ORIGINAL ACNWT-0081

OFFICIAL TRANSCRIPT OF PROCEEDINGS

Agency: Nuclear Regulatory Commission
Advisory Committee on Nuclear Waste

Title: Working Group on the NRC Staff
Performance Assessment Capabilities
in the Low-Level Waste Program

Docket No.

LOCATION: Bethesda, Maryland

DATE: Tuesday, March 22, 1994 PAGES: 1 - 312

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UNITED STATE NUCLEAR REGULATORY COMMISSION'S

ADVISORY COMMITTEE ON NUCLEAR WASTE

DATE: March 22, 1994

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UNITED STATES

NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON NUCLEAR WASTE

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WORKING GROUP ON THE NRC STAFF PERFORMANCE ASSESSMENT CAPABILITIES IN THE LOW-LEVEL WASTE PROGRAM

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Room P-110
7920 Norfolk Avenue
Bethesda, Maryland

Tuesday, March 22, 1994

The Committee met, pursuant to notice, before P. Pomeroy, Vice Chairman, at 8:30 a.m.

PARTICIPANTS:

M. Steindler, ACNW Chairman
P. Pomeroy, ACNW Vice Chairman
W. Hinze, ACNW Member
J. Garrick, ACNW Member
G. Gnugnoli, Designated Federal Official
R. Alvarado, State of Texas Low Level Waste Disposal Authority
S. Pennington, Texas Natural Resource Conservation Commission
J. Greeves, NRC/NMSS
J. Thoma, NRC/NMSS

P R O C E E D I N G S

[8:30 a.m.]

MR. POMEROY: The meeting will come to order. This is the working group meeting of the Advisory Committee on Nuclear Waste to review the NRC Staff's performance assessment and computer modeling capability in the low level waste program.

I am Paul Pomeroy, Vice Chairman of the ACNW and Co-Chairman of this working group session. The other Co-Chairman of this session is Dr. John Garrick, on my far left here. Dr. Garrick, in the future, will have primary responsibility for performance assessment matters for the ACNW in the future.

Other members of the ACNW present include Martin Steindler, Chairman of the ACNW, on my immediate left, and Professor William Hinze. As individuals assisting the working group today, we have with us Bob Budnitz, Scott Sinnock and John Starmer, all experts in various aspects of the fields that we're going to look at.

Our attention will be focused on the NRC staff's computer modeling and performance assessment capabilities in the low level waste disposal program. Evaluation is timely since the timeframes for bringing low level waste repositories on-line are, indeed, short relative to those in the high level waste program. It has been two years since the ACNW has had the opportunity to evaluate the low level waste performance assessment program.

Furthermore, guidance to the agreement states, compacts of states, and non-agreement states we hope is useful to those states in the implementation of their low level waste responsibilities. In our discussions, we must evaluate what the needs of those states are and whether or not the NRC has developed the appropriate capabilities to meet those needs in the performance assessment and computer modeling areas.

Today the working group will focus on the draft branch technical position on low level waste performance assessment. At the same time, however, the NRC clearly needs and has an internal capability, supplemented by contractors, to carry out performance assessments in the discharge of its regulatory and oversight functions.

Hopefully, our discussions today will elucidate not only the present capabilities in the areas of interest, but also determine what resources are needed in the years ahead. Our working group meeting is very informal. Most of you know that. I encourage pertinent questions from our experts and from our staff, as well as from the Committee members. We don't intend to limit discussion in any way.

At the same time, you can see from the agenda that you have in front of you that we have a large body of material to cover before the end of the day and I know everyone will cooperate in attempting at least to stay on schedule. I would also request that any of our invited experts participating in the working group today recuse themselves from participation in any portion of the meeting where the, feel that their opinions or advice would constitute a conflict with the generic goals and purposes of the meeting.

If we have time, a follow- p discussion will be held at the end of today's presentations. This follow-up will be in the form of a roundtable discussion where the working group members and experts will summarize their comments, observations and recommendations raised during the presentations.

Housekeeping items. This meeting is being conducted in accordance with the provisions of the Federal Advisory Committee Act. Georgio Gnugnoli, on my immediate right, will serve as the Designated Federal Official throughout the meeting. The rules for participation in this meeting have been announced as part of the notice of this meeting that has been published in the Federal Register.

We have received no written statements or requests to make oral statements from members of the public regarding this meeting. A transcript of portions of the meeting will be kept and it is requested that all speakers use one of the microphones, identify himself or herself, and speak with sufficient clarity and volume so that he or she can be heard.

Should any member of the public or any organization desire to make any comments relative to the subject of this meeting, please make your intentions known to Georgio Gnugnoli and we shall make every effort to fit you into the meeting schedule.

I would like to request our invited experts to prepare a short written summary of their overall impressions in this area and provide them to Georgio Gnugnoli of our staff. He will ensure that your thoughts will be factored into our deliberations on this subject.

I would also like to announce, for the benefit of the audience and the participants, that this Advisory Committee and our sister organization, the Advisory Committee on Reactor Safeguards, are all scheduled to move in the second week of June, June 13 through June 17. We are all reminded to keep an eye on the Federal Register because our meeting and other meetings like this may be in different places during the month of June, not necessarily here at the Phillips Building.

At this point, I would like to take the opportunity to ask whether any members of the ACNW have any comments.

[No response.]

MR. POMEROY: Any of our experts?

[No response.]

MR. POMEROY: Our staff?

[No response.]

MR. POMEROY: Fine. Hearing none, then I would like to especially welcome the representative of the State of Texas Low Level Waste Disposal Authority, the developer in this case, Ruben Alvarado, and Mr. Scott Pennington of the Texas Natural Resource Conservation Commission, the regulator, who have generously given of their time and effort to join us today in this working group.

Mr. Alvarado, who will speak first, will present the Authority's perspective and approach to low level waste performance assessment, as well as presenting comments and recommendations regarding the NRC's draft technical position on low level waste performance assessment.

Mr. Alvarado, the microphone is yours.

MR. ALVARADO: My name is Ruben Alvarado. I'm with the Texas Low Level Radioactive Waste Disposal Authority. I'd like to present just briefly our approach to performance assessment, which is what we've done now and actually have submitted to the licensing agency as part of our application.

Our approach was, first, to identify potentially important exposure pathways, to determine bounding pathways and scenarios, and to develop simple models for calculating releases from the disposal units, the environmental transport involved, and the resultant dose, and then to verify the level of conservatism by comparing the results from the simple models with the results that we would get from the use of more complex and comprehensive computer simulation models.

The use of the simple models, we believe, is consistent with the impacts analysis that was used when the rule was first promulgated, as well as the update to it. We do believe that it is consistent with the guidance that existed at the time we began. One of the things I will say is all of the models -- for those of you who picked up the handout material in the back, the complete assessment is in there and all of the equations are in there and I won't dwell on those very much, except to say that we ran everything.

They're straight-forward, analytical equations. If you can run a spreadsheet, you can run the code or you can run the models.

These are the exposure pathways of scenarios. After reviewing guidance that was provided in NUREG-1199 and in other places, these were really the top three normal release scenarios. We have leachate returning to the ground surface in the liquid phase, with direct exposure from soil and suspended soil particles, inhalation of trit' , carbon-14, suspended particles and injection along biotic pathways.

We have leachate going to the groundwater, captured by a site boundary well, and then the water being used for human and livestock ingestion and irrigation for a garden. Then we have the inhalation of radon and decomposition gases diffusing upwards in the gaseous phase through the disposal unit cover system.

We also looked at only one of the intruder scenarios, the intruder drilling, which we assumed that a driller would drill through a Class B/C disposal unit, bringing ion exchange resin mixed with drill cuttings to the ground surface, resulting in a direct gamma exposure from the mud pit.

I'll start out with some of the major assumptions that we used. Performance assessment, they're on assumed pathways for the facility, which we don't have yet. So all we know is what we have designed and we know quite a bit about the site itself. So everything we did is, of course, based on certain assumptions, including the inventory, although we have done the best we can to develop a reasonable and what we believe to be a reasonably accurate source term for the disposal site's operational life.

Site-specific characterization data plays a primary role in the development of the appropriate pathways for consideration. We are using concrete canisters in which we will place all of the waste. But rather than get into a lot of arguments regarding the durability of concrete and when they fail and how they fail, we just failed them totally at the end of a hundred years.

We presumed that at the end of institutional control, the canister degrades to its constituents and is no longer there. One of the underlying bases for doing this was that during institutional control, you are monitoring the site. Therefore, you should be able to detect something. If you had significant movement, you would hopefully pick it up during the institutional monitoring period and be able to do something about it.

After institutional monitoring, when you assume that the site is out there and nobody is really doing anything with it anymore, then we didn't want to depend on any type of manmade structure at all. The Class B/C waste form fails at 300 years. The waste form is supposed to be stable for roughly that period of time. So after that, we assume it's just waste in the ground, readily accessible for motion.

Then we just partitioned the radionuclides. We used Kd values for a human environment, some of the Savannah River stuff since they are some of the largest around and result in greater estimates of release. We used one set of pathways to evaluate the impacts due to all released radioactivity returning to the ground surface.

The groundwater pathway evaluates the impact of all released radioactivity being transported to groundwater, with the capture of contaminated groundwater by a site boundary well. However, we don't believe that there is a viable groundwater pathway at our site. We debated long and hard about whether or not we should even include one in the performance assessment or whether we should just make the statement we don't believe it can happen for the following reasons and be done with it.

We decided that for reasons really that were more political, we thought that the regulator would expect to see a groundwater pathway. We knew that the public expected to see a groundwater pathway because they certainly think that's what will happen to the waste. So we included one, but we just could not, in good faith, take it all down to the groundwater.

So we made an arbitrary assumption. We said, okay, one-fourth of it goes down and three-fourths of it goes up. That is an arbitrary number. In fact, in talking with the regulator, we will probably run scenarios that have all of the waste being transported to the surface and all of the waste being transported to the groundwater.

But this is what we did trying to show people we didn't think it was very realistic. Then the last one, again, we keep looking at that one intruder driller scenario for inadvertent intruders.

We did use quite a bit of different codes in the performance assessment. The actual assessment itself is done using analytical equations solved on a spreadsheet. But as I said before, we then wanted to go back and check the conservatism of our results by using other codes. So this is a list of some we actually did use. We used the HELP model for calculation of infiltration through disposal units. We used this primarily because it's been out there for a while. It's something that many of the regulators are used to seeing. It is what is done conventionally in all other types of waste disposal activities. So people have a comfort level when you talk about analyzing infiltration through the covers using the HELP model.

We used CREAMS to look at some of the answers. VS2DT we used in conjunction with breached leach and transport. BLT, as it's written, I think uses FEMWATER to get your input to the leaching part. We got FEMWATER up and running and could solve the problem exactly as Brookhaven did, but we couldn't get it anywhere near the convergence using our actual field data. It's something we talked with both Brookhaven and the NRC staff about.

We finally just gave up on using FEMWATER and went to VS2DT, which is another USGS code, and modified its output so that we could go ahead and use breached leach and transport. We also looked at DUST for an analysis of the source term. We used the GENII code for different release scenarios. This one you have to be a little bit careful with in that it was developed at Hanford and you really do need to go and look at each and every one of the subroutines and see which one of those hardwired inputs need to be converted to a variable format. If you're going to use it, you need to make sure it's somewhat representative of your site and not the Hanford reservation.

Then some of the other codes we used. MICROSHIELD was used. These are accident scenario things. GCUBE was also -- we used that as a sky shine accident scenario code. EXCEL is what we actually used on either PC or a McIntosh machine to run it.

As an example of what we did, and this will be the only time I actually put this, the leachate -- this is the source term modeling and we're using carbon-14 here as our example. The leachate flux from the disposal units is just modified -- is calculated using that equation. Most of these things are pretty straightforward. This little thing here, F of L, right here, this is kind of a funky little parameter. If you read IMPACTS, this talks about the waste contact fraction and the amount of time that water would realistically be in contact with the waste and how much of the waste can really be exposed to water.

It's a relatively low parameter, but it's reasonable, when you think about it, that in an unsaturated situation, you wouldn't have the waste constantly exposed to water, nor would you have all of the waste exposed to water at one time. Only the surface can be exposed for either mechanical rinsing of radionuclides or putting something into solution.

But I think this shows what we meant by checking the conservatism of our model. For carbon-14, we estimated a carbon-14 release at roughly 4E-to-the-minus-four curies per year. If we used DUST and INPUT, we'd get about an order of magnitude lower release, 4E-to-the-minus-five. When we went to BLT, it's even lower than that. It's now 2E-to-the-minus-six.

So then we can go back and we can make -- from here, you have to make some choices. You can sit there and go, well, if we like the answer we have and we feel it's real conservative, we just leave it alone, or we can go, well, maybe we've been too conservative, maybe we ought to go and drop some of those parameters and take advantage of what appears to be at least an order of magnitude reduction in the amount of carbon-14 that we can assume being released from the facility.

This is the type of thing we did with all of the models throughout the course of the assessment, was run things in a real straightforward, brute force, if you will, manner, but then go ahead and use some of the other codes that are available and then look at the answer and decide, well, should we leave it alone or should we take advantage of what appears to be some reductions we can take. It all really depends on what kind of numbers you'd like to present in your performance assessment.

We looked at a number of other codes and didn't really end up using them very much. But over the years, we did look at things like air AIRDOS, the CRRIS codes. FEMWATER, as I said, we had some real problems with. We also used INGDOS for some early on work and really didn't use it much in the final assessment. We also looked at things like PATHRAE, EPA, PRESTOEPA, and PRESTOPOP, the whole suite of PRESTO codes that were developed.

That's basically our approach to performance assessment. I didn't put the results up. They're in the report back there. Our highest projected dose is like about two millirem per year from the inhalation of radon at about a thousand years post-closure when it diffuses back up to the surface as the daughter of the radium we're going to get.

Radium is one of the numbers that we actually have some problems with in our source term, the estimates. We're going back now and have written to every licensee in the State of Texas who is licensed to possess and use radon. What we're finding out is a lot of people have it on their license, no longer possess any, have no intent to possess or to use it. We're really trying to get a much better handle on how much radium we will take into the facility over the life of the site.

Right now it's up to about 85 or 90 curies over the life of the site. If we can get that down some, we'll be a little bit happier. We're also looking at the way we ran the model right now. Once it gets to the surface and starts coming off as a gas, we use a real simple mixing box model with real conservative dimensions for the height and the width of the box, using actual wind speeds that we collected at the site.

It's obvious that if we make the box bigger, we can get it diluted down and reduce the dose, but you don't want to do that just in an arbitrary manner. But we really are looking at that number.

Doses to things like the groundwater or through the biotic pathway are all on the order of like ten-to-the-minus-two millirem per year. They are, for all intents and purposes, zero.

That was our approach; to be as simple as we could be, to try and explain things to people in a manner which we hope that even the general public can get a feel for, without trying to explain to them how finite differences in finite elements models were -- a lot of people, even in a rural community, have their own little PC at home, most ranchers and farmers do, to keep their books and keep their records and so they're all familiar with the spreadsheet. If you can explain to them that we did this on the same kind of spreadsheet you keep your accounts on, it's a little bit easier for them to grasp the concept.

I didn't intend to speak very long because I knew Scott has some things to so. If anybody has any questions, I'd be happy to answer them.

MR. POMEROY: Thank you, Mr. Alvarado. Are there questions from the members?

MR. STEINDLER: Yes. You have a table of inventories that you used for your calculations. Would you intend to have that inventory list represent a limit for the actual facility?

