and the final version is dated '86.

And then, one that you will hear a good deal more about when Paul Gnirk talks to you tomorrow, a postclosure analysis of nominated sites was done as a part of the comparative analysis of the sites, to pick one for site characterization.

Now, I don't intend to go through these because I think it will be more instructive to talk about what one is supposed to do, than rather what these small ones have done.

Each of them was, I think, adequate for what it had to do at the time, but none of them has the features built into it that are going to be required at licensing time. And I do want to show you one little result out of this one just to show you the kind of thing that they produced.

Abe Van Luik talked to you about some of the assumptions made about waste package in this one, and I would like to show you what comes out of the total system kind of modeling.

You can put that one up, Bob.

(Next slide.)

DR. BINGHAM: This is a simple little picture that says that it graphs cumulative releases from the repository, normalized properly according to the limits established by the EPA against time. And these are 10,000 year periods. So it shows that there is a potential for violating the EPA standards, if the calculations fall in that little shaded range up there. You notice that this is 10,000 years and this is EPA of a ratio one to the EPA limits.

The kinds of analyses that were done for the EA show that the calculations came out somewhere down here. Several orders of magnitude below the EPA limits and occurring much later in time than the regulatory period.

Now, this, of course, is a very simple calculation. And it made many assumptions that are going to have to be either justified or disproved by future work. But for the time, for the job that that kind of analysis had to do, it did its job.

So, let's go back to the beginning then. What is a total system performance assessment? What is it supposed to do?

At the risk of being very obvious, I am going to say that it is the process of evaluating the performance of the whole system then you do it because you need to meet requirements. I put up this simple thing because it gives me the chance of defining a couple of words. By performance, I am talking about the postclosure isolation of radioactivity. That makes it clear, even if it has not been in the title of the talk, that what I am talking about are postclosure phenomena.

And the system that I am going to talk about is the whole thing -- the site, itself, the repository and the engineered barriers within the repository. And the requirements that I am talking about are the regulatory standards for radio nucleid releases which I will probably call the EPA standard most of the time.

The next couple of viewgraphs expand on these two things.

(Next slide.)

DR. BINGHAM: Here is a picture of the system and you have seen slides like this a lot so that I won't need to say very much about them. On out there, there are TUFF's above and below the repository and the engineered barriers are within it.

And to remind you from what a number of other people have said that one of the principle phenomena that we are concerned with, is the movement of fluids through this rock.

Now, I am going to use the word fluid as another one of my definitions to mean both liquid and vapor.

And this is the standard. Now, this is a very schematic slide. And it is schematic in this picture and it is even schematic in this little bit of mathematics that is written over here. So let me explain it very briefly.

I think this is something that everyone is already familiar with. There is a boundary around the site that we have called the accessible environment that has received some discussion already.

If we can predict the rate at which radio nucleids will move across that boundry and I call that R dot over here, and we integrate that rate over the time from zero years after closure to 10,000 years after closure, we get a quantity that we can compare with some tables that appear in the regulation, that establish limits on the release of radio nucleids.

Now this is very schematic and it omits a lot of stuff. And this little phrase here, in fact, omits a lot of stuff. It is not just that this has to be less than that sum, there has to be a probabilistic comparison between this result and this sum.

That is why total system modeling is complex and there are at least two reasons why and the next couple of slides are going to talk about them. One is that the system, itself, is complex and the other is the way that the EPA recommended that people use for dealing with the problem that all of us in performance assessment have had for many years -- how do you handle the disruptive but presumably unlikely events that may occur in the future?

(Next slide.)

DR. BINGHAM: This slide is a little expansion on the reasons why the system, itself, is complex and it is a very simple thing, but it makes some points that I want to come back to again and again in the rest of the talk.

That there are really three components to assessing the total system. One of them is this fluid flow in the rock units because this is the way that radio nucleids are most likely to be moved.

One is the radio nucleid release from the engineered barrier system. Dwight talked about this and Abe talked about this, and these two things have to be combined with a few other concepts to predict the radio nucleid transport to the accessible environment.

And later in the talk, I want to talk about what total system assessment needs on each of these components.

Now, there is another reason that meeting the EPA standards is complex, and that has to do with how to handle a disturbed conditions? It is clear that each of those three components has somehow got a handle the behavior of the system under the conditions that you expect to happen there, as well as the disturbed conditions that are probably unlikely to happen there.

That dichotomy, that dual handling has to appear in each one of these components and that is the point that the artist is trying to make here with this double-sided arrow appearing in all of them.

And basically, these two, considering the both conditions must feed all of that information into this box up here which also must deal with both expected and disturbed conditions.

And that is the ultimate complexity -- go ahead, Bob.

(Next slide.)

DR. BINGHAM: -- with the EPA standard, because it asks that those scenarios, those hypothetical events and processes that may occur, be combined in some probabilistic way to estimate the performance of the system.

We expect, as the SEP explains in a lot of detail, to group those processes and events, that may occur in the future, into classes, scenario classes. Some of them may be expected conditions, and some of them may be disturbed; we expect to describe each of those classes, numerically, and then we expect to combine those using all three of these components of the assessment to produce this thing, called the cumulative complementary distribution function.

It has already been mentioned several times today and I will have some more to say about it a little later on if we don't run out of time too fast. But these are the two basic reasons that this is a complex job. The site, itself, is complex, it has at least these three components to it, and putting everything together is also a complex job that I don't believe there is complete agreement on just how to do.

There are still two more points to be made about total system assessments and what they must do. I think it has been obvious, especially from Abe's talks, just ahead of this one, that there is a kind of hierarchy of models, of methods that you can use to predict performance.

Abe's slide that he kept showing on the far screen over there, showed a lot of different kinds of models; some extremely complex. I don't remember the exact words, just which ones he called which on them, but there were models that modeled -- oh, let's see, degradation modes, in excruciating detail.

He also had on that slide though, some systems models that combined the information from the detailed ones to predict the behavior of the system. Now, it is a truism in a structure like this, that the parts on top must be simpler than the parts on the bottom.

And for total system assessment there are two reasons that that is so. One is, that you simply cannot include all of the codes that contribute to a system at one time. To put them altogether, they would run forever.

And that is even worse for a total system model which has to do that probabilistic estimate. To do a probabilistic calculation of a CCDF, probably requires that that system code be run thousands of times, over and over again, probably using Monte Carlo sampling for reasons that I will also mention a little later in the talk.