MR. ALVARADO: No, we didn't. What we did was we took what people told us they had disposed of over time and we looked for a base year. In the case of our current source term report, the base year is 1992; what did you ship in 1992. In your opinion, looking back at your own data --

and we also have other reports we've done over the last ten years -- how representative is that? 1992 was a big year. You had a lot of people cleaning house.

So you can get some kind of skewed numbers if you're not careful. Then we have to ask the question -- for the reactor people, we have relatively young plants. So you have to look at how they'll perform over time. But they have a bigger database. They can go back and look at other plants of similar size and similar design and kind of give us a feel for what they're going to do over time.

The real uncertainty comes in the institutional section, primarily in research. We don't know what researchers are going to do over time. A lot of that depends on funding and the course of their research and what's going on, where that leads them. We do know industrial uses have fallen off considerably in Texas over the last ten years, but we do still have a number of source manufacturers and they continue to work and expect to continue working.

One of the uncertainties, of course, is somebody could move to Texas who would generate a lot of waste and you can't really estimate that. So those numbers in the table were actually what we thought would happen. They don't have anything to do with what we might project.

Although when we look back, and radium being one, again, if we look at the number, it's real, if you want to call it real. It's between one and two millirem per year. We decide, well, we don't necessarily like that number. We wish it were lower, but if we can't find any real reason to make it come out that way, then we might, in fact, want to use that and back out an inventory cap for the facility.

Actually, since we assume that the radium was distributed throughout the site, as a practical matter, I think we will then limit the amount of radium that would go into any one disposal unit. So that at the time we closed it, we would be more comfortable that the radium was, in fact, diffused across the entire area of the site.

So we will do that sort of thing, but those numbers hopefully are -- well, they're real in terms of being based on our estimates rather than as a limit.

MR. STEINDLER: Thank you.

MR. GARRICK: I agree with the general approach of making the model as simple as you can and doing the calculations that need to be done at this point rather than doing those that may not be important. But having gone through this process and having been closer to the assumptions you've made and the data that you've used and anybody else, do you have any sense or can you share with us at all what your estimate is of the uncertainties or something about the uncertainties? What are the soft spots in the analysis?

Is this two millirem number plus or minus a factor of ten in the 90 percent confidence interval? What can you say about the uncertainties?

MR. ALVARADO: I don't believe it at all. I say that in that we're talking about infiltration through the cover system on the order of one millimeter per year. I just don't really believe that one millimeter per year is going to put anything in solution, going to make anything happen. But then, again, for the radium, it doesn't matter. The radium is going to decay to radon and it's going to move as a gas.

Then you get into things about, well, how much do we really -- we have some numbers for diffusion. They're all referencable and they're sound, but is that really true? The other thing is just how is the diffusion going to occur. We did it real simple. We took the area of the trench cap, summed it all up, and said that's the area that represents the surface area through which the gas will come back up.

That's probably not true. It's going to go to the sides. It's going to move in some circuitous paths back up toward the surface. So you'll probably have a larger volume involved. If I were to say, I would think that the two millirem really is to the high side of the limit of the real number. For the other radionuclides that we looked at, things like carbon-14 and tritium moving as a gas, I've never really felt comfortable with the fact that that's going to happen.

I know we looked -- because we had to assume -- because there's no water. Not only that, a lot of that comes out of BIOWAST. You've got the animal carcasses, but I know how they pack those things. They pack them in a line. So they jack the pH up close to ten. So now you've got a situation which is at least bacterial static, if not bacteria sidle. So how are you going to get the decomposition to occur to put these things into gaseous form to begin with? If it does happen, it's going to be a real, real slow rate.

What we did to estimate these kinds of things was looked at a lot of research that's been done in, say, conventional landfills, where you can actually -- they have numbers. You can relate grams of biomass to liters of CO2 generated or CH4 generated, but they're in situations where you really have a much wetter situation. You have an environment much more conducive to biodegradation.

I just don't believe that's going to happen. So I think that in being conservative, particularly in being conservative in the amount of the source term that's going to leach out, I think our numbers really do -- are to the high side. What the confidence level is, I don't know.

I would say that, in general, I think people put more significant figures in the answer that the data we have available allows us to do in good conscience. I see a lot of things out seven or eight significant digits and I know that the inputs are good to one, maybe two. They taught me a long time ago that I shouldn't do those sorts of things, but we're in the habit of doing them now.

In all honesty, it doesn't bother me to stand up and tell people that, in my opinion, the dose through most of the pathways is really zero. We have something we have calculated, but I don't believe we will ever see it.

MR. HINZE: Did your performance assessment lead you to make any further investigations going after more data, anything in terms of site characterization? Did you have any iteration as part of your performance assessment?

MR. ALVARADO: I think what it did, particularly on the infiltration work, it led us -- in an arid environment, what you really get is you're trying to cut off the water from the waste. So you're cutting the legs off the motion. But you just can't say that. You have to prove it. So we have spent, I think, a lot of time and effort in our characterization work trying to analyze the hydrology of the unsaturated zone, and that has driven us to do a lot of different things.

Trying to get at natural infiltration in the system, we looked at soil tritium and carbon-14 data, if we could do some things. We looked at chlorine-36. We've done a lot of things like that trying to get a feel for what's actually gone on over time, as well as taking physical measurements with sichrometers and that sort of thing, trying to get a handle on that sort of thing.

But they compliment each other. You can't do the performance assessment in a total vacuum. You can set up the models. These models are real straight forward and you can make some assumptions, particularly, if you want to be real crude or if you want to do what we've done, just assume a plug for the model. Once you have an estimate for porosity and an estimate for infiltration, that's all you need. If you know something about natural water content, you can go from there.

But we've done a lot, I think, to support the conservatism that we've taken.

MR. HINZE: Did your measurement in terms of the site characterization cover a period that might be included in what might be wetter years and the years in which there is more precipitation in that area? Certainly, there are variabilities.

MR. ALVARADO: We continue to run a number of the experiments that we set up. In fact, the year of record that we analyzed for the meteorological data was a below normal year. We only got about eight inches of rainfall during the period of time that we analyzed, which is about 65 percent of the 30-year average. So it was a below normal year.

But we did the same sort of thing at a previous site and we've now -- and we never shut down running the -- or continuing to take the data off the sichrometers. At Hancock, which is about 35 miles away, which is, in the overall size of the Texas desert, a next-door kind of thing. So we keep collecting the data from those two sichrometer nets we have over there. We've got about a four-year period of record now on one and about a three-year period on another.

We were fortunate in that we did catch a wet year. Particularly, we caught a wet winter, which is unusual. Most of the rainfall in the area comes in thundershowers in the summer. But we actually -- the winter, I guess, of 1990-91 was not particularly cool, but it was above average rainfall and the like.

So we can look at that and we can look at what we've done now. We're continuing to collect data at the site. We just didn't shut down and move away. We continue to operate the sichrometers. We continue to operate the MET station. We continue to take air samples. We continue to go in and run the neutron probe down the access tubes on a regular basis just to see what kind of a profile we get.

We will continue to do a lot of that stuff throughout outside operation. I think the real key will be when the day comes that we get this thing open and we operate and somewhere down the line my predecessors come in and decide that they want to close this thing and they apply to terminate their license. Now you have a 25 or 30-year record. Then you can sit down and go, well, this is what said back then and this is what we know now. I think hopefully everything will be fairly close. In fact, you'll have a much better period.

MR. HINZE: Going back to John Garrick's soft spots, do you -- as you were performing the assessment, did you have any feeling that you needed a better code in a particular area, that there was a -- don't smile -- that there was a soft spot in any of the codes that you were using? You mentioned one. Where was the weakest link?

MR. ALVARADO: We adopted this simplistic approach real early on. So we never thought there was need for more complex code.

MR. HINZE: Even a simple code is sometimes --

MR. ALVARADO: The only trouble is if you can tell me how to go to the site and measure KU directly instead of backing into it from four different ways, then I would say that, yes, there's something I really need. But other than that -- I mean, that's been one of our problems forever. We have real data from the site, real soil moisture data, and there's not a code available to us that will close and converge if we plug in the real data we get in the field.

Dr. Scanlon, who has done a lot of work for us in the unsaturated zone, Ed O'Donnell back there knows her fairly well, she actually developed a little code that will solve what we see, but it's real time. If you want a ten-year simulation, you turn the machine on and you run it for ten years. It does seem to fit the data quite well, but it's totally useless.

So in our case, if you could really model the unsaturated zone in the way we have it, it might be helpful. But on the other hand, I don't see anything -- I don't see any crying need in my case. If I were more dependent on my manmade structures, I might really want to know a little bit more about how the concrete degrades and how it fails. But since I don't really care too much about that and I don't worry that much about it, either the site does it or the site doesn't do it, the manmade stuff is so short-lived in comparison to the nuclides I'm really worried about. It makes no difference to me how the material stuff functions.

MR. HINZE: A final question, if I might, Dr. Pomeroy. You speak about this monitoring for the first hundred years. How was that envisioned at the Texas site?

How was that going to be done?

MR. ALVARADO: You mean for the post-closure monitoring?

MR. HINZE: Yes.

MR. ALVARADO: What we have done -- and we did it primarily for doing some economic analyses and trying to figure out how to fund -- how much money to put in the post-closure fund, we assumed that for some relatively short period of time after we closed, that the environmental monitoring program would be up, would be operated much as it was during site operations.

That is, say, for the first five to ten years after you close, you would take the same type and quantity of samples that you did throughout the operational life of the facility. At that point, you would then go back and look and make an analysis and use some judgment and decide whether or not you thought that was still prudent and necessary. If it wasn't, you could take that down to, say, 75 percent of the number, of the quantity, and run that out through the next 25 years.

By the time you get to the last 50 years or so, you might be reduced to just a quarterly monitoring kind of thing. But all that's going to depend on what you really see. If you don't see anything, if you don't collect anything in your sumps at the bottom of the trenches, if you don't see anything moving, say we use -- and there are some things we still haven't quite figured out how we're going to do.

But say we put in some relatively deep neutron probe access tubes, down to, say, 30 or 40 meters. If we look at these over 30 or 40 years and we don't see any pulses, we don't see any moisture migrating down, I think that tells us that maybe we can -- and we look at the rainfall record and we go, well, we've had good years, we've had bad years, it's about the long-term average, I think we can back off a little bit.

But the idea is that as you go farther and farther into the institutional control period, hopefully, by looking at the data you've collected, you'll be able to reduce the amount of monitoring that's required.

MR. HINZE: Thank you very much.

MR. GARRICK: Do you believe that the intrusion scenario that you considered represents an upper bound to any episodic event that you may not have considered?

MR. ALVARADO: Yes, we do. We looked at a lot of different intruder scenarios and we decided we would run this. The result of dose was relatively small. But in this part of the country, you can't survive without a well. So if anybody at the end of post-closure purchases this property and builds a house, they will drill a well. They have to. It's the only way you're going to get any to water your house with.

So it is a -- and assuming the guy uses a reverse rotary rig, he will put cuttings in a mud pit and stand there -- if he drills a thousand foot well, he's going to be over the hole a while. So he's going to be standing there being exposed to anything he brings up.

We laugh, on the other hand, if he brings an air rig in here and just starts spewing this stuff out all over the surface. It will happen a lot quicker and we don't exactly know what's going to happen. It's just one of those assumptions we made, but we do think it's an upper bound.

A lot of the intruder scenarios, because of the isolation, the fact is people don't grow vegetable gardens out in this part of the country. There's not a milk cow in the entire county. The only cows are there because they've got a calf to take care of and that's what you're in the business of producing.

So it's not that kind of place. There's a lot of scenarios involved with human habitation that don't really fit when you look at the character of the area.

MR. POMEROY: Could I ask you one question? Can you comment at all on how your interactions with the NRC went during the course of this thing? Did you get what you needed from the NRC and how did that all work?

MR. ALVARADO: Yes, I did. I thought, on the whole, the NRC has been real helpful to us within the bounds that they can. You have to understand that although I work for a state agency, I am not the agreement states person. So there are things that they have to treat me like they would treat any other private company that was in the business of developing a facility.

But I always thought that if I called -- I know early on when John Starmer was still with the Commission, we had a number of conversations about characterization and the resultant performance assessment that I thought were real valuable and really useful. I think we've gotten a lot of information out of the Research group that's been real helpful.

So I think on the whole, they've done what the regulator can do. I was a regulator once upon a time in another life and so I realize there's a limit to what you can say to somebody who will be part of the regulated community. You obviously can't say if you do this, it is fine. You can only offer up a suite of options, if you will, that appear to be acceptable; if you do it kind of this way, we think it will be all right.

Well, that's about the best you can expect to get from a regulator. You can't prejudge the situation. It wouldn't be ethical.

MR. POMEROY: Thank you. Bob?

MR. BUDNITZ: How long is it before you're going to have to use this model or something like it before your regulator?

MR. ALVARADO: It's before the regulator now.

MR. BUDNITZ: Like this year?

MR. ALVARADO: Yes. We hope it's this year. We'd like to go to public hearing next year. Like I say, we've already had some preliminary feedback. I think there are some things we will change. I think not so much in the environmental transport, the normal release scenarios. I think there are some accident scenarios that we didn't consider that the regulator would like to see run, different things like that.

But to be honest about it, right now they're still at that point in the license review where they're going through the things that they're going to have to read and analyze before they can ask questions about that. That is they've got to get a feel for the geologic setting and the hydrology of the area before they can start asking -- before they can, in their own minds, start asking themselves the question do I believe the methodology is appropriate for the site involved.

They haven't really gotten there yet and I don't expect them to be there until probably this summer, maybe, start getting some feedback from the geo ogists and hydrologists and then they can talk to their performance assessment folks about what they think is reasonable or unreasonable in the scenarios that we've used.

MR. BUDNITZ: The reason I asked the question is that -- of course, we're going to hear from the regulator next, but if I was the regulator, I would have asked John Garrick's question and I hope and assume that they are. You're not going to g a license, I don't think, until you can answer it.

MR. ALVARADO: About what?

MR. BUDNITZ: That is what are the soft spots in the analysis, what can you say about them, and how can you bound them? Because the fact is you don't have a lot of margin here. You don't have ten-to-the-minus-four millirem per year. So there isn't enough margin for you to be able to say with confidence, without answering John Garrick's question --

MR. ALVARADO: Well, I can have ten-to-the-minus-four millirem if I wanted.

MR. BUDNITZ: But that's not what you showed us.

MR. ALVARADO: No, I didn't. I gave you what I think is a very honest and conservative approach to the problem.

MR. BUDNITZ: I understand.

MR. ALVARADO: And it says ten-to-the-minus-two for most things and ten-to-the-zero for one.

MR. BUDNITZ: Right. So just to try to make the point, you and your colleagues who are doing the analysis are going to have to answer that question by going into those -- and I don't like the word code. You're going to go into the models that support those calculations, the assumptions and the data, and try to understand where the weak spots are or where you have large conservatisms that you can point to that can be used to cover yourself against some of those weak spots.

Otherwise, you're going to be vulnerable, and you should be, to the hard questions which are coming.

MR. ALVARADO: I would agree with you that if it wasn't for the fact that -- the models are not really models. They're analytical questions. You can argue about the input parameters and there is a place where we can, I think, demonstrate the degree of conservatism we've used in our approach, and, in fact, not submitted because we knew the questions would come, but we saw no reason to do it till we were asked, is compiling a big relatively -- it's probably four times thicker than the document.

For each and every input parameter, you have to have a description of where the parameter came from, why you used it, why you believe it to be conservative, and all of the basis that we did.

The other thing is for things like on the source term, you had a model, you can run BLT and you can run DUST and you can see that this number up here is, in fact -- you could reduce it by at least one order of magnitude by running one of these other codes, and we've done that in a number of different areas.

Other things, soft spots, all the infiltration numbers, we used HELP, but I could take my HELP model and I get an answer of roughly a millimeter per year of infiltration. I can go look at the work done on the unsaturated zone using chlorine-36 and soil chlorides and soil tritium and I look at all their analysis and they say it appears that natural infiltration over a long period of time has been one millimeter per year or less.

So I have this code number over here that says this manmade trench cap I will build is 1.4 millimeters, natural is about one millimeter, so I think they fit together quite well. I also know that in designing my trench cap, I looked at about six or seven different alternatives and used HELP as a tool in evaluating among the trench cap designs. What I found out was that because I'm in an arid environment with high temperatures, high evapotranspiration and very little rainfall, it doesn't matter what I make the trench cap out of. All the work is being done in about the top four feet, mostly by the plants.

Transpiration is sucking up water just as quick as I can get it in there. So what happens down at a depth of ten or 15 feet is really not all that important, unless it's ten or 15 feet of gravel. But as long as it's something that has relatively fine grains, it's not that big a deal.

So, yes, it's one of those deals. We thought about how much do we give the regulator. Well, we give him what we think we need to give him and then we hold something -- we kept something in back. We knew we were going to get asked questions. You might as well have the answers ready before you get them.

MR. POMEROY: Bob, I think we better move on. Perhaps we'll get another perspective from the regulator. Mr. Alvarado, thank you very much. We appreciate deeply your time and effort in coming to talk to us. I would have to second John Garrick's statement that it's pleasing to see a performance assessment document that's relatively easy to understand and work with.

We'll get a different perspective perhaps from our next speaker, who is the regulator for the State of Texas, in effect, Mr. Scott Pennington. He's going to speak on the state perspective on the NRC staff's draft technical position on low level waste performance assessment, but, more importantly, on anything else that he'd like to speak on. Mr. Pennington, thank you very much for coming. We appreciate it and we look forward to your presentation.

MR. PENNINGTON: Good morning. My name is Scott Pennington. I'm with the Texas Natural Resource Conservation Commission. I work out of Austin, Texas. My agency is, I think, about the same size as the NRC. It employs about 2,500 people, has 13 regional offices.

However, there are very few people dedicated to the review of the application that's been submitted by Ruben's group, a total of maybe seven. Also, there are only maybe two to three individuals that will be looking at performance assessment for the proposed facility in Huspeth County.

As Ruben alluded to, we haven't gotten that far into this part of the review. So there's really not a whole lot I can contribute with regard to performance assessment for this particular site. Also, I'm afraid that the draft branch technical position -- we only received it last week. We're not really sure why, but it arrived late. So I can comment on it. I'm about the only one that's read it. I only have three general comments.

On Page 20, the BTP talks about the role of the regulator. It also talks about, on the next page, participation of interested parties. I think it would be helpful if especially the discussion on the role of the regulator were moved up to an earlier part of the BTP. We think that that would be more appropriate.

I am a health physicist by training. In reviewing this document, it refers to dose many times. It talks about annual dose, which is discussed in 10 CFR Part 61. It also talks about annual dose commitment, annual effective dose commitment. These things mean different things to a health physicist. They're not one and the same. So I think you need to go back and look at the branch technical position and clarify that.

One example, on Page 42, talks about the maximally exposed individual, where they're receiving a dose from the intake of radioactive material, I believe, by the groundwater pathway, if I'm not mistaken. It talks about calculating the annual effective dose equivalent to that individual. Well, that's your whole body dose. You're also interested in the committed dose to an organ, either thyroid or any other organ, and it would be respectively limited to 75 and 25 millirem.

So I think you need to go back and look at the BTP and clear up the inconsistencies in the use of the terminology regarding dose.

Also, something I found interesting since I've gotten into this area within the last few months. I used to work for the NRC. In fact, I used to work for John Greeves, but it was in the fuel cycle area, not in low level waste. Correct me if I'm wrong on this. The annual dose that's described or the limit that's in 10 CFR Part 61 is an annual dose as opposed to a committed dose. Is that correct? By committed dose, what I am referring to is the concept that's applied in ICRP-26 and 30, also in ICRP-60, and now is reflected in the new 10 CFR Part 20.

So I think it would be helpful at the very beginning of the BTP for there to be some discussion on that so there's no confusion about it.

I also found it interesting that, again, on Page 21, participation of interested parties. This is the first time I've ever seen anything like this. I was just wondering if this is a new approach that the NRC is taking; not just for low level waste disposal facilities, but for all future license applications, be it for a reactor or for a fuel cycle facility or whatever, that the public be involved early on in accident analysis and so on.

I will pose a question to Ruben. Did you solicit the participation of any interested parties in the development of your performance assessment?

MR. ALVARADO: No, we did not.

MR. POMEROY: The answer is no, then. Maybe we can do that in a roundtable later on, if you're going to be here this afternoon.

MR. PENNINGTON: Yes, I will be.

MR. POMEROY: It will be easier if we keep going here.

MR. PENNINGTON: Okay. I was just going to say with regard to this, the interested parties, I asked my management about if we intend to solicit the participation of other interested parties and I believe the answer is no.

That's all I can add right now. I'll try to answer any questions.

MR. POMEROY: I'm sure we have a few. I guess I have one that I'd just like to ask your general comment on. Clearly, the branch technical position, reaching you when it did, reached you at a very late stage in where you are and I have to commend both Mr. Alvarado and yourself for being in the advanced stage that you are in, relatively speaking.

But is the branch technical position going to be very useful to you in the future? Do you have anything to say --

MR. PENNINGTON: Any help we can get, yes. As I mentioned, our group is very small. There are only seven individuals involved with this. Just making a quick read of it, I found it to be very helpful. In fact, just recently, I was at a safety assessment methodologies course that was held by IAEA. In fact, NRC sponsored my attendance to that meeting.

I know that the State of New York was reviewing the draft at the time and I thought we had a copy back in the office, but obviously we didn't. They told me that they thought it was a very well written document and it would be very helpful to them, and I think it will also be helpful to us. I've gained a lot out of just reviewing it.

MR. POMEROY: Just as a follow on to that. In general, in your working relationships with the staff, are you getting the responses that you need? Clearly, if you know John personally, why, it's going to help a lot.

MR. PENNINGTON: I haven't worked for the NRC for over seven years. I have a lot of contacts within the agency. So it makes it easier for me to call people. So I have somewhat of an advantage maybe over others who have not worked for NRC.

MR. POMEROY: Are there questions from the other members?

MR. STEINDLER: Yes. When the performance assessment hits your desk for review, what are you going to review it for?

MR. PENNINGTON: I think you're getting back to the uncertainties that are associated with the performance assessment. Obviously, we're going to look for conservatism and their methodology. We're also going to look for uncertainties. In fact, when I first met Ruben back in

November, one of the first things I asked about the performance assessment was had they conducted a sensitivity analysis. He indicated they had.

First of all, we'll look for -- well, initially, we're looking to see if, as he mentioned, there's enough data to back up what they've done, looking at hydrology, geology and so on. We will also look at the approach that they have taken, how much conservatism there's been in the modeling and the calculations.

Also, I think we're going to have to get a handle on what the uncertainties are. I reviewed this lessons learned report recently that was written, I believe, by EG&G for DOE and I think there's a lot to be learned from the Illinois experience with regard to uncertainties. So I think we want to avoid that situation, if at all possible, when we get into the hearings process.

I don't know how the other states do it. In Texas, once we complete our evaluation, once we deem the application administratively complete, we had 15 months to do our evaluation and write it up. Then it goes before a hearing examiner, which can take several months. It's very similar to what goes on in NRC. There's evidence presented and so on.

The burden, I think, is going to fall on the Authority to have to defend what they've done, but, first of all, we have to conclude that it is acceptable, in the first place.

MR. STEINDLER: I guess what I'm driving at is what is acceptable.

MR. PENNINGTON: With my health physics experience, as long as there's a lot -- if there are conservative calculations put in place and they bound the assessment well, they have addressed all those things that will prevent or could impact the facility with regard to meeting its performance objectives, as long as they've bounded that.

The dose they come up with, in my mind, is ALARA. Now, when I was in NRC, ALARA meant about ten percent of the maximum limit; in this case, 25-75-25. So if they're in that ballpark and if you look at the uncertainty, if it falls well below -- if I feel confident that any uncertainty that's involved in the approach is well below the regulatory limit, then I would be, personally, comfortable with it.

MR. STEINDLER: What sort of set of intellectual resources are you going to be able to draw on to evaluate the quality of the data that they've used? I assume that the seven folks that you have in the group may not be able to handle it all.

MR. PENNINGTON: We are already looking at the socioeconomic impact. We are having to go right now to a contractor to help us out with that. I don't know who else we might have to turn to. But from what my management has told me, we will do most of this in-house with the seven people we have.

Now, this is not the first time, with the exception of myself, that the staff has reviewed an application for a disposal facility. They had an experience with Texcorps, which, for various reasons, was -- the applicant was not granted a license. I won't get into that, but they've learned a lot from that experience and I t'ink they won't make the same mistakes, if you want to call them that.

MR. POMEROY: You do, of course, have access to what I would call the Texas Geological Survey and so forth if you do need that kind of expertise, is my understanding. John?

MR. GARRICK: Just to carry on with this line of questioning a little. I think you said that of the seven, probably two or three of these people will be looking at performance assessment specifically. Could you just characterize, without a lot of detail, the backgrounds of those people?

MR. PENNINGTON: I'm one of the three. I'm a health physicist. I have a Master's degree in radiation science from Georgetown. I've been in the nuclear industry for years. I was with Babcock & Wilcox in Lynchburg, Virginia, for a number of years and then worked here in Licensing for over seven years. In my position, I dealt with decommissioning, decontamination, not necessarily disposal.

The other people -- Steve Edder, he is a geologist. I think he has a Ph.D. in geology. He has dealt, I believe, with many disposal issues. He was involved with the Texcorps application. I've looked at what they've written up and passed out. I thought they did an excellent job in their evaluation of that facility for that application.

The third person is a physicist. He has a Master's degree in physics. He is relatively new to this, like myself. We are going to be relying on codes. We are now trying to acquire codes. We do agree with the recommendation in the branch technical position with regard to verification. So we will be trying to do some verification of what they've done.

I don't think you can go before a hearing examiner and expect that they won't ask, well, have you done some verification. I think you lose your credibility if you haven't done something.

MR. POMEROY: Can I ask you -- we have heard in the past that DOE has a major effort in assisting the states in helping to get low level waste facilities on-line. Could you tell us a little bit about that interaction? That's about the limit of what I know about it.

MR. PENNINGTON: To my knowledge, there's been none, unless you know something, Ruben.

MR. ALVARADO: Yes. Under the Low Level Waste Policy Act, the Department of Energy was charged with providing technical assistance to the states in the development of new facilities. They have done this over the years in a number of different ways.

They've published a whole series of reports on things like site characterization, performance assessment, different design concepts. They also have a little bit of money each year for what they call state-specific requests. This is individual states can go and ask for support in doing something that may not have national import, but is important to that individual state. So they can provide funding to you for that.

They also do cooperative ventures. We just finished one last year in terms of developing our operating procedures. We got them to fund probably 20 percent of the total package and what they got out of it was a set of generic procedures, things like waste acceptance criteria and how you would inspect a shipment and things like that that are going to be pretty much the same from site to site.

We got the rest, which was operating criteria tailored to our site and our operation.

They have done a lot in performance assessment over the years. They have a computer database now that has just about all of the codes that anybody has ever talked to that are up and running. They used to put on -- they haven't done one in a while, but they used to have a short school for anybody who wanted to go, where they would actually bring you -- you would go to INEL and spend a week actually getting into the codes and how you set them up, how you run them, how you input the parameters, a little bit about what the basic equation that was being solved by the code was and what it did, so you could come to some understanding of it.

That's all still available, as I understand it. If you had a modem, you could tie into their computer system and actually run the codes on their machines. I don't know how you go about paying for the time and that sort of thing, but it's all there and available.

Some people have used them more than others. They also support -- through that, that's where the Low Level Waste Forum gets their money and also the Technical Coordinating Committee gets -- actually, they provide coordination and that type of support, no real funding of a contractor.

Right now, DOE is paying for the review of the topical report on 3RSTAT at the request of the state. So we all -- there were several of us who thought it was important enough that the NRC review the code and make comments, either say yes, we can accept it, or no, we can't. So we asked the DOE to use some of their funding to actually go ahead and do it. So DOE, on behalf of the states, is paying for the review of the topical report.

They've done a lot of things over time on things like concrete degradation and funded people to look into things like that. Work on other nuclides, carbon-14, tech-99, some of these things. So it's been helpful over the years. It doesn't get a lot of -- if you're outside of the business, you don't know too much about it. But for those of us who are in-house, I think DOE over the -- they have -- through EG&E, their prime contractor in Idaho Falls, they've done quite a bit for us over the years in terms of doing research and other work that we thought was necessary and was useful to the whole country.

MR. POMEROY: Fine. So you've utilized it extensively, then. Thank you. Are there other questions from the members or the consultants?

[No response.]

MR. POMEROY: If not, I'd like to thank you very much, Mr. Pennington. We do appreciate your taking the time to come and talk to us. We commend the State of Texas for moving forward in this difficult area.

MR. PENNINGTON: Thank you.

MR. POMEROY: Thank you. We are now going to move away from our discussions with the state matters directly and move to the main subject today, which is look at the NRC staff's low level waste management performance assessment capabilities.

Our first speaker and, I presume, our lead person, who is already on the podium, is John Greeves. John, I'll let you introduce yourself however you'd like. I'm assuming you will introduce other people as they come along.

MR. GREEVES: I am John Greeves and I'm the Director of the Division of Low Level Waste Management and Decommissioning in the Office of Nuclear Materials Safety and Safeguards. I know most of the people in the room. We've talked over the years. I was in the low level waste business back in the early 1980s and I migrated out of that into the industrial and medical area a few years ago, and then moved over into the fuel cycle arena, where Scott was, in fact, working for me last year. So I've moved around and recently I've come back to the low level waste program in August. So that's sort of where I've been.

We've got a lot of material to cover here today. I think if everybody has picked up a packet in the back, we've got an ambitious schedule in front of us. So I'm going to move rather quickly through the few slides that I have.

One introduction, and it isn't in your handouts, I just want to quickly throw up this slide. I think most of you are aware that we are in the process of a reorganization within the waste business at NRC. As of about April 1, both high level waste and low level waste are being combined in one division. The Director of the division will be Dr. Malcolm Knapp. I think most of you know Mal. I will be the Deputy Director.

There will be four branches. John Austin will be focusing on low level waste and decommissioning projects. He's mostly been focusing on decommissioning. So he'll have the lead on project management and low level waste. Uranium recovery is Joe Holonich. For the purpose of this meeting, interest should focus on the Performance Assessment and Hydrology Branch. Margaret Federline is the Chief of that branch. The Committee has dealt with her on high level waste issues and now you'll be dealing with her on the full spectrum of waste management issues, including low level waste. So we look forward to that.

As far as engineering and geology, Dr. Michael Bell, who, again, I'm sure the Committee is quite familiar with. So just for information, I thought I'd put that chart up.

In this particular chart, I'm really just going to set the background. We've got a rather large group of staff available today to walk through a number of these presentations and I'll have John mention them individually so you'll get a little bit of an idea. John Thoma will mention who the names of the staff are. So when people stand up and answer our questions, you'll have an idea about who they are.

But as we all know, the source of these efforts in low level waste is 10 CFR Part 61. This is the regulation that calls for analysis of the dose to the public. So that's the regulation that we look at in writing these guidance documents.

I think most of you are familiar with the fact that we have been putting out guidance documents over the years. Principal among them is the standard format and content guide and also the standard review plan that has been to the Committee. The Committee has reviewed those and we've worked on those comments. In fact, these are the types of documents that you do review on occasion and periodically they will be updated.