Now, it would be possible to couple, say, the Pandora code that appeared in Abe's, with one of the two-dimensional codes that Dwight Hoxie talked about, and run them together to be the first two bottom components of the total system. But if you run a code that takes two hours to run on a cray computer, with another that runs two hours on a cray computer, and couple them, they are going to take an awfully long time to run on the cray computer.

And if you have to run it 10 or 100,000 times, you have probably exhausted most of the resources available for computing. So that is the second reason that this total system models which tend to appear at the top of this pyramid have to be much simpler. They have to incorporate all of the relevant physical phenomena that occur, that are modeled below in the pyramid.

And the difficult part of total system assessment is being sure that those simple codes accurately mimic the complicated models that appear below it.

Now, having said all of this, mostly directed towards showing compliance with the EPA standard, I want to use this slide to point out that there are a number of other things that total system performance assessment is called upon to do.

These, I think, have already been alluded to, but I want to reinforce it, because my talk tomorrow has to do with one of them and I wouldn't want you to feel at sea when I get up and begin talking about it.

One thing that total system performance assessment must do is to help define the site characterization program. That, of course, is a process that is already under way. The performance allocation tables in the SEP are the most obvious place where that process appears.

The groups that do this have to evaluate the impact of the site characterization activities, themselves, on the integrity of the site. We have to be sure when we make the exploratory shafts, for example, that they don't somehow compromise the site and make it unsuitable for repository.

It is the total system performance that really must do that. This is another activity that is also under way.

Information from site characterization will have to be interpreted. I think that it has been pointed out several times this morning, there is this kind of feedback going on between the characterizers that supply the data and the modelers who must use it and interpret it. That, of course, doesn't start until we begin getting data from site characterization; that is a feature activity.

To evaluate alternative design configurations. An architect engineer cannot really be expected, when he comes up with a design, to do all the analyses to show whether or not they will comply or somehow compromise compliance with the EPA standards. That is another job for the total system performance assessments.

The long-term environmental impacts need to be predicted for the environmental impact statement. And then, last is the one that I have been talking about for most of the time since I have been up here, and that is, determining compliance with the EPA standard.

All of these are important things that have to be done.

All of these are things that a total system assessment must do. And I hope it is clear now, why the assessments that have appeared up until now, don't meet these standards; they don't do the probabilistic analyses that are going to be required; they don't do a number of other things that the next session of the talk will talk about.

A peculiar feature of total system modeling is that it relies very heavily on information from other parts of the program. And here is another one of the grade school kind of slides that does, after all, have a few important points to make on it.

To do a total system assessment, you really need to start with the concepts and the models that describe the system, and you have to develop some methods that use these to predict the performance of the system. And then you can apply those methods to determine compliance. That, of course, is obvious.

The point that I want to make from this slide, and reinforce is, that the total system performance assessment, itself, doesn't do all of this. It relies on other parts of the system to give it these concepts and these models. It must understand them, because the methods that it produces must use them and must use them correctly. But it is from the people like Dwight Hoxie and Abe Van Luik and Mik Apted and others who are talking here, in this seminar, that these ideas must come.

I want to make it clear that the poor people who call themselves total system performance assessors are not always experts on hydrology and metallurgy and geophysics and seismology and all of the other disciplines that it takes to come up with these concepts and models.

CHAIRMAN NORTH: I think that there is another point that might be made on this same chart. In some situations, we can check overall performance through monitoring. That is clearly not feasible given the time scales and spatial extent that we have here. Therefore, we are forced to model.

DR. BINGHAM: I couldn't agree more.

Now, I would like to talk to each of these components about the sort of thing that the total system performance assessment expects to get, needs to get. The first of these components is the one that I call fluid flow, and it is in the lower left hand corner of that simple set of three boxes.

Concepts and models that must be supplied. This is another picture of the repository and it shows liquids and gases and those of you with sharp eyes, will notice that it allows for the possibility that liquids and gases may possibly go in either direction. Dwight, I think, has already mentioned that possibility.

We need to know, though, the mechanisms for this flow and I am helped out a lot here, because Dwight has already talked about most of these things; the hydrologic properties of the rock, that is something that total system assessment would like to know.

It is of extreme importance to understand the differences and similarities between matrix and fracture flow; if the fracture flow occurs, under what circumstances does it occur?

What are the driving potentials? Gravity is an obvious one, and the heat from the repository may be another. And what are the things that make the fluids move? And finally, peculiarly gas flow characteristics that is an area that has not received a lot of attention until fairly recently.

But since, for reasons that Dwight explained, gas flow could turn out to be significant to us. The total system performance assessment folks are very interested in understanding those characteristics.

I think it has been clear and been pointed out by questions from the audience that what may be the overwhelming parameter of importance at the site is the flux in the unsaturated. And so for that, the total system performance would like to know what sort of climatic conditions are going to happen in the future? If they happen, how will they affect the infiltration near the surface and most important of all, how will they affect the percolation at the depth of the repository?

These are the things that generally speaking that the performance assessment would like to know about. Would like to have supplied to it. The bottom line only is that they would like to have velocity distributions for the fluids, and the saturation conditions in them. With those things, we can probably make a pretty good effort at predicting the performance of the whole system.

I am using this to define the word, velocity distribution, which is going to appear on another slide and I want to point out that none of the assessments that have been done so far, none of the three that were on that first slide, have had scientifically, thoroughly justifiable data to back up the assumptions it made about these important mechanisms and about the flux.

(Next slide.)

DR. BINGHAM: We also need some information from the engineered barrier system analysis. And here is a picture of a cannister sitting down in a hole and the idea is that there is some slow movement of water past it.

And we would like to know what the waste package life time is going to be. We would like to know what the local environment is going to be and we would like to know about the degradation modes and rates. These are things that Abe Van Luik just finished talking to you about.

But I think it is also clear that we don't want to have them in all the detail that Mr. Van Luik and Mr. Apted and their cohorts are going to supply, can supply us with. In terms of that pyramid of models that we had before, we will need a much simplified version. We will not be able to couple them together, all of those codes that Abe showed on the slide on that screen and make them run, we will have to simplify them.

We would like to know the radio nucleid release rate then in addition to knowing what is happening with those packages. And these are obvious things that one would like to know.

What we need to get then, from the engineered barrier system, are the temporal and spatial distributions of the radio nucleids as they are injected into the fluid flow. Another phrase is going to appear on another slide, source term distribution; a shorthand for all of that.