They didn't contain enough information, as we're all familiar. Performance assessment is a difficult topic unto itself. So during the same timeframe, we marched off and have been working on additional documents. Some of them that you are familiar with are referred to as the performance assessment methodology. These have been worked over the last five or six years.

I will point out that performance assessment is something we obviously bump into in other arenas, the high level waste business. I know I started working on that back in 1980. We were doing performance assessment back in those timeframes. The uranium recovery arena, we have transport issues associated with that. The SDMT or site decommissioning management program area, we look for opportunities to use performance assessment there.

Let me take a stop here. There was some mention about public participation. The Commission encourages public participation. I think some of you probably have seen the enhanced participatory rulemaking proposal that's on the street. For difficult sites, there is a proposal to have site-specific advisory boards. In fact, in some of the SDMP sites currently, we really are implementing that process at the present time. So we can speak to the stakeholders in these various arenas.

With that, let's talk about a little bit of the history of the development of the low level waste performance assessment program. We can go back to June of 1991 where the Commission sent down a memorandum to the staff asking them to put together information on where are we on performance assessment and give a report back to the Commission.

We have a performance assessment working group that you people, I think, have dealt with over the years that put that plan together. We also had the benefit of the Committee's comments to Commissioner Rogers in October of 1991. Actually, the Committee reviewed our work in October and sent a letter to Commissioner Rogers in December.

With that, we put together a program plan, which is SECY 92-06, in February of 1992, addressing those issues identified by the Commission in their memorandum. This is basically the start of our program plan or strategy as to how we are working through the performance assessment process. It addresses issues like integrating staff and contractor activities. We're going to hear more about that today.

It identified this as being a phased process. It also went on and discussed the picture in terms of coordination with others, including DOE, EPA, and the agreement states.

As far as the goals identified at that point in time, the first of those was to improve performance assessment guidance available to people. This includes things like developing acceptable approaches for performance assessment modeling and integrating the results of our research activities. You're going to see the results of these efforts since the 1991 timeframe with the follow-up speakers.

A second goal was to enhance the NRC staff capability. This includes our ability in terms of computer codes developed for computer assessment and how are we in terms of looking at uncertainty and performance assessment modeling and doing sensitivity studies. Again, the people doing the work will be briefing you today and you can judge for yourself how far we've come since that timeframe in 1991.

As far as implementing this program, it was basically intended to be in two phases. We're really sort of at the end of the first phase, which spans from 1992 to 1994. Most of our work was focused on two products running concurrently, the first of which is the branch technical position, which you have in front of you and have had a chance to review. The second is what we call the test case. You don't have that information. You're going to see a lot of it in the presentations. The staff has benefitted from running these two projects concurrently.

The accomplishments are to get the branch technical position out on the street. It's under review by the Committee. It's also out to the agreement states, DOE, EPA, others. We have a little bit of feedback in terms of who has been commenting on it and we'll give you a little insight as to that as the briefings go on.

Also, another accomplishment was to improve the staff capability. You're going to see and hear about that in today's presentations. A third product is the recent user need letter that we have sent out. That also is receiving comments from the states, DOE and others.

Phase II. This is sort of where are we going in 1995 and beyond. We will be documenting this test case modeling approach that you're going to hear some details about here today. We also will be developing performance assessment approaches for SDMP sites. Recognize the Commission doesn't have a low level waste license application, doesn't seem to have one on the horizon, and the Commission does have a large number of contaminated sites in front of it that we are making some progress on. However, I think we could make considerably more progress on them and maybe come up with better solutions by using the methodology that's been developed here for low level waste in this SDMP arena.

This will also help us maintain the staff capability per chance the Commission does get a low level waste license application. So I see us focusing on continuing to develop these skills with case work in the decommissioning arena.

MR. POMEROY: John, am I correct in assuming that this represents a refocusing, if you will, or a change of emphasis as far as the program?

MR. GREEVES: Yes. I think it does. As I said, I came back to the program in August and quickly sat down and had to re-read all the Commission papers that had been submitted, etcetera, since I had been away. You can go back and look at the first paper and it talks about a first phase and a second phase. The second phase, to me, looked like it was going to continue test case modeling, maybe do another different kind of a site.

Since I've been back with the division, I can tell you there is a real challenge in the decommissioning arena. I'm sitting here looking at this picture in front of me where I have this talent, these resources that can do performance assessment, and I have this big problem over here in terms of sites that need to be decommissioned, and some of them have significant waste and need to be analyzed, etcetera.

In good conscience, I came to the conclusion I've got to marry these two up. I don't have enough resources to do this one and I have resources over here looking at test cases. I think it's good use of scarce Federal resources to push those together and continue that development process in the decommissioning arena.

We need to be a little bit careful because there's expense associated with this development process. So we will continue to use the Research side of the house in the developmental mode and we will be using the Licensing side on case work, and we're going to have to be careful about how those costs are allocated.

You can be assured that the licensees are interested in that and the Commission, also. So that's an area that I'm going to have to be careful with, but I think it makes eminent sense to take these capabilities and apply them where they're needed and continue to develop those tools.

It sort of leads into my last slide. We are putting together the annual status report. We do this once a year for the Commission on the low level waste performance assessment. Staff has completed this paper. It's up to the EDO. You know the process. As soon as it comes out, you will have access to a copy of that paper.

Also, we will be briefing the Commission on the first of April, if you're not aware of that. I wanted to mention that to you. That's basically a summary of the program, as I see it. I've got a few additional items up here in terms of things that I would look for some feedback from the Committee on.

This is a draft report. You have it. Our peer review group, DOE, others have it. But there are some key questions that are lurking out there, one of which is the systems approach to performance assessments. Some of the comments we're getting are that it's too complicated should we set up that expectation level. You've already hit on the uncertainty approach. You can read the document and see that the staff is recommending using uncertainty techniques, like Latin hypercube sampling, to help you evaluate where the soft spots are.

Another one is interpretation of analysis results against the dose standard. How do you do that? It isn't something we've done in the past. As we approach that, I think we need to be careful and look at all sides of the issue. So I'd appreciate your feedback and your thoughts on that.

Timeframe for performance assessment analysis. People think in terms of 10,000 years. You can read what the staff put together. Ten thousand years is in there. It also references looking beyond that for any peaks that you might want to use in terms of evaluating inventory limits. This is an area that I think we'd appreciate some feedback from you on.

The last one I've said a lot about already, which is the paper is identifying the need to use these techniques in the site decommissioning area. There are large inventories out there at these sites. They've got some long-lived materials and some of them may require some institutional control.

I personally am looking forward to using these types of resources in that arena. I just wanted to give an overview. At this point, I will take any general questions or whatever your pleasure is.

MR. POMEROY: Fine, John. Let's inquire. Are there questions from the members?

MR. STEINDLER: If you look at, as you well know, the history of low level waste disposal, I'm sure you will recognize that we have drifted at a headlong speed toward the 10,000 year increment, starting from what used to be a fairly modest view of the world of low level waste disposal.

What, in your judgment, drives this and what has been the rationale of the NRC in moving toward 10,000 years and beyond as a horizon for which to do analyses?

MR. GREEVES: I can speak for myself. The point is I've talked to the people who worked on Part 61 and they said they looked at 10,000 years back at the time the regulation as written. So that's one guidepost going all the way back to the early 1980s.

You certainly hear discussions about this topic in this country and abroad. You've got the high level waste standard at 10,000 years and there's something nice about the 10,000 year number. It's the timeframe that you get, as I understand it, things like the return of glaciation, etcetera. Go beyond that and people aren't as comfortable with the concept of knowing what is the ground, the biosphere, etcetera, going to be like, how real are the things that we could put into a modeling approach, etcetera. So you start to lose confidence, as I understand it, in your ability to understand what's going to go on beyond 10,000 years.

So there's a certain degree of nicety associated with the 10,000 year timeframe. It certainly covers the large spectrum of the nuclides of interest. That's about as much as I'd want to say on that. We actually have this out in draft and we're getting some comments back, and, as you can imagine, they vary somewhat.

MR. POMEROY: Bob?

MR. BUDNITZ: I just want to be sure to jump on your comment that the high level waste standard is at 10,000 years. There is no high level waste standard for Yucca Mountain. It does not exist. It's gone. It's not in remand. It's gone. There's an Academy committee which is going to recommend a technical basis to EPA, but that's probably two or three years away before EPA does anything.

I can tell you from personal knowledge that there is no way on earth that anybody in this room or anywhere else, because I'm on the committee, the Academy committee that's looking at that, can now predict how that's going to come out one way or the other.

I think referring to that 10,000 year number in the old standard, which doesn't exist, is actually misleading because -- well, just because it's false, never minding that the considerations that went into it have little, if any, bearing on the issues involved in low level waste.

MR. GREEVES: Let me assure that I didn't intend to mislead.

MR. BUDNITZ: Of course, you didn't. I just wanted to make sure that everybody in the room understood what the status of that thing isn't.

MR. GREEVES: I think we're all re-appraised. I think it is just a point of reference. As I said, I was speaking for myself earlier. I think there's something nice about the 10,000 year timeframe in terms of a point of reference.

MR. POMEROY: Dr. Garrick?

MR. GARRICK: Yes. This is a comment that may lead to a question. It may be something that should come up later, but given that it comes under your responsibility, I thought I would mention it. On the matter of qualifications in the performance assessment area, I sort of draw an analogy between that and the experience base we have in the risk assessment business. Being a Bayesian, I kind of move from there to performance assessment, with some preconceived notions.

I see the activities as distinguished in three areas. One would be the area of capability to build a model in the first place. The second would be the area of applications, where the center of gravity of the activity is more with respect to applying the model than building the model. The third would be an even different area and it would be where the center of gravity is more in the role of reviewing the models.

Of course, if you have the kind of expertise that's required to build these models, you can most likely do the other two. But my experience has been that the most efficient approaches are not necessarily the approach of training everybody to be a model builder if their principal role is applications or their principal role is review.

I guess as a bit of advice in how to make the department, the division efficient in doing its job, that it's important to recognize these differences. We have found in the risk business that if we can teach the utilities, for example, to be very proficient in the application of the risk models, the results and the impact on the performance of the plants is greatly enhanced, rather than spending too much time, too much energy, too much cost in teaching them to know how to build a model.

I assume this is something you are thinking about and these distinctions tend to make sense to you.

MR. GREEVES: They're very familiar to me. I've been in the regulatory business about 20 years with the Federal Government ｕnd seven years before that in private industry. Your comment on the first one, I think, is quite on in terms of -- I understand the three areas you mentioned. If you're capable of building it, you ought to be able to do the other two, also.

I would like for you to take a look at the briefings you're going to get today and I think you will see all three of these areas unfold. In terms of building a model, I'd like for you to ask the staff what they did to put this thing together. In terms of the application, I think that's going to be quite clear in terms of the presentations that you will receive.

The role o viewing the model is sort of the questions that I had p on the last slide. So I take part in that process. There's a real advantage to doing the review if you've done the work. Back in the old days when I used to work in the reactor business, I basically designed and constructed -- worked on design and construction of the reactors. When I came down to the Commission and was asked to do the review, the job was easy, because I did it on the other side. And that same process applies to performance assessment.

It's a whole lot easier. We see that today in terms of the capabilities of the staff. So all of those seeds come back home and pay off when you have to do a review. But I a hundred percent relate with your comments.

MR. BUDNITZ: Going back to the 10,000 year question, I didn't mean to accuse you of purposely misleading or being disingenuous. It was, I'm sure, inadvertent. The fact is, and everybody, again, in this room recognizes it, that the further out in time you try to model, the more uncertainty comes in, if only because various processes that we know won't occur in the next five or ten years could occur thousand of years hence.

I hope and assume that you and your colleagues are going tc try to address that piece of the uncertainty of the performance assessment later today. If you are, I will at least be asking you to see if you can help us understand where the modeling capabilities over, say, a few decades or a few hundred years break down as they get into the millennia timeframes or become much more uncertain.

MR. GREEVES: We're better prepared to talk about the models, putting them together, operating them, etcetera.

To me, to look beyond 10,000 years, we need to pull together a group of experts in terms of what's going on in geologic time, people like John Starmer who have looked at this, Dr. Pomeroy.

So I hope your expectation isn't too large in terms of the presentations on what's going to happen beyond 10,000 years.

MR. BUDNITZ: If you had said that first sentence and used the word a few hundred instead of 10,000, I myself would agree. To look beyond a few hundred years --

MR. GREEVES: To make you happy, let me say a few hundred years.

MR. BUDNITZ: Look beyond a few hundred years or maybe even a few decades is where we start having less confidence that today will continue.

MR. GREEVES: The thing that we have focused on is concrete degradation. You can read in the paper the staff is looking at a 500 year horizon. So we've taken a little risk. We've gone beyond your 200 years, but we were thinking about the topics. You'll see a lot of that today.

MR. POMEROY: Right. I think we probably ought to move on. The next subject is directly related to John's previous question. This is an overview of staff capability. John, will you introduce John?

MR. GREEVES: Yes. John Thoma is going to come on up. While he is, Dr. Bill Morris is with me today. I don't know that John was going to introduce him, but he's Director of Research. Which division?

MR. MORRIS: Division of Regulatory Applications in the Office of Research.

MR. GREEVES: And John Thoma will quickly introduce the rest of the staff so that as things -- if somebody pops up, you have a little bit of idea of where they are. We'll also give you a little bit of insight as to these people, who they are and the fact that we have a fair amount of resources devoted to this. I believe John has provided to you a little bit of background material. Have you provided that piece yet?

MR. THOMA: I provided it for the members only, the background material, the 14 key members

MR. GREEVES: Hopefully, that's helpful. Thank you.

MR. POMEROY: Welcome, John. Get your microphone.

MR. THOMA: My name is John Thoma and I'm the Section Leader. NMSS has been responsible for the development of this branch technical position that we're going to be presenting today. I've been the Section Leader for about a year-and-a-half.

I have a tendency to refer to this group as my staff because I've worked so closely with them, but I have to emphasize right up front that it's a combination of Research and NMSS staff. They work very well together, many different technical disciplines.

My presentation is basically going to focus around five areas; to say what are the capabilities of the staff, what have we done since the last time you all were briefed to develop the staff, where do we plan to go in the future, and what have we done to provide them resources. Then we'll get into the staff themselves to present the technical presentations.

You've heard the term PAWG or performance assessment working group many times. Basically, right now, as of today, there are 14 key members -- key staff members that are members of PAWG. There had been more in the past. When we need other expertise, we will go outside of the group and on a temporary basis obtain the expertise. We've had people come in for a six-month rotation to give us assistance in the development of this program.

Where we don't have the background -- or we think we have the background, because if you notice, everybody has a Master's or a Ph.D. or advanced education. But we still, like when we were doing uncertainty, we went into other areas of NRC and talked to the experts on statistics, about are we doing this in the right approach, what is your recommendation, and proceed from there.

I would like at this point in my presentation to introduce the 14 key members of the team. We have divided the group into various sub-groups and each sub-group has specific responsibilities, but the groups overlap. You'll find people that are members of multiple groups.

The first group, which I will refer to as the BTP Revision Team, about a year-and-a-half ago, when I first came on board, I had them assemble their first branch technical position and it was a document that had been written by 14 different people with 14 different inputs. I got a lot out of the document because it told me this is where we are today, this is where we've got to go forward. But it became important to assemble a team of three people and say your job is to produce a readable document at the end, one that flows, has the right amount of emphasis on the various subjects, and intermixed the groups.

The leader of that team is Andy Campbell, if you'll stand up right quick. The members of the team are Fred Ross and Tom Nicholson. Tom, do you want to stand up so they can see you back in the back? Okay.

We had a Model Integration Team. The leader of that was Ralph Cady. He's also the leader of the Groundwater Team. Infiltration was led by Mark Thaggard. We had a Source Team, with Tim McCarten, Phil Reed and Rob Lewis. Rob Lewis is an intern. He is now on a year's rotation and we'll get him back in the group in January. But although he is on rotation, he happens to be physically be about half-a-dozen chairs away from my desk. So we still use him quite a bit.

The Engineering Team, Bob Shewmaker is the leader of that group. He also has on the group Joe Kane. I did not see Jake Philip. Jake is all the way back in the back. Didn't see you come in, Jake. And the wolf in sheep's clothing, Ed O'Donnell, he is actually a Section Leader in Research, as well, but he's done technical work. So we include him as a member of the Technical Team. That's not to belittle any management, because you notice you don't see my name anywhere in here and I've been heavily involved the last couple of years.

These are the core members that we expect to stay together even in the new organization. They may work someplace else, but we fully expect them to be matrixed in to continue this effort. I will be assisting, but I won't be directly in charge of performance assessment because I will be in the Engineering Group in the new organization.

Tom Nicholson, which I already introduced, is the leader of the Surface Water. On our Dose Modeling Team, we have Bob Hogg. On Air Transport, we have Chris McKenney, and I did not see Chris come in this morning, either. Those are your 14 key members of the performance assessment working group.

As you can see in the background, they have a fairly wide variety of technical disciplines, educational backgrounds, work experience, but we've still found that we've needed contractors to assist us in our review. Right now, most of our contractors are coming from the national laboratories. We have them divided into longer-range research work or shorter-term technical assistance work. For the most part, the technical assistance work is controlled by NMSS staff. In the long-range, research is controlled by the Research staff.

We have had several universities that we've also used outside of the national labs and the National Institute of Standards and Technology, which we've used quite heavily, particularly in the concrete degradation area.

MR. POMEROY: John, before you leave that, could you just give us a feeling for the magnitude of -- I don't know whether it's dollars or FTEs -- the total contractor assistance effort versus the in-house effort? How are you going to do that?

MR. THOMA: If you're looking back at the last two Commission papers, the NMSS in-house effort has been right around 3.5 to 3.8 FTE. The Research in-house effort has been right around 2.8 FTE in the previous years. Now, that's going to change in the years coming up. Contractor tech assistance is roughly right around a half-a-million. And the research depends on how you count it. The research directly related to performance assessment has been roughly around a million dollars.

But a lot of the other stuff that Research is doing in the low level waste area really comes back to performance assessment. They're doing some stuff on engineering barriers and concrete degradation, which still applies to performance assessment, although we don't directly link it to it.

MR. POMEROY: Thank you.

MR. THOMA: Let's talk about the development of the staff. In reality, what I'm talking about is development for performance assessment, because there's a bunch of different things the agency as a whole will develop its staff for. But I'm focusing strictly on their capabilities of conducting performance assessment and how we help them along.

The most practical of elements has been the physical let's develop a branch technical position, let's develop a test case. They had to get down and ask the hard questions. Then they asked the hard questions, they had to say what data don't we have; is this the best we can do right now with the literature search; if it is, do we need more research or do we need to get a contractor in to help us find some values.

Just the interactions of getting together and putting together these two documents is a considerable development expertise. The NRC does have formal training programs. We do not have a training program where I can say if you're going to be in performance assessment, you've got to go to these five classes.

Where we've used the formal training programs is in areas that we've needed it. The two individuals that we have in dose assessment, we sent them both to the five-week health physics course in Oak Ridge, Tennessee, that the NRC uses. We were in a fairly detailed discussion on vedo zone monitoring and flow. We found it prudent to send a member to a week-long course given by the University of Arizona. He just got back last Friday. I haven't had a chance to debrief him yet to find out how that's going to help us, but it's hopefully going to help us focus a question of do we need further research in an area or not.

That is the type of stuff that we do for formal training. Now, code usage depends on whether or not you want to call this formal training or not. One of the tasks that we gave to our contractors was -- and you will find it in the performance assessment methodology NUREGs that we've put out -- is look at all the codes that are out there, give us an evaluation of the codes, and then once you've done that, we sat down and discussed it with them and we brought them in and had the staff trained on a whole variety of codes.

Most of them that Ruben mentioned this morning we brought in and did some training on. I have just listed the areas. I could have listed the codes. I found codes as a multiple soup. It's always three digits and a couple of numbers and you can't tell what that is. These are the principal areas. Those courses may last a day, a day-and-a-half.

From that, we will pick certain codes that the staff will go through and exercise more. We found codes which were good codes for what they were originally designed for, but you had to make sure you didn't get out of that area, like the GENII code. It was real good for Hanford. Once you leave Hanford, there's a lot of questions raised about that specific code.

We have conducted workshops. I have listed here four of the major workshops that we've conducted. These are typically two to three-day, sometimes a little bit longer, workshops where we'll bring in people. Sometimes they're open to the public. Sometimes it's just an in-house, bring in all the contractors that are associated with geochemical modeling for both high and low level waste and let's have an open discussion.

The most recent one we had was a concrete seminar given at the end of January, first of February. We have taken the staff and we've participated in national conferences, both as speakers, as members of panels, as coordination of part of the event. An example would be the DOE national low level waste program that they give typically in December of every year. There's the waste management courses of instructions -- not courses, really. Presentations that are given typically in February of each year. We have participated both as presenters and as general staff members.

We try to get the staff, as much as we can, to participate in their professional societies. Sometimes this is resource limited, but particularly if we look at a professional society meeting and it's going to focus on an area that's directly related to performance assessment, we will get some members of the staff to attend those meetings.

We've had interactions with state efforts, to the extent practical. We have not been tasked to review any particular state license application, but we have attended these meetings that I mentioned up above and the state representatives have been there and we've talked to them on the breaks. When they'd call us up and ask about specific problems, we've given them our advice. Sometimes our advice has been right now you're going to need to talk to some other people in the area because we need to do some more work in that area. Sometimes it's been we'll give you our best opinion.

Until we can get this BTP -- right now it's been made publicly available, but we haven't asked for public comment. We need to get it published for public comment and then our intention is to hold a workshop so we'll have more interactions of that type. We put our positions on the table and it's time to open the discussions. That's all part of development.

We've interacted with Federal agencies. Primarily we've interacted with the Department of Energy in three areas; the national low level waste program, which was mentioned earlier. We've had personal contact. They send us stuff to review. We send them things. We also interact with the DOE performance assessment task team, and that's a group within DOE that is doing their own performance assessment for their own facilities. They're physically doing that.

We've made presentations to them. We are a member of their team. When they meet, periodically we go and critique what the other people are doing. Also, with DOE, there is a peer review panel which all of their performance assessments will go to this peer review panel before it's finalized in DOE, and we're a member of that panel. So we get their input and are able to provide our input.

We have a memorandum of understanding with the USGS. In fact, they conducted one of the workshops with us that was mentioned earlier. EPA -- we've had discussions with EPA. I personally met with some of their representatives, for example, at the Technical Coordination Committee meetings, which I'm the NRC representative to, or the CRCPD E-5 Committee. We've met with them and had discussions with them.

With this BTP, we formally requested EPA's comments and, in fact, I just received them in the mail the day before yesterday. So we're starting into more interactions. I know that EPA, in particular, is looking at finalizing their rules on low level waste, which have been in limbo for a long period of time. So I want to increase that interaction with them.

The international efforts we've had the staff involved with in several different ways. We are directly involved in an IAEA test case on performance assessment, which we encouraged and got the IAEA to let us provide a major source of the test case data that 13 different nations are now using to analyze. We're looking at their different ways of approaching performance assessment.

We've been involved with the INTERVAL project. We've had direct contact with countries such as France, Spain, Sweden, Canada, to talk about their programs, what are they doing, what are their problems, where could we get a benefit from their program. Canada has done a lot of work in carbon-14. We might as well, as much as we can, tap into their work.

One of the things, conceptually, we knew that I wanted to point out is this is a multi-disciplined effort. Many technical issues are involved and, yes, we have the individual teams that get together and focus, like, on engineering or infiltration, but it's important to get these teams together, particularly when you're doing analysis, and start letting them talk to each other, because sometimes a simplifying assumption that one team is making is not helpful to another part of the analysis. We need to make sure they coordinate.

Sometimes, like when the modelers present their detailed results and you're looking at 200 pages of graphs, I've seen other groups look at that and come up to a totally different conclusion that I hadn't seen. But by getting them involved, getting them in the room, getting the discussions going, you get basically a synergistic effect. You have to have time to do that. That's not something that you can say we're going to have a two-hour meeting and we'll reach our conclusion. You need time to develop team coordination.

We think they've been working together well enough right now that they communicate very well with each other. The different groups will communicate with each other and they hold periodic meetings just to brief everybody and say this is what we've done.

This next slide talks about hardware/software requirements. We use anywhere from simple codes to complex codes. Right now all the codes that we're using in our test case you can do on a 486 PC. We received four 486 PCs back in 1992. Now, this slide calls them enhanced. By 1994, you may not call them enhanced anymore, but they were still better than what the normal staff was getting and they're capable of doing the job that we need to have done right now.

It does take some time and we've put on our test case and we've put on our integrated model. It takes two to three hours to run a realization. Typically, we'll run 25 to 200 realizations at a time. So sometimes it's -- I'm turning on my computer and hope by Friday I have the results. Research has recently obtained two workstations which will enable them to work faster. It will also enable them to come up with some more complex models that we can try out.

One of the things that you'll get a presentation on later today is we're working with the Department of

Energy and EPA on a -- if it works, and, conceptually, it's an automatic integrated systems code generator. You put into what site data you have and it comes out saying these are the codes that you ought to use.

EPA and DOE have been more heavily funding it than the NRC has, but if we -- if that does come to pass, these workstations will help us to use that system.

Now, they mentioned that NMSS is doing a reorganization. High level waste and low level waste will be combined into one group. High level waste, for some time, have had the workstations. So one of the things that Margaret is going to do is to look at integrating the low level waste people into the use of the workstation, some training for it. They will have to redo -- it's called the advanced computer system review to extend the coverage to low level waste, to make sure that what they have is -- do they have to expand its capabilities in any way. But that's going to have to be looked at after the reorganization.

Right now we see a mix of 486s and we're right at the point where we're ready to use a workstation and a workstation is going to be made available to the staff. So from a hardware perspective, we think the staff is adequately supported right now.

The future staff development.

MR. STEINDLER: Excuse me. Does the staff share your view on that?

MR. THOMA: Staff helped me write the slide. I'm going to assume, unless anybody on the staff -- would they like to have a new computer? Yes. They'd like to have a new 486, but the 486 they've got right now is adequate for running the programs that we have. They haven't had a chance to work with the Sun workstation. They're excited about it, but that's going to require training.

Does anybody from the staff want to make any other comments on that?

MR. STEINDLER: Thank you.

MR. POMEROY: Maybe when you have the roundtable discussion you can get at things like that. We'd be happy for them to answer those questions.

MR. THOMA: One of the advantages of combining the high and low level waste divisions in NMSS is that we'll have more communications between the two staffs and we'll learn more from the individual experiences. The new branch chief has tasked the Office of Personnel to look at the computer, as I've already mentioned. They have also tasked the Technical Training Center in Chattanooga to say how can you revise the formal training courses that we have to make it more applicable to high level waste and low level waste.

Right now, if you look at most of our courses, even the ones in PRA are all slanted towards operating reactors. Could they revise them with examples that would make them more applicable to low level waste. We will continue to transfer capability from the contractors to the staff and we're going to continue to incorporate new methodologies and new techniques.

We're going to expand not only the low level waste, but also the site decommissioning activities that we're getting into and we may have to develop a methodology for that. We intend to continuously evaluate our computer in-house modeling capability. It is not our desire to get into the more complex codes. If you can do it with a simple code and prove that you've addressed uncertainty and all the other concerns, then that's appropriate. Some of these sites that have a long travel time to any groundwater, it's going to be easier for them to do than sites in a humid environment.

At one time, some of the states we dealt with were talking about they would love to have five feet to the nearest source of groundwater. That's a mark different from Texas or California, who have 600 feet to source of groundwater. So you may get into the more complex codes and we want the capability to exercise those.

That was the end of my presentation on the development of the staff and our future plans. The rest of the presentation will be the staff themselves, saying this is what we've done and to answer the technical questions in that area.

Are there any questions on the general overview?

MR. POMEROY: Thank you, John. Members, questions? Marty?

MR. STEINDLER: The schedule that was put out in SECY 92-060 is one year off from the schedule that John presented. The Phase II start-up was called for 1994 and it's apparently 1995. To what extent is that change caused by inadequate resources or inadequate total staffing?

MR. THOMA: It's a more difficult question for me to answer. Some members of the staff would have said, when the first Commission paper was written, a two-year program was too aggressive. When I first came on board, it was one month before the first product was due. We put together a document and it was a good document, but I would not present it to any group.

I was one of the groups back then that said we're going to have to have a year delay. I wouldn't necessarily say it was inadequate staffing, but there's a lot of coordination that has to be done. There's a lot of discussion that's got to be done between these groups to work out what the technical positions.

If we put more staff on it, you may have been able to meet the first year, but I'm not really sure if you could have because you needed to think a lot about what was coming out. Believe me, I talk about it being a nice team. They coordinate well together. They're not shy about communicating at all and we've had quite a few heated discussions back and forth as to what's the right way to go.

So I think we needed the time. If you look at the modification to 92-060, which was 93-060 -- just by accident it had the 60 number on it -- we talked about having a year delay. But we also said it would be a year to produce what we called a strategy document, which is basically Sections A through D of the branch technical position. Then sometime in 1995, we would produce an implementation document, which would be Section E.

So we're ahead of that schedule now because we produced A through E all at one time. But I don't think it was strictly due to inadequate resources. We just needed the time to communicate.

MR. STEINDLER: Okay.

MR. POMEROY: Other questions?

[No response.]

MR. POMEROY: John, one last question from me will bring us up to 10:30, hopefully. We see periodic contractor reports to you on the evaluation of the methodology and improvements in codes, primarily, that various people are carrying on for you.

In general, do you see an end point for that? One could think in terms of a continuing effort in that regard forever, because it's probably going to be true that we will continuously evolve new codes, one way or another. Could you just comment on where you see the end points in that kind of approach?

MR. THOMA: There will be an end point, but there will be some continuing effort. When I say an end point, if you look at 92-060, even going all the way back to that SECY paper, it talked about a lot of staff resources and a lot of contractor resources for a two to three year period. Then you went to a maintenance organization that you did your Phase II, your long range.

Basically, that is still the plan. We cannot -- because of other priorities, and John Greeves would have to speak to this more than I would, but we cannot continuously say we're going to devote three to four FTEs solely to low level waste performance assessment. That's one reason why we're getting into the decommissioning work. Keep the team together and keep them working, but they're working in the area of decommissioning.

Same thing with contractual assistance. It will go down. It will be the last -- do I have an end point right now? No, because there's some areas that we have to look at. Performance assessment methodology, if you look at the PAM, we need to upgrade that in the area of uncertainty analysis, what are we going to do. We have a position now which we reached by the discussion with Sandia, but we're going to have to task them to upgrade that section.

Some aspects are not covered at all and we've got to debate are we ever going to cover them. So there will be an end. There won't be shortly.

MR. POMEROY: Dr. Steindler has a question.

MR. STEINDLER: You indicated that you're continuing to transfer capability from the contractor to the staff. What is your target or milestone or goal or when is the staff going to be able to function entirely on its own without contractor help?