Now, for both these conditions and the ones on the preceding slide about the site, we need to know not only what the current conditions are, but how they will change in the future. How they will change, the changes that we expect to occur and the disruptive ones that we think are probably very unlikely.

The section of the SEP that deals with this total system issue has, I believe, at the last count, 16 reduced typed pages of tables, explaining in a great deal more detail just what parameters are needed to supply this kind of information.

The box at the top of these three components is the one that had to do with radionuclide transport. And given those velocity distributions and the source term distributions, what happens in this area is that they get combined with a few other things, like the effects of the repository, itself. Does it deform the rock? What are the seals do? Are the seals necessary and if they are, how are they going to perform?

How about the thermal effects that the site characterizers by themselves, who tend to do non-isothermal effects, having tended to do isothermal effects are not likely to calculate?

And then the transport phenomena, that as the radionuclides move with these fluids, there will undoubtedly be chemical retardation in some form. What form is appropriate? And given an appropriate form of an appropriate mathematical representation for radionuclide retardation, what value should be used for the parameters in it?

The coupling between the matrix and fractures can be of extreme importance to this business of transport. It has become clear that even if there is fracture flow, there may still be close coupling for the radionuclides between the matrix and the fractures. If the radionuclides spend a good deal of their time in the matrix, as they are transported by fractures, the transport times will be somewhat longer than you would guess from just looking at the invection times in the fracture.

The primary results then, though, are the radionuclides concentrations as a function time out of the accessible environment. And given that all the information has to be supplied both as a function of expected conditions and of future conditions, we will have this for all time, up to 10,000 years.

And I hope what that section makes clear is that there is a great deal required from the total performance assessment and that none of the performance assessments done so far have had anything like a full plate of information available. Mostly because the site characterization data has not yet become available, but also because the methods for doing total system performance have also been being developed. And this next section, part three of the talk, deals a little with what those, what some of those aspects of total system assessment, just for it, are.

The first one that I am going to talk about here is this one to say a little about the CCDF. It is my understanding that you are probably already familiar with the idea of the CCDF so I will kind of go through this quickly.

There is a performance measure for the overall system. If you add up the releases of all radionuclides, and divide it by the release limits that are set up, you can get this quantity called M and that is a performance measure.

We use that in a CCDF and I guess the next slide shows you one.

(Next slide.)

DR. BINGHAM: This is the hypothetical CCDF and they are expected to look something like this and plotted over here is the probability that that M, the system measure, exceeds little m, which are values, 1 and 10 established by the regulation. They are plotted here along the system.

But the regulations says then, that if the distribution function falls within this envelope defined by these steps, the site will be presumed to meet the regulations.

Now, there is a great deal that could be said about these, but I am going to assume that you have seen enough of them and heard enough of them to be fully comfortable with them and to be tired of hearing about them, in fact, so let's go on to the next slide.

(Next slide.)

DR. BINGHAM: One of the things that we tried to do in the SEP was to put that calculation of a CCDF on as rigorous a basis as we could. And appearing in the SEP is this expression for the CCDF, for the probability that the performance measure exceeds those EPA standards.

This turns out to be simply a large, well simply, simply a complex interval over a lot of variables, over all the variables of the system that are important to isolation. This could be the flux, it might be the porosity, the release rate, whatever.

And to use it requires that you have a joint probability distribution for all of those variables. And but if you throw this step function into it, in this way and integrate over everything, you will automatically generate the CCDF. Now, to me this is the useful formulation because it points up a couple of things.

One is that it shows the usefulness of Monte Carlo simulation. And those of you who are old enough to have been around at the time, probably remember that a Monte Carlo simulation was invented as a way of calculating large multi-dimensional integrals. And that makes it singularly appropriate and explains, to me, why Monte Carlo simulation has been a good thing to use in

CCDF.

Another thing that it shows is the complexity of the job. And there are an awful lot of variables that in principle could be integrated over. And the job of total system performance assessment is to cut back on that interval and, in fact, it can of course, be reduced as all intervals can to a sum of intervals and in our way of talking, in our language that we use, it can be reduced to a sum of intervals where the variables define those scenario classes that we talked about.

So if we can break up all the expected and future disruptive events that may occur at the site, into say, seven classes, we can reduce this interval to seven intervals, defining the variables over which the integration must be done, appropriately for each of those scenarios.

And now, the next slide is a little bit more about how a CCDF gets formed but you can take several models, chain them together and if you have a probability distribution function for each of the variables, you can compute that interval, come up with normalized releases and once you have that, it is easy to get a CCDF.

I think this is probably guilding the lily, so I am going to move on to the next thing up there that says scenario analysis, the second dot. I guess this slide says, scenario selection but we will talk about both.

(Next slide.)

DR. BINGHAM: Why are scenarios useful? The first point I want to make is the one that I just finished making with that long interval. That we can expand the CCDF in doing integration over. Another thing is that, that is useful about scenarios is that they are a short cut to deciding which of the state variables are going to have to be integrated over. And it is lots easier to think in terms of future events and processes than to think abstractly in terms of state variables and what they might contribute to releases.

So that kind of use is important to guiding site characterization, because for making up the SEP it forced everyone to look into the future to see what processes and events might be important and to come up with a characterization program that would supply the information needed about them.

It also, oddly enough, helps communication. The field workers who gather site characterization data tend, in general, not to be performance assessors and performance assessors tend, in general, not to be collectors of field data.

They have a common ground though, when they are talking about things that can happen in the future, like movement along faults or the currents in volcanoes, or increased rainfall. That is something, that is a common ground with which they can all talk. People who are given a headache by long intervals like that one, and people who are given headaches by trying to see how long a cyclometer will last when it is put underground, can talk together about things like those scenarios.

And well, so far the site characterization that has been done, and this is where we now stand, is the scenario selection is done in the SEP. And that was done just for the purposes of guiding site characterization. In making them up, the idea was let's make the scenarios exhaustive enough that they will help us obtain the data that we now think that we will need. They are an early step in the performance allocation, in the detailed listing of the data, the parameters that must be measured during site characterization.

All of this has an important implication that I want to point out because I think that we have seen misunderstanding about this point that the selection has done so far, that is the selection that is in the SEP, isn't necessarily the selection that will be in the license application, itself.

We expect to learn a lot during site characterization and among the things that we expect to learn are new scenarios, to learn some of our old ones are not a problem at all. We don't expect that what we have done so far is in any sense the end of this process.