MR. THOMA: To be blunt with you, this is an evolving technology. We're going to have to use some contractual assistance.

Now, I say never, because right now I have got tech assistance contact on geochemical modeling. Dr Campbell could do that if I would give him the time to do it. I have given him 12 other jobs to do. So, he has had to contract that out, and I foresee that being a continuing function.

The staff has the capabilities in many areas, and they're learning from it, but it's going to have be a tradeoff of when can I say I can totally devote Dr. Campbell to doing this or when am I going to have to say you oversee a contract so that it gets done properly and here are some other functions that you have to do.

So, I expect that we will always have some contractor assistance involved.

MR. STEINDLER: I guess my question, then, needs to go to John.

What's the philosophy or the policy or the approach that you're using concerning freestanding capability on the part of the staff to encompass the entire scope of an assignment? The choices are obvious, I think.

Is it going to be necessary, based on either Commission desire or your own internal approach, to have the staff completely capable, and therefore, that's the resource aim that you're looking for, or in fact, is it desireable or advisable or satisfactory to continue to have reliance in some areas, on a functional basis, on outside contractors?

MR. GREEVES: Let me preface -- I have been back in the program since August, and the program is decommissioning, uranium recovery, low-level waste, and now high-level waste.

I don't know all of the things that the staff has out in there on these various topics, I'm still observing, but I have to tell you that my insights -- and I need to do more -- in talking to the staff, listening to them do presentations like this, etcetera -- the staff is capable of doing Performance Assessment right now. They don't need contractors. That's my insight.

Now, do they use contractors? Yes. One of your questions was do we need that capability? My answer is yes, we need that capability. Do we intend to be somewhat dependent on contractors in the future in these four program areas, at least the three I'm responsible for? Yes. With the environment of shrinking resources in the Federal sector, I'm not going to get additional FTE. I can, on occasion, get some dollars to apply.

So, my clean answer is my insights are telling me the staff -- and I hope, after you see these presentations today, you come to that conclusion -- the staff has the capability to do Performance Assessment now. Do they incorporate and utilize contractor support? Yes, and we'll probably continue to do that in the future.

Marty, am I hitting the principle pieces of your question?

MR. STEINDLER: No.

MR. GREEVES: Well, let's try again.

MR. STEINDLER: No, no. I understand what you're saying to me, but let me just mull it over, and maybe it will come up again.

The thing I'm looking for is the functional capability of doing Performance Assessment sufficient to either defend a situation or to go before a licensing board or, you know, basically be tested. Is that going to reside within the staff, or is it going to reside with the staff plus a required outside input from a contractor?

That's a policy issue that the Commission, I assume, has made clear to somebody. It certainly has been made clear to me. The reason I'm fussing about it is because one of the things that we're looking for here is what is the required staff capability, and does the staff have enough resources?

Well, it depends. It depends on whether or not you are going to rely on external contractors, which does not require, necessarily, a staff person, except to monitor a contract. That's the background of what I'm fussing about.

Let me not hold up this part of the session. I think the issue will come up again.

MR. POMEROY: That will be fine.

John?

MR. GARRICK: I'm going to defer my questions until the general discussion, because I want a break.

MR. POMEROY: Very good. Well, I concur with that last suggestion.

John, thank you very much for your assistance today.

We will take a 10-minute break or a little more than 10-minute break, and we will reconvene at 10 minutes to 11.

[Recess.]

MR. POMEROY: Andy, you have, according to my schedule, an hour. I hope that we can fit within that.

[Slide.]

MR. CAMPBELL: My name is Andy Campbell. I'm with the Division of Low-Level Waste Management and Decommissioning, soon to be the Division of Waste Management, as John Greeves pointed out earlier, in the Office of Nuclear Materials Safety and Safeguards. I'm the Project Manager for the Low-Level Waste Performance Assessment Program, and as John Thoma pointed out, I'm also a geochemist, by training.

So, what I'd like to do for this next hour, or maybe less if we can but probably not, go through the initial presentation of the Branch Technical Position for Low-Level Waste Performance Assessment, and what I'd like to do is focus on the first four sections of the document, with Fred Ross giving a presentation on the technical issues discussion, or Section E of the Branch Technical Position, which will follow after lunch.

[Slide.]

MR. CAMPBELL: The objectives of the Technical Position -- and these really correspond to the five sections of the document which I've mentioned -- Sec.ion A is to define Performance Assessment in the context of 10 CFR Part 61 requirements; Section B provides a background on the Performance Assessment methodology, its applicability to low-level waste disposal, and some of the specific technical issues; Section C describes an iterative and comprehensive process for conducting performance assessment modeling; Section D of the TP -- I will use throughout the presentation the letters BTP or TP to refer to the Tech Position -- addresses important policy or technical regulatory issues, if you will, that will become policy issues when, ultimately, the decisions are made as to how to handle some of those issues and interpreting and implementing Part 61 technical requirements; and then, Section E, which I already mentioned Fred will be covering after lunch, is to provide guidance on acceptable approaches for resolving technical issues in modeling low-level waste facility performance.

[Slide.]

MR. CAMPBELL: In terms of background, traditionally in the U.S., for commercial low-level waste disposal, shallow land burial has been the preferred option. It's currently banned in the many states. There are some exceptions to that in very arid regions, but in general, in more humid regions, it has been banned by various state laws.

In addition to shallow land burial, there are a number of near surface disposal technologies which can be used, and we're defining that, and it's defined in Part 61 as the upper 30 meters, and these include below grade vaults. Sometimes you see the word "below ground," and we're distinguishing below grade from below ground, because in an earth mounded concrete bunker, the vault itself may be partially or completely above the original grade, but when it's closed, when closure occurs, earth materials will be mounded over that with a cover design such that it is below the surface of the earth, and we're distinguishing those two from an above ground vault where no earthen cover is ever put on the facility.

In general, states and compacts are developing engineered disposal systems. Ruben Alvarado presented the discussion of the disposal system planned in Texas, which is a shallow land burial system. In California, they're using an engineered cover, a multi-layer cover design that's fairly thick. So, those are the two arid sites.

Mostly, below grade vaults and earth mounded concrete bunkers are being considered by most other compacts and states, and all of these systems, especially in the humid areas, rely on multi-layer cover designs.

For Part 61, the performance objectives -- that's Part 61.41, 61.42, 61.43, and 61.44 -- all apply to all types of near surface low-level waste disposal. However, the technical requirements in Part 61 apply only to disposal below the ground surface, and on a case-by-case basis, above ground vaults with no earthen cover will have to be handled for that.

[Slide.]

MR. CAMPBELL: This is just a quote of 10 CFR 61.41, "Protection of the General Population from Releases of Radioactivity."

The concentrations which may be released to the general environment in the ground water, surface water, air, soil, plants or animals must not result in an annual dose exceeding 25 millirem whole body, 75 millirems for the thyroid, and 25 millirem to any other organ.

The dose people at some point will discuss differences between the ICRP methodology from which this is derived and the current methodology incorporated in Part 20 or at least mentioned.

Reasonable efforts should be made to maintain releases of radioactivity in effluents to the general environment as low as reasonably achievable.

The staff has struggled with exactly what this means in terms of long-term performance of the system, where one has a facility where you're looking at exposure to the workers. It's much easier to understand what this means in comparison to a disposal site with the material that may be there for thousands of years or longer, especially in the near surface region.

[Slide.]

MR. CAMPBELL: We have, in the document, defined Performance Assessment in terms of the technical analyses required in 10 CFR 61.13(a) used to demonstrate compliance with 10 CFR 61.41

In 61.13(a), the pathways analyzed must include, as I pointed out, air, soil, ground water, surface water, plant uptake, exhumation by burrowing animals. Now, for a concrete vault system, that's must less important than perhaps in some of the previous designs for shallow land burial.

Analyses must clearly identify and differentiate between the roles performance by the natural disposal site and design features, and the analysis must clearly demonstrate that there is reasonable assurance that the performance objectives -- that releases of radioactivity will not exceed the limits set forth in 61.41.

In terms of defining Performance Assessment, we focused on the -- for low-level waste disposal -- concerned with long-term performance; that is, the post-closure timeframe. We're not applying PA to operations, and we're not applying it to analysis of the stability of the site. Those aspects of the license application would have to be addressed, but in terms of the Branch Technical Position, we have not addressed those issues as part of the Performance Assessment process.

In general, intruder analyses are not covered within the Branch Technical Position. The waste classification system, as it was designed for Part 61, is specifically intended to protect the inadvertent intruder in a low-level waste site.

There may be situations, however, where proposed disposals of very large amounts of long-lived radionuclides which are outside the bounds considered in the Environmental Impact Statement for Part 61 may require that an intruder be considered as part of a Performance Assessment analysis, but in terms of the Branch Technical Position, we have not focused on the intruder analysis.

[Slide.]

MR. CAMPBELL: As Director Greeves mentioned earlier, the documents that provide -- currently provide some guidance in PA-related areas include the Standard Format and Content Guide, the Standard Review Plan, particularly Chapter 2, which is on Site Characterization, and Chapter 6 on Safety Assessment, and also certain areas of the Environmental Standard Review Plan provide some guidance, in general, on types of issues that one needs to look at in Performance Assessment but not any very specific guidance in terms of conducting Performance Assessment.

[Slide.]

MR. CAMPBELL: Some of the needs for developing further -- or developing low-level waste PA guidance has been a process of identifying these needs through a number of interactions, interactions between the staff and various agencies, state -- agreement state activities, interactions of the staff with other Federal agencies.

In addition, the National Low-Level Waste Management Program conducted a survey or an evaluation of state progress towards developing new disposal capacity, and these were a number of issues identified through those various processes, including providing -- the guidance should provide an overall understanding of the PA process, the relationship between site characterization and PA data collection, how one would go about using generic data in a Performance Assessment.

In many cases, one is not going to have, especially in the early stages of Performance Assessment, a lot of site-specific activity. One may have general information for the region and general information for the site, but through the process of site characterization, one will be collecting more data. So, there is a role for generic data in PA.

Another was the resolution of the policy issues, which I'll talk about later in the talk. The specific interests were in modeling and filtration, concerns about how to model concrete degradation, source term, and also transport in the environment of radionuclides.

Other specific issues include how to approach uncertainty and sensitivity analyses, and verification and validation of computer models: What do you mean by verification and validation?

In the Branch Technical Position and through our presentations throughout the rest of the day, we will address these issues.

[Slide.]

MR. CAMPBELL: The Performance Assessment methodology was developed by Sandia National Lab. It was a series of NUREG documents issued in 1989 and 1990. There has been a recent update of the PA methodology, and Fred will address that a little bit and provide some status of the PA methodology.

It's broken into subsystem modeling areas, including infiltration, engineered barrier performance, source term, transport, including ground water, surface water, air, pathway analyses, and dose.

[Slide.]

MR. CAMPBELL: What I'm going to show here in a flow chart that -- you've seen various versions presented before, but it basically shows the relationships of those sub-modeling areas in the PA methodology, including -- and the single lines here would correspond to water flow through the system.

So, the infiltration model feeds into not only the module for engineered barrier performance, which would include both cover designs and vault systems, percolation of water through the vault walls, as well as providing information for recharge to the ground water system in arid sites, when they have a very thick unsaturated zone, whereas in many of the humid sites, this zone is measured in a few feet.

One is also concerned about saturated zone transport, surface water transport, drinking water from a well, analysis of the pathways and dosimetry.

In the source term area, we're looking at containers, leaching process, and near field transport processes. We've also analyzed, through our test case, a bounding calculation for air transport and then finally calculated dose to humans.

The concept here is that each of these modules will have varying degrees of information available to the analyst and that the complexities of the models have to recognize what kind of information is available, and that would also be reflected in the types of assumptions that one would be making for each of these modules.

MR. POMEROY: Andy, are you going to cover at some point, though, the systems interrelationship between these modules?

MR. CAMPBELL: Through the test case presentation, I think that would be the best way to cover it. Fred will talk, to some degree, about that in the technical issues discussion of the BTP and then also through the test case. I just wanted to give an overview of it at this point.

MR. POMEROY: Fine.

[Slide.]

MR. CAMPBELL: The approach the staff has followed in developing the Branch Technical Position is -- it's structured basically after the PA methodology.

The process of identifying the technical issues has included the test case modeling program, the NRC research program, the states' experience in trying to develop new low-level waste disposal capacity, staff's interaction with the DOE Performance Assessment Task Team, interaction with the DOE Low-Level Waste Management Program, as well as staff participation in international programs such as the IAEA test case program and the participation in the INTRAVAL program.

We've been developing the TP in parallel with the test case modeling such that we could get some sort of synergistic effect between what we've learned or experience gained from the test case, as well as to try and evaluate various proposed regulatory positions that have been developed in the TP, and as mentioned earlier, this work is being carried out by the Performance Assessment Working Group, or PAWG, which consists of people from both NMSS and Research.

[Slide.]

MR. CAMPBELL: In terms of the Performance Assessment process and the attributes of this process, what we wanted to do was provide an overview of the PA process, an overall, if you will, strategy to implement the PA methodology. We're calling it the PA process, but it might be thought of in terms of a strategic approach to conducting Performance Assessment.

One important point is that should be iterative, one attribute. To the extent practicable, it should be comprehensive and quantitative.

The process should integrate site characterization and design activities with PA modeling activities, rather than seeing Performance Assessment as something done after you've characterized your site and after you have a facility design.

The staff feels that it would be much better to integrate PA modeling into the early stages of that, such that the insights gained from Performance Assessment can feed back into further site characterization and perhaps modifications to an original design concept.

The idea of the iterative process that it ultimately provides -- the process itself provides a means of coming to a regulatory decision about the adequacy or that there is reasonable assurance that the site will meet -- the proposed facility will meet the performance objectives.

There should be in this process a procedure for documenting how one went about conducting the process.

We have incorporated a formal treatment of uncertainty, parameter uncertainty, and sensitivity analyses as an intrinsic part of the process, and again, the goal is to reach defensible regulatory decisions.

MR. POMEROY: Andy, before you leave that, at some point -- and perhaps this isn't the right point, but I would like to talk a little bit about what you see as an iterative process.

It seems to me that one of the things that, in reading through, didn't come through clear enough.

It's very clear, in some of the discussion in Section D and E, that you intend to have this iterative kind of process take place, but in the first part, reading through Sections A through C, at least, and partially in D, also, I think we get the feeling that you were suggesting that -- strongly enough, perhaps -- that this should be something -- a process that goes on even after the regulatory decision is made, that if new factors are found or some changes are found during site construction and operation or monitoring, that you wouldn't go back and revisit and find out why the Performance Assessment might have changed.

MR. CAMPBELL: Well, in general, the concept is focused on the process for licensing.

MR. POMEROY: Right.

MR. CAMPBELL: However, in the technical policy issues, one of the modules is what is the role of Performance Assessment during operations, and I would consider that, if you come across significantly new data that changes your conclusions or assumptions dramatically compared to what was done in the licensing process, then ultimately that does have to be incorporated and an analysis, ultimately, at closure will have to be done that would not only include new information discovered during the monitoring program, it also could conceivably involve an evaluation of a test plot for particular cover designs.

You won't have, necessarily, the final cover in place until you close the site. You may have 30 years of operational data in terms of infiltration analysis. You will have an actual inventory, as opposed to a hypothetical inventory.

There are a number of areas that fit into that, but why don't I delay any other discussion on that until I get to that position?

MR. POMEROY: Fine.

MR. STEINDLER: Again, before you leave this, there is nothing in your either attributes or the general discussion that I can find that allows for any kind of gradation in the level of effort, gradation determined to some extent by some measure of importance.

In fact, there are statements in the Technical Position that urge the reader to use the broadest loop of effort in finding as many codes as you can possibly find or models as you can possibly find that could have some bearing on it.

Other folks in other areas, perhaps not this agency, have begun to realize that regulations need to somehow be graded to the situation and the urgency and the risk, etcetera.

Am I missing something here, or did you explicitly exclude that approach from the Branch Technical Position?

MR. CAMPBELL: What we recommend is that, in an initial data evaluation as part of this process, one is going to be faced with essentially a very limited amount of information.

There is always some information available about a site, but the amount of information available in the early stages, if Performance Assessment is coupled to the site characterization or even the site selection process, that's going to be very limited, and any modeling, simple models that would be necessary at that point, would have to encompass a range, a fairly wide range, to handle the fact that you simply have a lot of ignorance about the site, and that would only be used as an approach to feed back into further site characterization.

You would basically do an early iteration through this process to develop a broad range of conceptual models and, through the site characterization process, eliminate from further consideration models that are clearly outside the bounds of what you have at that site.

The whole focus of the process is getting to models that are reasonable for the site that you have.

That doesn't mean you have to consider every conceivable model.

There's obviously going to be a lot of

professional judgement as to what needs to be considered in doing the Performance Assessment.

So, I think the confusion comes from focusing on the very initial stages where one has very limited data for a site to a more advanced stage of the iterative process, where one has a lot more data about the site and one can clearly eliminate hypotheses that just simply aren't applicable to that facility.

MR. STEINDLER: I hear what you're saying, but I am reminded that you start out this document, which I think is a pretty good document, by the way, with a guidance objective, and the guidance objective does not talk about the development of site data.

It talks about -- the objective of this Branch Technical Position deals with defining an acceptable strategy to demonstrate compliance, and you're already past the point of, I think, site characterization, if you look at your objectives. You shift that significantly as you go through the rest of the document.

So, I wasn't quite sure exactly where you were coming from, and so, I was looking for some kind of a commentary on gradation, and maybe it's there and I just missed it.

MR. CAMPBELL: Perhaps Fred -- since Fred has been involved in writing this document, as well, he can provide some insight as well as I can.

MR. ROSS: I'll just say this. Maybe you can answer it. Fred Ross, NRC. I just would like you to refocus your attention on box 7.

I think the answer to this question resides in what's going on between -- when you hit box 6, then move over to 7 and go back through the loop, that's your focus on what's important and trying to figure out the things that are important from the things that aren't important and then refocus your data collection needs to address those specific issues, to go back through until you get to a point where you have demonstrated compliance with the performance objectives.

MR. STARMER: John Starmer.

I think that this is an area that we might want to talk about in this working group session later, because it's an area that I see multiple models in this diagram, and it becomes a matter of where do these multiple models -- and are we computer modeling at this stage?

It is one thing to develop conceptual models, maybe even when you realize that you have to have a site, but how far do we carry these through and how far do we parameterize them or develop data to go into them and how does that guide all these other activities that are implied in the document?

MR. CAMPBELL: Once you have a conceptual model, that's obviously the first thing that you have to do. The question, then, is how do you judge whether that's an adequate conceptual model?

So, a conceptual model has to go into, ultimately, a mathematical formulation of the processes, even if it is a simple model, and one has to carry through the analysis.

MR. STARMER: You pointed to number 2, and you talked about model, but it says "models," and it says parameter distributions, and if you look at the diagram in the document, it has multiple models, which are -- you are developing data for and distributions for, which appears to me to be a very large effort at this early stage of the process.

MR. CAMPBELL: Can you rule out all but one conceptual model at any site? I mean we're developing a document here that would be applied to many different types of sites. Can one, at every site, rule out everything but one conceptual model? That's a key question. Is the data sufficient to do that, especially at the early stages?

MR. STARMER: I think this could deserve quite a bit of discussion, and that's why I suggested maybe that we ought to talk about this particular subject in the round table.

MR. POMEROY: I think that's an excellent point.

We will do that.

[Slide.]

MR. CAMPBELL: Let me proceed through the process diagram.

Even if one only has one conceptual model for a site, keep in mind that you're dealing with an infiltration analysis, engineered barrier performance, a source term analysis, a ground water transport, maybe a surface water transport model, an air transport model. So, in that, in and of itself, you're looking at multiple models.

Now, you ultimately may link all -- will link all of those together into a single approach or a single model of performance, but even at this stage of the game, for any analysis, one is going to have multiple models for the various sub-models.

Now, you may link those into one, but they're still initially -- each of those modules in the PA methodology has certain parameters associated with it.

What we are recommending is that one look at a range of parameter values instead of selecting a single value, primarily because, through the process of doing the analysis and a sensitivity analysis, one can ultimately gain a feel and a better understanding for how important are particular parameters in terms of the analysis of dose, and this will help in determining and reevaluating the data and assumptions, whether or not one needs to expend further effort characterizing a particular parameter and the range of values associated with that parameter.

So, one will carry through the analysis by formulating mathematical models from the conceptual models and then selecting codes.

We distinguish a code from a model, and sometimes that distinction gets blurred that codes are the models. A code just simply implements some mathematical formulation of a model, of a conceptual model of a site, and because certain codes intrinsically contain certain conceptualizations, one has to be very careful in selecting codes and not say that a particular code is applicable to all sites.

It may contain within it, either implicitly or explicitly, certain assumptions and conceptualizations that may not be appropriate for your particular site.

The consequence modeling is simply carrying out the dose calculations, a sensitivity analysis to focus the efforts, to understand which of the parameters that most influence your result. Not all parameters are going to have the same impact.

A determination of adequacy basically will focus on whether or not one is meeting the performance objectives in principle, but also, it will focus on has one adequately addressed the uncertainty in some of the parameter distributions, and obviously, that may require reevaluation of data assumptions, developing new information, and updating the conceptual models if particular site data has been developed that can clearly rule out a conceptual model considered in the early stages.

Then, ultimately, the developer would submit a license application to the regulator.

The activities of the regulator, as they're conceived of generally, are separated from the activities of the developer in this process, but the regulators are going to develop a series of questions that will allow them to feed back into this process, ultimately making a determination with respect to the Performance Assessment, whether it reasonably demonstrates compliance.

MR. SINNOCK: Mr. Chairman, may I make a comment, please?

MR. POMEROY: Yes, Scott.

MR. SINNOCK: As you go through this, I know you're going to be getting to the treatment of uncertainty, etcetera. Could you expend some effort trying to distinguish what you mean by an alternative model versus differences in parameterizations of a single model?

You're drawing a very important distinction between how you treat alternative conceptual models and parameter distributions, and I know you're going to be addressing this under the uncertainty, if you could just perhaps try to be a little clearer on what that distinction is and maybe using some examples of what an alternative model is versus a parameter distribution.

MR. CAMPBELL: Okay. I'll actually put this up. I was going to talk about it a little bit.

[Slide.]

MR. CAMPBELL: If one has a site -- let me give you an example -- and there is some uncertainty as to whether or not there are some geologic features that indicate there is some layering there -- you have clay lenses and sand lenses -- one conceptual model might be that there -- that you would homogenize the material, you would say that basically you don't have interconnected sand lenses.

An alternative conceptual model would be that, if we don't know, we don't have enough information at this site, there may very well be a sand lens that goes from the disposal site directly to the site boundary such that the transport times for water, flow and transport times, will be much shorter than one would anticipate if one modeled that as a continuous porous medium, that the heterogeneities of the site would be such that you would get much faster transport to the wall.

So, there's two different conceptual models of the site, and through the process of developing more information on the site, one could develop a better understanding of which of those is an appropriate conceptual model, as opposed to a parameter distribution for each of those models -- for example, you would be looking at the hydraulic conductivity of a sand lens, would be fundamentally different than the hydraulic conductivity of, say, a loam or something like that.

MR. SINNOCK: If I may, that's exactly what I'm getting at. I can treat hydraulic conductivity of, say, a random field throughout my site and perhaps capture both heterogeneity and homogeneity by sampling out of a random conductivity field or perhaps conditioning the conductivity field in alternative ways and sampling those alternative ways, but I'm solving the same fundamental equation; I'm just distributing hydraulic conductivity differently through the different parameterizations of conductivity in a given Darcy equation, for example.

MR. CAMPBELL: So, to a degree, one can address different conceptual models within a parameterization is what you're saying.

MR. SINNOCK: Yes, exactly. I can set up my parameter space that I sample from such that I can accommodate what someone else may consider alternative discrete models.

MR. CAMPBELL: Right. And that's precisely what we've done in some portions of the test case, where we have provided a broad enough range of parameters for particular parts of the test case analysis, we're essentially analyzing different conceptual models within our parameterization.

So, it is not the intent of the Branch Technical Position to preclude that in any way, shape, or form, because staff is essentially following that type of process with respect to certain parameters.

MR. STARMER: It would appear to me that, if you do not have enough information to differentiate between a homogeneous conceptual model and a model that has a fast travel time through sand lens, you still have not characterized your site adequately to even begin any sort of modeling efforts or even perhaps conceptual model-building, and I guess that's why I'm wondering why we're putting this emphasis on developing parameter sets and multiple conceptualizations or realizations or whatever for all these models if what we're admitting is we don't know enough about the site yet to start the process of doing a Performance Assessment.

MR. CAMPBELL: If Performance Assessment is conducted in the early stages, there will always be a very limited amount of information available in the early parts of -- what you're suggesting is the PA should never be done until you've fully characterized a site.

MR. STARMEF I think you put words in my mouth there, but I would say this. I think that you have to have a pretty good idea of what's at your site and what it's like before you start. If you don't, I think you're spinning your wheels and probably wasting a lot of effort and money.

MR. CAMPBELL: There is certain basic information that you're going to have to have in order to -- and we distinguished just any old data from basic information when we wrote up this section, and what you're suggesting is that there is some minimum amount of data necessary to even attempt to do a Performance Assessment. We would agree with that, but there are also sites that are fairly complex that you will not necessarily be able to rule out a multiple conceptual model approach.

MR. STARMER: I would point out that staff, in 1981 or '82, suggested in a technical position, which is available, that sites should be simple enough to be modeled and explained approximately what that meant. So, I'm wondering if there's a little bit of a disconnect here.

MR. CAMPBELL: I don't think so. I think that -- I mean how do you know something is modelable until you've actually gone through the process? The definition of modelability isn't very strongly defined, and in many cases, modelabilit, ultimately is going to come down to actually doing it. The proof of the pudding is in the eating.

MR. POMEROY: We'd better go on, Andy.

[Slide.]

MR. CAMPBELL: Technical policy issues that we discuss in the Branch Technical Position -- that are discussed in the Branch Technical Position include the role of the site, the consideration of site conditions, processes, and events, the role of engineered barriers, timeframes for Performance Assessment, the treatment of uncertainty, and then the role of Performance Assessment during operational and closure periods, and so, what I'd like to do is go through these, each section individually in terms of the discussion.

[Slide.]

MR. CAMPBELL: One area that we focused on was can we -- when we were putting the document together -- can we provide basically a list of processes, conditions, and events that must be considered in a Performance Assessment, or more importantly, what can be excluded from a low-level waste Performance Assessment, and one of the site suitability requirements in Part 61, Section 61.50, specifically focuses on site stability and the ability of the site to isolate the waste and long-term performance, and particularly, sites are excluded from being developed in the

100-year flood plane. The presence of volcanic activity nearby should not be such that it precludes defensible modeling of the site. There should be basic stability to the site. So, in looking at the -- what conditions, processes, and events, certain events would be excluded from an analysis by virtue of the site selection process.

So, that's an important point to keep in mind. We're not analyzing everything that could conceivably happen in nature. What we're looking at are sites that were chosen for particular features -- minimizing upstream drainage, for example.

So, in terms of an analysis, for example, of the probable maximum flood, one is not looking at an analysis in a PA of a flood coming downstream and washing the site away. It should be sited in such a way that that is not going to occur.

Site characteristics should be considered in terms of the indefinite future and evaluated for at least a 500-year timeframe. This doesn't mean that, at 500 years, you're done. What it means is, in terms of looking at the site and the characteristics that one is concerned about, one has to be looking at at least a minimum of 500 years but should be concerned with possibly the indefinite future in terms of processes that may be ongoing at the site.

MR. POMEROY: Excuse me, Andy. What do you do with that? I mean, if I'm an applicant, I mean I would have a difficult time evaluating things into the indefinite future. You've got some specific numbers.

MR. CAMPBELL: Okay. Well, let's look at the meteorological information. You're not going to have, for example, 500 years of information for meteorology. If you're lucky, you might have 30 years of meteorological information.

You may have some information with respect to long-term trends at the site that can be shown through, you know, tree-ring research that's ongoing in the area or something of that nature, but ultimately one is going to be basing an analysis on a weather pattern that may only go back about 30 or 40 years, if you're lucky.

Clearly, you can't analyze what's happened at that site over thousands of years without spending an enormous amount of money to try and do that.

In terms of infiltration, one is also concerned with the biosphere at the site, and clearly, one is faced with basically developing a reference biosphere of the site based upon trends that have occurred over the last few hundred years, and if you go back far enough in natural history, you can find a very different environment at that site, but what we're suggesting is that's not necessary in an analysis for low-level waste Performance Assessment, to go back in very long reaches in time.

Geologic processes -- characterization of the site can kind of elucidate geologic processes that have been occurring over much longer periods of time than a few hundred years, and so, one ought to be concerned with that kind of longer timeframe for geologic processes that could affect the disposal system, and then, clearly, land-use parameters are basically going to tie you into what people currently do in that area.

There is no way we can predict in the future exactly how people will be farming or if they will be farming at all, whether or not there will be a city in an isolated region and so forth.

So, the idea is to develop a basis set of processes, conditions that try and encompass current trends at the site based upon kind of looking at at least the last 500 years beyond that for geologic processes but not try and predict the future. We are not in the business of predicting the future. A PA will not give you a prediction of the future.

So, one of the things that we think should be excluded from Performance Assessment is global climate change, and there's a reason for that beyond just simply the complexities of, for example, the global circulation models developed.

Those models do not predict on a very specific basis at a specific site what's going to occur at that site. All they can do at the present time is predict, in general, what might happen over the entire earth, with some trends in particular regions.

There is a high degree of uncertainty with global circulation models. So, trying to incorporate climate change into a low-level waste Performance Assessment we think is inappropriate.

The other thing that we consider inappropriate is considering glaciation. The pronounced effects on society and lifestyles and human health and public health and safety from a glaciation of the northern hemisphere far exceeds any possible consequences of a low-level waste site long in the future. So, we're excluding that from the realm of consideration.

MR. STEINDLER: Let me suggest to you that the reader might well have a little problem with this part of the Branch Technical Position.

I think one of the most useless statements in all of Part 61 is the one that you've got up there that talks about consideration requirements for the indefinite future, and then you correctly, I think, say, well, we don't really mean that, and you now select certain aspects of the indefinite future and say, well, we don't really need to consider them.

On the other hand, I think one can make an argument, since the inventory of a low-level waste disposal site might have, you know, half-a-curie of Cobalt-60 left in it after 500 years or 1,000 years, that some of the things you're talking about may also come under the heading of not being worthwhile to consider, and so, the thing I'm looking for is some guidance in this document that give me some rational view that I can use of what I can exclude and what I can't.

You've considered specifically exclusion of global climate change, you've just mentioned -- and I think correctly -- that glaciation is an issue which we need not concern ourselves with too much, but those are somewhat arbitrary determinations on your part.

What guidance do you give in this Branch Technical Position to the reader who is trying to figure out where you guys are coming from and what else he can exclude?

MR. CAMPBELL: Well, volcanoes is another one because of the site suitability requirements.