I thought that it might be worth reviewing the principles that have gone into what we did so far. And the idea was to try to take into account all of the sufficiently credible ones and what I mean by sufficiently is generally, if the likelihood of a scenario category is less than about 10 to the fourth in 10,000 years, let's don't include it in the list.

And if we have some reason to think that a scenario category, even though we are not sure what its likelihood is, will not contribute significantly to a CCDF, we also tended to omit it and the SEP tries to explain why, not only why scenarios are chosen but why they were omitted.

We specifically included some scenarios initiated by human activities and there seems to be some question in the minds of the public whether we would or not, but we did.

CHAIRMAN NORTH: I would like to interrupt you for a comment. 8.3.5.13 page 23, extending on 24, on the site characterization plan says the following on those pages.

The scenarios and scenario classes associated with human activities are often highly speculative and often do not involve significant impacts on the variables important to waste isolation.

Therefore, the specification of highly speculative low-impact human activity-related scenarios and scenario classes, the development of methods to analyze these classes and the identification of data to support these analyses will not be allowed to dominate the testing program.

My comment is, that I am afraid that some people might have the wrong reaction to those words. You don't want to dismiss something too quickly that some people might feel is quite important. And it would seem to me that to the extent that you can document that the probability is clearly low, and the impact is, indeed, not significant, you have made your case. But when I read through this document and find references to page numbers of a document that I don't have, for where those explanations are found, I don't find that very persuasive.

And it seems to me, therefore, that as you go forward, you want to be very careful in terms of the way that these scenarios are documented and how you can justify bounding out all of those scenarios that you have decided not to take into the analysis.

End of short lecture.

DR. BINGHAM: Go ahead, you had something to say?

MR. ALEXANDER: We agree with that and if you look at the site characterization plan carefully, you will note that we have not excluded scenarios other than a very few which are clearly out of bounds and those are not in the arena of the human intrusion arena.

And so we have not taken a position on many of these yet, we are just saying that we don't want some of these low probability effects to dominate, or low consequence effects to dominate our site characterization effort, which needs to establish the suitability of the site unperturbed by human interference.

But we definitely need to document the human interference scenarios and the consequences from those scenarios.

CHAIRMAN NORTH: Yes, I don't dispute the insight that some of these scenarios may not be worth analyzing. I think you simply have to go even further to document carefully what the reasons are, why you can take them off the list.

MR. ALEXANDER: We have had that same comment I would say a little over a year ago with the NRC staff and we agree with that.

DR. BINGHAM: We didn't and we had some final material that we asked them to explain in more detail why some subscenarios were omitted, but the key consideration that we thought of as we made it, just happens to be the next bullet that is here. That we attempted always to be conservative. We wanted to make sure that if they were wrong, we still will collect all the data that we might need. We tried to make our mistakes, if any, on the side of asking for too much information rather than too little.

And I think the sentence that you quoted out of there was put in to try to assure people who would look at it and see perhaps an overzealous construction of human interference scenarios, that we did not intend to let them take over the entire budget, let's say for characterizing each site.

But your point is certainly well taken.

CHAIRMAN NORTH: My problem is that people could easily read words, like highly speculative, the wrong way as a value judgment and I don't think you intend that.

DR. BINGHAM: Of course, what we intend is the difficulty in predicting what human beings will be doing 10,000 years from now. I have not heard one of those predictions, I believe, yet.

CHAIRMAN NORTH: Paying taxes.

(Laughter.)

DR. BINGHAM: This is just an example of one of the series of scenarios that could occur. If the initiating event is a climate change, there are a lot of things that might happen. The climate change might increase the infiltration and then that might increase the flux down to the repository level. Another sequence that begins with climate change might be that the climate change, as it gets wetter, the water table rises above the Calico Hills unit and we have a shorter path down to that saturated zone.

The SEP has six sequences and this just shows that there are six of them. I put this up only as an example for someone who has not seen this already in the SEP and this is an example of what we might mean by a scenario -- a sequence of events initiated by some change in the future.

CHAIRMAN NORTH: The Ross Study would appear to be a very interesting document too, so that it would appear that a lot of the scenario discussions in the SEP were taken from the Ross Study, some of which you have decided not to agree with, that he took off the list, you have kept them back on.

I wonder if we could perhaps obtain copies of this document with, perhaps any commentary that you have put together on it, subsequently indicating which parts you plan to refine?

MR. ALEXANDER: We would be happy to do that.

DR. BINGHAM: Now, this is just a grouping of the scenario classes that we have put into the SEP. I don't believe that there is much point in dwelling on them, especially since the time is running so short. Let's just go on to the next one.

(Next slide.)

DR. BINGHAM: I wanted to give you a couple of examples of some modeling that has been done with one total system model that is available and this is a model that is called TOSPAC and it has two or three modules in it. One is a hydrologic module and this particular system code is able to model water movement through the unsaturated zone using Richard's equation that is here.

It takes all of these properties, these initial conditions and some boundary conditions. There is no point, I think, in going through all of this, except to show you that it does take a pretty full sweep of input conditions to try to calculate as rigorously as we can, how the water will flow and to give us the pressure head saturation and water velocities in the system.

That module, then, is coupled into the next module which is a transport module. This is simply a radionuclide conservation equation. If you had the time to pick your way through this, you would see that it has the invection terms, just the gradient of a potential here, radionuclide decay, in-growth and out-growth.

And then the signal over here happens to be a coupling whose form is at yet, very poorly defined between the matrix and the fracture.

To understand this term is one of the most important things about total system performance assessment.

At any rate, this particular code takes these two modules along with one that specifies the initial conditions, the radionuclide inventory and predict things. The hydrologic module alone can predict what is on the next slide.

(Next slide.)

DR. BINGHAM: This is a calculation of average water velocity in the rock units, the repository being in here. And it shows a fairly complex distribution of water velocities and with information like this, we can calculate, using the transport module, some releases to the accessible environment, or, in this case, releases to the water table and that is the next slide.

(Next slide.)

DR. BINGHAM: This shows as a function of distance above the water-table, there is the repository here, and of time, in the thousands of years, and concentrations at the water table, what the I-129 releases might look like. And as you would expect, it rises slowly over here in time and it looks like it is hardly appreciable because you are getting up somewhere around 10,000 or so years.

In this calculation, after 100,000 years, it has not reached the water-table yet. This is only a moderately retarded radionuclide.

Now, what is the significance of something like this? Well, the significance that I want to claim for it today is simply this, that it shows you that we have got a tool that can handle these things, when we get some good data on the hydrologic properties, -- even some good data on how the properties will change under future disruptive events.

We have a tool in place that we think solves a complex enough set of equations to be able to predict something. It does help give us the feeling that our initial guesses about how this repository might perform are still thought to be correct. There doesn't appear to be anything very startling or dangerous about that particular calculation.

But I would not want anyone to go away here today thinking of this as some sort of proof that this is a good site or a bad site or any sort of site at all. This is an example of the use of a tool.

CHAIRMAN NORTH: Clarification, this does not include a decay of this particular radio-isotope, does it?

DR. BINGHAM: Yes.

CHAIRMAN NORTH: The calculation does?

MR. ISAACS: The half-life is a half a million years.

DR. BINGHAM: But if it had been a short one, you would have seen it.

(Next slide.)

DR. BINGHAM: Well, here we are at the end. Future and current activities, the current and future activities. One thing that we intend to work on in the near future is the scenario selection. What is in the SEP now is where it stands. We want to begin, from the results that we have already recorded, of course, but we want to shift to getting up the selection of scenarios to be used in making the CCDF. To do that, as the years come by in the near future, we can make increased reliance on data. As the site characterization program produces data, we can use those to make the selection, to weed out scenarios, to add ones that perhaps we had not thought of before.

And in fact, the site characterization plan, has been designed in part, to help with the scenario selection, to help weed out scenarios and add new ones.

I think it is important to point out that the final selections about scenarios are always going to rest on judgment of some kind, but I want to make it crystal clear, that by that, I mean informed judgment.

I hope that no one will have the feeling that somehow the DOE will get a bunch of experts and have them sit around a table and draw cards out of a Tarot deck to decide what scenarios ought to be analyzed. The idea is that with increased reliance on data, and many sources of data, and many sources of judgment, and the use of formal procedures to control and document what is done in this selection, we can arrive at a selection of scenarios that will be defensible in terms of the data we have. We will be conservative enough to make sure that we are not overstepping our bounds in them and will be acceptable through the regulators and the public alike.

(Next slide.)

DR. BINGHAM: And last the few near term activities in the total system modeling. You have heard mentioned several times today the set of test problems to be worked. Some of those problems have to do with the total system and we will participate in that.

The total system model still needs more refining. Transport modeling, in particular, is a place where there needs to be some more advances. That term I am pointing to, the big sigma stuck out at the end of the equation that right now is just a symbol, needs to be understood much better.

The model, the particular model that I talked about needs to be modified with a lot more complex source terms to be put into it. The total system simulator, itself, is a model that will be even simpler than that TOSPAC code. In order to put all of these things together to achieve that final synthesis that appears at the top of that hierarchy, even that TOSPAC code is going to be probably too hard to use.

It goes into too much detail in solving those nonlinear equations for unsaturated flow. The total system simulator will be even simpler and the construction of that system is for the near future.

Codes need to be benchmarked, that has been mentioned already and a big effort in total systems assessment is going to be this. That as the exploratory shaft facility is designed, performance assessment for reasons that I explained way back on a slide a long time ago, will have to supply a great deal of support in determining whether those designs will allow the ESF to keep from compromising the site.

CHAIRMAN NORTH: One observation, I would urge you to consider adding to your near term activities, points from your last bullet on the preceding slide on the importance of judgment. And judgment controlled by formal procedures, you might want to test out some of those procedures and getting the judgment from many sources, it seems to me that you can't err by starting that process too early.

DR. BINGHAM: I did intend this slide to be the first set of bullets on the second slide, so, yes, these are things that we expect to begin working on, including this one.

CHAIRMAN NORTH: Yes, the selection of scenarios really is a critical aspect and I would urge you to go as far as fast as you can in terms of developing those scenarios, putting it out for a wide review, from all concerned parties and then as you learn more, both about the formal procedures, and about the judgments that are appropriate from the various experts, then iterate on the selection that you have got, at the same time that you are developing the models.

DR. BINGHAM: I think that is really what we intend to do.

I think that you will hear more on that from Charles Voss tomorrow.

CHAIRMAN NORTH: Good.

MR. ALEXANDER: Yes, there has been a lot of discussion between the NRC staff and our staff about the need to settle on the scenarios that we need to take forward into licensing.

Dave Michlewicz is our next speaker and Dave is going to be talking about a new area, preclosure risk assessment. In contrast to postclosure performance assessments, the preclosure area is one where we have a lot of experience. We are not dealing with a time frame that we were dealing with in the postclosure analyses and so I think Dave will give you a feeling that much of this is in hand and there are only a few areas where there are uncertainties left, as I mentioned this morning, the accident source term is one of those.

Dave?

PRECLOSURE SAFETY ASSESSMENT BY MR. DAVE MICHLEWICZ

MR. MICHLEWICZ: In addition to making sure that the repository does not pose undue risk to the public and the environment in the future, DOE is also responsible for making sure that the public and the repository workers are adequately protected during the operational period when the waste will be shipped to the repository and will be processed there and will be placed underground.

The analyses that are done to demonstrate that has been achieved are what we call preclosure performance assessment or preclosure safety assessment. It is making sure that the workers and the public are adequately protected and demonstrating that and that is what I will be talking about.

(Next slide.)

MR. MICHLEWICZ: I will briefly overview the NRC and DOE requirements applicable to preclosure safety. Describe results of assessments that have been performed to date. Describe what additional information we think we need and how we are getting that information.

The regulatory requirements applicable to the repository during the preclosure period are essentially the same as those for other nuclear facilities. The repository subject to the radiation protection standards in 10 CFR 20, and that is both for the workers and for the public and here I have shown the annual dose limits that apply to the workers and to the public. It is also subject to applicable DOE orders when they do not conflict with the NRC requirements and here is a DOE order that is under development that is analogous to the 10 CFR 20.

In addition to part 20, the repository is also subject to subpart A of 40 CFR 191 which contains generally applicable environmental standards.

That is for normal operation.

For accidents, the 10 CFR 60 does not contain any numerical criteria for accident dose limits and it does have a half rem criterion for identifying structured system and components for safety basically structured systems and components for safety are those which are required to prevent or mitigate an accident that could result in off-site dose of more than half a rem.

But it is not an actual criterion for the accident. And there is also a DOE order which addresses the accident and that has higher dose limit. DOE is in the process of developing a petition for rulemaking to amend part 60 specifically to include an accident dose guidelines in 10 CFR part 60.

DR. CARTER: Let me ask you a question about those last sets of numbers. There is obviously a tremendous difference between the draft DOE order and 10 CFR 60.2.

MR. MICHLEWICZ: Okay, the number of 60.2 is the threshhold for determining when something is important to safety. And it is not the limit for the accident, itself. It is not the limit for the effectiveness of the engineered safety features, for example.

Part 60 is silent on that. The number in the draft DOE order, the 25 rems is basically the old 10 CFR

100 number and the value that DOE does propose for the repository will be 5 rems, which is the same value that is currently in 10 CFR 72 for the MRS and independent spent fuel storage installations and that is used for fuel handling accidents at reactors.

So, DOE will propose a value that is lower than this.

DR. CARTER: I am just going to ask you the question, if you think that will apply?

MR. MICHLEWICZ: It is used for essentially essential operations. We are not going to propose 25 rem, we are going to propose 5 rems.

DR. CARTER: Well, what you are going to propose is different than this then?

MR. MICHLEWICZ: Right. This is just to illustrate what criteria there are. Obviously if part 60 were to contain a guideline of 5 rem, this will be more stringent than the current DOE.

DR. CARTER: Yes, those numbers look like they are about 25 years old.

MR. STEIN: Our requirements is to comply with the regulations of the Nuclear Regulatory Commission and if the DOE orders are less stringent than those requirements, then the NRC regulations apply.

DR. CARTER: I think you can almost guarantee tha.

MR. STEIN: You are right.

MR. MICHLEWICZ: Since the preclosure safety assessment of repositories similar to the safety assessment of other nuclear facilities, we know how to do that, do those assessments and many of them have been done. They have been done for various candidate repository designs and repository sites throughout the repository program and they have included the TUFF site, the Healik site and the salt, and various potential salt sites.

(Next slide.)

MR. MICHLEWICZ: Here are the results of some real results for safety assessment of routine operation for the Yucca Mountain sites, specifically you can see that -- well, because we are dealing primarily with sealed sources, that is, the spent fuel and the glass waste, the primary concern is from direct gamma radiation, which is amenable to control by shielding and primarily and this should be. The estimated collective dose of the workers is about 100-man rem, that should be and this is all based on a conceptual design. Just for comparison that is about 1/7 of what a fairly clean reactor runs in a year.

So the collective worker dose is not that great compared to reactors.

The public exposure under routine conditions would be due primarily from any gases and particular effulents that will be released just from the handling of the spent fuel, from any, releases from cladding breaches that are in the fuel or when it is shipped to the repository or that may be caused during and the handling and from any rod that is shaken loose from the spent fuel when it is handled in the repository.

The particulates are amenable to control by filtration and the doses are very low. Again, based on the conceptual design analysis. Both the individual doses and the collective doses are very low, and since the doses depend on the design, of course, the dose has to go through changes as the design evolves.

DR. CARTER: Let me ask you a question about the occupational collective dose. What did you say that number should be?

MR. MICHLEWICZ: 100-man rem.

DR. CARTER: 100-man rem, and how many people does that involve at the repository?

MR. MICHLEWICZ: I don't remember what the number is. It is on the order of, I think, 160 or 100.

DR. CARTER: Okay, so that is essentially a rem a person?

MR. MICHLEWICZ: Yes, most of the doses are under a rem.

Okay, let's talk about accidents now. There is a consideration of accidents is one of the most important factors in the design and licensing of nuclear facilities. So I will discuss them in a greater detail than with the routine operation.

Again, there have been many proposed designs in repositories and many accident analyses have been done. Various accident types have been considered, both external events, such as earthquakes, floods and tornadoes and as well as internal accidents due to internal equipment failures, such as hoist cage drops and fuel handling accidents, a crane drops. One particular accident, the hoist cage drop accident, which was very severe at the other site and modified at this site, because we don't have a hoist. We take the fuel down by a ramp.

DR. CARTER: Is your maximum credible accident above ground or underground?

MR. MICHLEWICZ: I will present that.

DR. PRICE: Let me ask you how you know that you have covered the potential accidents that you know what the population of accidents is?

MR. MICHLEWICZ: We don't. My point here is that many analyses have been done and by independent people and it is unlikely that, at least as far as external events are concerned, that significant accident initiators are being missed. Of course, for internal events, events depend on the design of the facility so that we are not in a position yet to say that we have identified all of the potential internal events. They will depend on what the facility looks like.

DR. PRICE: At this point though, do you have a systematic way of approaching potential accidents other than experience?

MR. MICHLEWICZ: We have work under way to develop a methodology for identifying and screening initiating events. And again, I discuss that in one of the next graphs.

(Next slide.)

MR. MICHLEWICZ: Okay, these are the results of the analysis that has been done to date. And basically all the analyses have shown that the consequences of accidents at the repository are less severe than consequences of accidents at reactors and this is due to the fact that we are handling fuel which has very little energy output. It has less decay heat, it has less radioactivity in it and most of it is short-lived fission products have decayed away. And there is less intrinsic energy available to disperse radioactive material so that you need some kind of an impact, something to hit the fuel, to break it open before you get a release of radioactivity.

So the mechanisms for generating the radioactivity release is different from that in reactors. These are the sources for nuclide releases, and gases, volatiles in particular, would be released from the gap in the spent fuel when the cladding is breached.

And if you have severe enough accident to pulverize the fuel some fuel powder, actually pulverized fuel could be released. For high-level waste we don't have any volatiles, organic gases because there is none in the flask and the only release would be the pulverization events or if we had a fire, which would again have had to be an external source of energy.

These are the radionuclides that are of concern and you can see that if you compare them to say radionuclides that are put in under reactor safety analyses, we are here concerned about the transuranics to a greater extent than plutonium if we reach them, but also the strontium 90, the refracturing elements which are the constituents of the fuel itself, and would be released if some of the fuel were pulverized, in addition to those volatiles and gasses which are in the cladding, or on the cladding.

(Next slide.)

MR. MICHLEWICZ: Specifically for Yucca Mountain site some analyses have been done. The facilities have been basically all of the conceptual repositories have been analyzed including the surface facilities and the underground facilities and even the exploratory shaft facility when it will be converted to be part of the repository. The analysis that was done was probabilistic risk assessment in that both the consequences and the probabilities were estimated and the analyses were directed primarily at identifying structured systems and components of safety, that is to see whether we exceed that half a rem criterion on that.

(Next slide.)

MR. MICHLEWICZ: These are just selected accidents. You can see that they all involve either a drop of the fuel or some kind of a collison which subjects the fuel or the waste to a mechanical impact.

And you can see the probabilities are quite low and the doses are quite low. They are all less than a half a rem except for this one particular scenario.

There is quite a bit of uncertainty both in the probabilities and in the doses and they were derived primarily on the basis of expert judgment rather than hard data since we don't have a final repository design.

And you can see some of that here, where the doses for these two different events are the same but that really reflects that the assumptions were the same by how much fuel would be released.

DR. CARTER: Well, I presume from looking at those that the release rate in those cases is quite small?

MR. MICHLEWICZ: Right, the release rate becomes significant in accidents when you start to pulverize the fuel. And here is an example of that. This is where most of the dose in this event is from the seizium and the other fission products that are released from the fuel cladding.

When you start you can release quite a bit of that and still have a small dose. When you start pulverizing the fuel, very little release will give you a high dose.

DR. PRICE: I would like to ask again, how you came about identifying the scenarios?

MR. MICHLEWICZ: This was done primarily by the facility designers where they looked at what operations are performed in each section of the facility and speculated as to what could go wrong? For example if a crane was picking up spent fuel and the natural thing would be that it could be dropped. So it was basically an actual facility operations as described in the conceptual design report and also on the basis of known site characteristics for the external events.

DR. PRICE: I guess I would like to see a more systematic approach to it than appears to be being identified at this point, and not necessarily dependent upon some later design stage. Systematically you can approach it deductively and inductively. You could have an undesired event, a false reading and come up with those kinds of things as you go down the levels of the fault tree that may call out certain of the scenarios.

You can have operations that occur as you are identifying here, but carefully going through each mode of operation and finding out its potential failures and consequences with task analysis and so forth and I don't think that you are at a stage of design that prevents this kind of an approach rather than what I seem to be hearing, that is, that you picked a few and people sat down and sort of rummaged around and came up with these?

MR. MICHLEWICZ: Well, I gave the wrong impression.

Evidentiary analysis was used as part of the accident development. The start was the initiating event and then you have the flood barriers are around the radioactivity. For example, the primary confinement of the hot cell and then whether the filter would fail and then you construct eventually. And that is how the probabilties were obtained. Detailed events and probabilities were developed for the various accidents. They were quantified. However, they were quantified primarily on the basis of expert judgment as opposed to hard data since we don't even know what some of the equipment will be. Whether the crane will be electric or hydraulic or what.

But we do have work in the area that you are suggesting. And we will get into that. Just to illustrate the fact that the accidents at the repository are a little different from those at the reactors. Here you see the critical ordinance for the more severe accidents in which the fuel is pulverized. And here you see the fact that when you pulverize fuel, you release the transuranics which are alpha emitters, and bone seekers so that the critical organ is the bone surface.

This is something that in reactor accidents the bone is not the critical organ.

(Next slide.)

MR. MICHLEWICZ: And --

DR. CARTER: You better be careful though in one of your earlier slides you talked about the consequences of release and you use the argument that this stuff had been aged and was sitting around and was completely different than the reactor. I really don't think that you meant that earlier. I think you were talking about the significance of the accident rather than the release mechanisms.

MR. MICHLEWICZ: Well, both, the radionuclide mixture is different. We --

DR. CARTER: You would have a lot of people that would argue that the consequences are greater if you pulverize fuel and release the transuranic rather than an inventory of fresh fuel.

MR. MICHLEWICZ: The point I was trying to make is that the mechanism for release, for access in the release is different. It is like a different animal.

(Next slide.)

MR. MICHLEWICZ: The next viewgraph just illustrates just a little further and shows you the principle contributors to the dose and you can see that they are the transuranics, the plutonium.

(Next slide.)

MR. MICHLEWICZ: To given the fact that we have done these analyses, why can't we write the SAR yet? Well, first, we don't have the SAR level design. And we need to design, we need the SAR design plan analyzed. We need site information, specifically you know, what are the -- of the site, and where the people are and what are the environmental pathways by which the radioactivity will reach the people?

(Next slide.)

MR. MICHLEWICZ: Because of the importance of the transuranics and pulverization phenomena, to the accident, we need to get a better handle on how much of the fuel will be pulverized, in a given accident? Should we work with the particle size and how the particulates would be transported throughout the repository before being released?

We also need to get a better handle on

identifying initiating events and developing accident scenarios and we are looking into some techniques that are employed in the chemical industry. One technique is the HAZOP technique and we are also looking at the use of some smart computer programs prologue as part of a program called identity relationship models and where you specify basically describe the design of the facility and the location of the various hazardous materials in it, and the computer sort of traces how one part of the repository will interface with the other.

What are the paths for release and will give you an insight on how both the initiating event, what initiating events will occur and how the accidents will progress.

We also need the information on the equipment failures. Most of the data that is available for safety analysis for probabilistic assessment is being developed for reactors and we are going to have quite different equipment and we need data on equipment failures for the repository.

And we also need some data on mining type accidents.

DR. PRICE: Let me just return and add to a comment I made a minute ago. You indicated that you had gone through a deductive kind of a process with some events and then gone into a potpurri and so forth, and you can go through a deductive process and still miss some scenarios that maybe you should be identifying.

And likewise, you could go through an inductive process through the operational side of things and miss some scenarios that you maybe should have identified and should have, that are foreseeable that you did not foresee.

I think that the only safeguard that you have got, at least in defense of the procedure that you put into action, is to do both and cross-check one against the other in a very systematic sort of a way. And that is the kind of systematic approach that I think builds the foundation for, at least you were able to foresee or tried to foresee that which was able to be foreseen.

MR. MICHLEWICZ: Okay, just to summarize, well, not to summarize, these are the activities which we are carrying out now. They are basically oriented at characterizing the accident source term, and identifying initiating events.

We are trying to define what is the bound of inventory of some of these transuranics, the spent fuel. If you look, the radionuclides that are used in these analyses are outputs of the origin program which is an isotope generation deficient code. And their best estimates of what is the concentration or specific activity of radionuclides in the spent fuel?

We want to know how much error does that introduce if we use those guides? That is how much more could there be for a given burnout of spent fuel? Is it a factor of two or three or is it a factor of ten?

Because the serious accidents that we postulate do depend on the transuranics so that we are trying to bound the uncertainty in that source term.

And also, evaluating the work that has been done as part of the casks certification program to certify the casks, the shipping casks, you have to make estimates, well, you have to analyze how the casks will respond to accidents, environments, including fires and impact. So the accidents that are being evaluated as a part of the cask certification program are analogous or similar to what we have concern about. They are somewhat ahead of us and we have a technical interchange with that program and we are taking a look to see what information they have that we can use. And we have a literature survey on particle transport phenomena.

And also we are doing a literature assessment of methodologies for identifying, screening initiating events.

DR. CARTER: Isn't the mixture waste spill subject to change as far as the proportion and the time sequence as far as high-level waste versus used fuel elements?

That is not fixed is it?

MR. MICHLEWICZ: It is not fixed, but it will probably have to analyze for accidents the worst case, you know, for spent fuel. Whatever the combination of the highest burnout and lowest decay time.

Just to conclude then, the repository requirements for preclosure are safety similar to other facilities. Here it is primarily a matter of applying a methodologies that have been developed for other facilities to the repository rather than developing new methodologies. And many of these analyses have been performed. The conceptual design of the Yucca Mountain repository has to be analyzed and we are working on the additional information that we need for the safety analysis report.

Thank you.

Any questions?

DR. CARTER: Let me ask you a question about the mixture of dose terms that you are using. Have you had any druthers, would you just as soon stick to the effective dose equivalent or use the origin doses? I notice now that you have got a combination of those.

MR. MICHLEWICZ: I would rather stick with the effective doses. The viewgraph that I presented was just to show the radiological characteristics of the source term, the fact that it does go to the bone. As a matter of fact, in the petition for rulemaking to amend part 60 of the specified dose guideline, DOE will recommend that the dose be expressed in terms of effective dose equivalent.

DR. CARTER: Yes, but some of your accident scenarios, you had a mixture of units, in some cases, you were talking about effective dose and the other you were talking about organ doses and other body formulations.

MR. MICHLEWICZ: Okay, in the beginning viewgraph where that was for routine operation. I assume that 10 CFR part 20 is going to be --

DR. CARTER: Conform to these then?

MR. MICHLEWICZ: Yes, it is going to be promulgating in a form similar to the draft.

DR. CARTER: Okay.

CHAIRMAN NORTH: I would like to raise one other issue which is the question of something, an accident which would not lead to a dose in excess of the limits but might lead to some very expensive clean-up. We have seen the situation with PCB's in Videnze, France, when a transformer catches fire at an office building. The problem is not the dose of the toxic material to the people in the building. You get them evacuated. The problem then is that you have got years before that building can be reoccuppied.

And I worry about an accident in this facility which will be a unique facility that might involve years and tremendous expense in cleaning it up and I wonder if an accident analysis has been done that addresses that kind of scenario? If not, I think it might be considered to the list.

MR. STEIN: Low probability/high consequences?

CHAIRMAN NORTH: Yes, not high consequence in terms of exceeding the allowable exposure, but in terms of the magnitude of the subsequent clean up in economic costs.

MR. MICHLEWICZ: Not specifically. These analyses were done primarily to identify what is important to safety in the repository.

CHAIRMAN NORTH: So I think that we have

identified a gap which seems to me important. The kind of accident, I mean look at Three Mile Island, and the costs involved there.

DR. PRICE: It is the existence of these potential gaps such as this that really concerns and prompts my comments about the way in which these things are identified.

MR. MICHLEWICZ: There is one analysis where that has been looked at, and it is a preliminary analysis of the risk posed by cipher units and it is a cost benefit analysis. And I am not sure that it has been finalized but we have begun to look at them where we are planning to use PRA, probabilistic risk assessment not just to evaluate the risk to the public but also as a design tool.

MR. ISAACS: The only point I would suggest we keep in mind. I think that these points are all well taken and need to be accommodated. It is important in things like this when you talk about these accidents not to lose sight of the compared to what and the compared to what in this case is a relatively benign environment compared to say, a nuclear reactor. There is no non-stacastic events that one dreams up like one dreams up in a reactor, for example, or dispersal for large quantities of material. We are talking about dropping a cask or a transporter having an accident.

And that is not that it is little, they are very serious and they have to be looked at and they have to be looked at consistently and I think your point is well taken.

CHAIRMAN NORTH: Let me give you an example. You have got plutonium dust into the ventilation system and I suspect it would be very hard to clean it out.

MR. ISAACS: There is no question that we have to evaluate those.

MR. ALEXANDER: That concludes the presentations for today and we are a little bit late, but a couple of remarks about tomorrow.

First of all we are scheduled to begin at 8:30 a.m. and I would recommend more that we try to get folks in here about 8:15 so that we can start promptly at 8:30 unless there is a problem with that.

CHAIRMAN NORTH: I think that is an excellent suggestion. Why don't we ask everybody to aim for 8:15 and we will start very promptly at 8:30.

MR. ALEXANDER: I appreciate that and I think that is a great idea.

I wanted to talk for a moment about tomorrow's focus as compared to that of today. And today we were trying to give everyone a general overview of the assessments that we need to conduct over the next several years, a direction that we are thinking about carrying the program, over those years.

And tomorrow the focus changes into considerable more detail in terms of some of the presentations that will be made.

Tomorrow morning early we are going to be talking about the interrelationships between the site characterizations program and performance assessment and much greater detail.

We are going to begin that by talking about model validation and I think that will be a very important discussion followed by this iterative nature of performance assessment and testing.

The second session has been discussed all day long, the recent applications, I think there are some very interesting talks tomorrow. I encourage you all to come for these talks. These recent application talks will review the assessments that were used in support of the site characterization plan and the assessments that were used in the comparative site analysis which I found to be very interesting myself as we put these talks together, and then the review of performance assessments to evaluate impacts of site characterization on long-term site performance which has been a hot subject in recent months.

And then finally, I think it is really important for you to understand how we are taking these physical or constituitive models and rolling them up into a subsystem model. I know that Felton touched on that today and tomorrow you are going to see more about how we collaborate to get that kind of job done and I think that you will be very interested in seeing that session as well.

So there is a lot more to come tomorrow and I think it will be very interesting for those of you that are interested in the subject. I hope to see most of you come back.

CHAIRMAN NORTH: Good, we will resume then sharp at 8:30 a.m.

(Whereupon, at 4:15 p.m., the hearing in the above-entitled matter was adjourned until May 17, 1989, at 8:30 a.m.)