Seismic events -- a facility, if it's properly designed and back-filled so that you don't create instability within the disposal units and the facility is designed to withstand seismic events through that area of a particular magnitude -- can be excluded from the analysis.

MR. STEINDLER: Are the criteria that you're using based on the likelihood of events, or are they based on some other aspect? Are you throwing out global climate change because you can't do it or because it's unlikely?

MR. CAMPBELL: We're throwing it out because we can't do it.

MR. STEINDLER: Okay. So, some things you just can't do.

MR. CAMPBELL: You can't predict locally what's going to happen from the global circulation models that exist.

MR. STEINDLER: Okay. Do you see what I'm driving at? Am I being too fuzzy here? I think the reader has a problem trying to figure out whether something is important to discard because it's either too much trouble or he can't really get it done or else, you know, the probabilities are too low. If somebody says worry about the volcanoes coming out to the disposal site, there is a fair argument to be made that the probabilities might be too low.

MR. GARRICK: Marty, just to carry this thought forward, it seems to me that the regulatory process ought to accommodate the logical notion that, if there is some evidence that one of these things would be important or a threat to the repository, that that evidence ought to be considered. I think what is bothersome here is just the arbitrary exclusion of things.

If there is a site where there is evidence that, in fact, there could be a climate change or one of these other phenomena that you've excluded, I suspect that, in fact, you do consider that, and so, the underlying principle of the Branch Technical Position ought to be that you don't exclude anything, but what you may be talking about here is, in the absence of evidence that this is a genuine threat to the repository, the position you take is not to model it, but I think what I'm concerned about here is the tone that there is a certain arbitrariness here of assuming your way out of doing things just because they're complicated or for some other reason.

MR. POMEROY: Scott?

MR. SINNOCK: Yes, I would like to follow up on that. As one of the readers -- Scott Sinnock from TRW -- do have problems with this. It seems that some of the things that have the most potential for significantly altering the behavior of the system are excluded from consideration.

So, therefore, I see a very formalized analysis, paying great detail to perhaps alternative conceptual models, the definition, and great detail to parameterization and probability distributions in regions that may have minor influence on the performance, while excluding areas that may have very major influence on performance, without any justification.

If the justification is because we can't model it, coming from the high-level waste program, I think we're in a lot of trouble then, because this is one of our very big concerns, is how to treat the change in flux, particularly due to climate change in the future, and there is no intent whatsoever to exclude that from probably a probabilistic treatment, also, in terms of an estimate of the range of climate changes that are possible.

We don't consider that beyond our abilities to estimate possible ranges. We certainly can't predict in detail what the climate will be, but we think we can bound it, as we can bound many other parameter distributions.

MR. POMEROY: John?

MR. STARMER: There is a point, I think, that Marty was making that could be taken to heart here.

If you explain what the licensee has to do to justify not considering global climate change or any other issue that they feel isn't important, you have provided important guidance which can be just as useful as prescriptive guidance that says you don't need to do this or you don't need to do that.

In other words, you tell them what they would need to provide to justify excluding one of these features.

MR. CAMPBELL: With global climate change, one would look at an increase in infiltration at the site. What infiltration do you use?

I mean it's easy to focus on the high-level waste repository, which has one site. There may be as many as 14 or 15 low-level waste disposal sites, and none of those systems are being developed by looking at global climate change.

The issue is what infiltration do I use in analysis? I can bump up the infiltration and cause any facility to fail at some point in time. If I push enough water through a system, I can fail it.

In the analysis developed for the intruder for the waste classification system in the EIS, they looked at some very specific intrusion scenarios. They did not consider every single possible scenario that could occur.

The reason for that was that the philosophy was that, by providing an analysis of some specific scenarios that they felt would bound the problem, that they would, in general, be protecting the intruder. If one wishes to, one can generate an intruder scenario which will cause the system to fail.

The question that we struggled with in developing this position is, when you start looking at the global climate change models, what infiltration do we tell people to use? Any infiltration possible for the site.

What vegetation is going to occur at that site thousands of years down the road where you're in a much wetter or a much drier climate, because that's going to affect your evapotranspiration, which is going to be a fundamentally important feature in terms of calculating how much percolation actually occurs.

So, simply saying we ought to consider global climate change has a lot of implications in terms of essentially an open-ended analysis for performance assessment.

What the staff was trying to do was focus on the trends that are currently occurring or have been occurring at the site over some reasonable timeframe, the last few hundred years, where you can actually collect a data set to tell you what's going on at that site.

If we then were to go back to 10,000 years ago, the last glacial epoch, we could do that, one can do that, but the costs will go up enormously in terms of site characterization. Is that reasonable in terms of the types of inventories that one has at a low-level waste site?

The other important point here ought to be kept in mind is Part 61 also provides for the possibility of inventory limits -- in particular, the focus on the global long-lived radionuclides such as C-14, Tech-99, I-129, but there may be other radionuclides that are there for very long periods of time.

It may, we felt, appropriate to look at what are the impacts using a set of data that essentially bounds current trends, current trends being over the last few hundred years or maybe 1,000 years or something in that time range, no more than about 10,000 years in terms of geologic processes, such that if, under those circumstances, one has a great deal of difficulty demonstrating compliance with a particular inventory, then one should focus on possibly limiting that inventory.

It was not the intent of a Performance Assessment model to try and address every single possible conceivable event or condition or process that could occur at a surface disposal site. Otherwise, we would never have any sites developed anywhere if we do that.

MR. POMEROY: Andy, let me ask Bob Budnitz to comment here.

MR. BUDNITZ: Just amplifying the comments of my colleagues around the table a moment ago, I would feel better about the support for your positions if you could have described better the criteria that you used in either concluding that global climate change or glaciation was to be excluded or not or just, in general, for these unlikely events, what the criteria area, and then, instead of saying exclude them, say you can exclude them if these criteria are met.

The reason I feel that is that -- and I don't have to remind you, but I will -- this has to apply to the entire United States of America, which includes a hell of a lot of tundra -- I'm not saying a site would ever be put up there -- and it also includes Guam, American Samoa, and Puerto Rico, which are very, very different in their -- in everything about them, never minding it includes Canadian Shield and the arid Ward Valley.

Our country and its potential sites are so different, so varied, that there could be sites where even a little bit of global climate change could make a hell of a difference, and therefore -- and the same thing with glaciation, and therefore, it would help me better if you could have expressed -- and I hereby recommend that you express the criteria under which this things that you claim should be excluded should be excluded, and perhaps it's trivial to show at Ward Valley that glaciation isn't a problem and meets the criterion easily, but that may not be true everywhere.

MR. POMEROY: Andy, perhaps we'd better move forward if we can.

MR. CAMPBELL: Okay.

[Slide.]

MR. CAMPBELL: The role of engineered barriers --

we are, in the BTP, defining engineered barriers as encompassing human made materials and natural materials which are reconfigured to perform a specific function.

In other words, for example, a clay which is reconfigured to form a water barrier in a cover design is an engineered barrier even though it consists of a natural material which may have been exhumed from a quarry of some sort.

In terms of considerations, what went into the thinking process for the role of engineered barriers, one is that, of the inventories of waste disposed of in low-level waste, we evaluated the '87 through '89 database, as well as updates of that for '90 and '91.

There are certain basic conclusions one comes to for commercial low-level waste.

One is that, after a few hundred years, most of the activity, especially in the Class B and C waste, is gone and that, after a few hundred years -- and we call this a crossover characteristic or it's been called a crossover characteristic for low-level waste, the remaining inventories of long-lived radionuclides in the inventory are such that they will be there for very long periods of time, and we're looking at Uranium, Thorium, as well as Iodine, Technetium, Carbon-14, and the like, and so, the state of knowledge about engineered barrier materials are such that, even for that material that's there in the facility, taking credit for engineered barriers for very long timeframes, thousands of years for their performance, still doesn't remove that inventory, doesn't allow for any further decay of that inventory of any significance.

You would have to be looking at the decay of Carbon-14, which has a half-life of about 5,700 years. So, you're looking at maybe tens of thousands of years of performance before you get a significant reduction in the C-14 inventory.

So, in looking at possible timeframes for the role of engineered barriers, this was one important point, and another is the state of knowledge about how engineered barrier materials perform is relatively limited. We're looking at 10, 20, 30 years in some cases, maybe 100 years for material performance or understanding of that.

Even though the Romans built concrete aqueducts, the fact of the matter is they built a lot of them, and there are only a few that are left. So, trying to say that, because this material has been used 2,000 years ago therefore means -- and some of those aqueducts are actually still in use -- doesn't mean that any facility built out of concrete is going to last 2,000 years.

One also has to be concerned with --

MR. STEINDLER: Excuse me. Before you move off that, the waste inventory characteristics that you used in your consideration here, did you compare those to the original Ford, Bacon & Davis Utah study that was the basis for the classification A, B, and C to see whether or not there is any relationship between what you're currently using and what the original designations were?

MR. CAMPBELL: We compared it to the inventories -- I compared it to the inventories used in the EIS, and for the materials in Tables 1 and 2, they actually compare fairly well. There are differences. The EIS considered 19 curies of Uranium. We are currently looking at thousands of curies of depleted Uranium, for example, going into low-level waste sites. So, there is a big difference.

Thorium was not considered in the inventory, and we see tens of curies of Thorium-232 going into low-level waste disposal. So, there are some differences.

Chlorine-36 was not considered, and yet, we've seen it in the inventories that pop up, and because it's a mobile radionuclide, you have to consider that in any analysis, and so, those are some areas where there are differences between what was done in the EIS.

On the other hand, there are some radionuclides -- I believe Americium-241 -- the EIS considered a much larger inventory than what we see going into low-level waste sites.

MR. POMEROY: Scott?

MR. SINNOCK: Scott Sinnock, TRW, again, and I have made a comment about two out of three of my major concerns, and now I'll make it about my third, and maybe then I won't say anything the rest of the day.

I feel it's imprudent for you to recommend that the owner/operator not take credit for more than 500 years for an engineered barrier. Again, if you specify what criteria on which you do that, there are arid sites in which I think concretes could probably be shown to last for a very long time, and I think I would leave this up to the owner/operator to determine how to allocate their reliance on the engineered versus the natural systems unless you want to work that into your actual rule.

I think it's inappropriate, in a Branch Technical Position, to basically exclude reliance on an engineered barrier that the rule says is perfectly acceptable.

MR. CAMPBELL: What we were focusing on was not the particular performance of one component of the system but how long can you rely on the entire system as designed to perform.

That doesn't mean, after 500 years, that everything goes away, but the fact of the matter is that some of the models that focus on concrete performance for these very long periods of time -- for example, if you're relying on concrete to provide an impenetrable barrier, a very low permeability barrier to water flux, focus on particular degradation mechanisms for concrete.

There is abundant evidence that, under certain conditions, concrete does undergo fracturing, and it doesn't take a lot of fractures in a concrete barrier before your permeability, your effective permeability, is essentially much higher than if you took a core sample of a particular chunk of that concrete and did an analysis on it.

So, one has to be very concerned with what is the long-term potential for cracks developing in a concrete barrier.

We have cover systems that have multi-layers within them. Some of these layers are designed to shed water -- they're all designed to help shed water from the system. How long can you take credit for that cover, which is built on the land surface, to last with respect to, eventually, trees growing on the site and the roots penetrating all those layers of cover?

Now, you can design into that system some sort of a bio-barrier, but ultimately, those bio-barriers will fill in with material and roots will penetrate the cover.

So, you're looking at a few hundred years of performance, maybe, before that process begins to take over. There is a great deal of uncertainty about how long that process will occur.

Certainly, in an arid site, one could look at a concrete system performing for very long periods of time, but why, necessarily, would one want to build a concrete system in an arid site, where the aridity of the site itself is an important barrier to the leaching of radionuclides out of the waste, as was presented earlier by the State of Texas?

MR. SINNOCK: Well, I wouldn't want to preclude the owner/operator from making that choice by some exclusion of using an engineered barrier for longer periods. I agree with everything you're saying, but let the owner/operator make the choice of how to rely upon particular barriers, and I think some engineered barriers could be relied on a long time.

In fact, I have many colleagues who are now saying we need, in the high-level program, to rely much more completely on engineered barriers, because prediction of the natural site is impossible to obtain.

So, I think the statement that it's unreliable to predict engineered barriers is equally applicable to the natural system, and so, I think we need to look at the reliability of predictions rather than arbitrarily making a distinction that we can't predict one and we can the other. Let the analysis determine the reliability of the prediction.

MR. CAMPBELL: Again, I'd defer to Bob Shewmaker from the engineering group, who is the team leader for that, to address any further questions on that.

If you have anything to say on this area, Bob --

MR. SHEWMAKER: I think we can cover additional discussion in the round table.

MR. CAMPBELL: Okay.

MR. POMEROY: Right. I think that's probably a better thing to do.

Andy, we have probably a half-an-hour or so, and we have a couple of key questions that I hope you will be able to get through in that time.

[Slide.]

MR. CAMPBELL: Well, let's start with the next one, then.

In the discussions earlier about timeframe, there were a number of issues that were raised, and I made, extemporaneously, a couple of overheads that I have. This is what's in your packet, but I'm going to talk to some overheads that I've got that address the timeframe issue in a little more detail.

The objectives of the Performance Assessment is to analyze the radiological impacts to reasonably demonstrate compliance with 61.41, and part of the reason that we have developed the timeframe position that we have is to help in the determination of inventory limits when necessary.

As pointed out -- has been pointed out before, Part 61 does not specify a minimum time of compliance. Throughout Part 61, there seem to be minimum times of concern, rather than a cutoff beyond which you don't look.

In the development of the Draft Environmental Impact Statement and in the FEIS, the Final Environmental Impact Statement, the calculations were done to 10,000 years, although in later documents, a sensitivity analysis was done to 20,000 years. So, even in developing the rule itself, they looked at least 10,000 to 20,000 years of analysis.

The waste classification system was specifically developed to provide protection to the inadvertent intruder, and in doing that, as I mentioned earlier, not every single possible event was considered, but what we considered a reasonable set of possible events were considered in terms of intrusion.

In terms of ground water protection, the EIS specifically said that -- and addresses that issue as something that has to be done on a site-specific basis. They could not provide concentration limits such as in the waste classification system because of the varying differences of sites and facility designs. Any analysis of inventory would have to be done on a site-specific basis, and the impacts on ground water would have to be done on a site-specific basis. So, therefore, any inventory limits for a particular site would have to be based on a site-specific analysis.

MR. STEINDLER: Is there anything in Part 61 that specifies or identifies the need to provide inventory limits?

MR. CAMPBELL: Yes. Specifically, in 61.7, in the concepts section, it specifically calls out the potential for the mobile long-lived radionuclides. They also called out the problem with Tritium at a particular site. In the EIS, they were mainly looking at trench disposal, but in particular, the EIS identifies Carbon-14, Tech-99, and I-129.

MR. STEINDLER: And that's in terms of --

MR. CAMPBELL: Possible impacts.

MR. STEINDLER: I guess the thing I'm looking for is -- the instructions to the licensee is to use inventory limits in order to limit the dose, offsite dose? Is that the point?

MR. CAMPBELL: For particular radionuclides that are very mobile, that may be appropriate under certain circumstances.

MR. STEINDLER: So, that's an option rather than the requirement.

MR. CAMPBELL: That's an option.

[Slide.]

MR. CAMPBELL: Several important issues and concerns for timeframe -- one is that significant quantities of long-lived radionuclides are being disposed as low-level waste.

As I mentioned earlier, 19 or 20 curies of Uranium, U-238, was considered in the EIS. We are looking at thousands of curies of depleted Uranium going into low-level waste sites. The possible impacts of Uranium and its daughter products therefore become a much greater issue.

Now, for the offsite individual, that is an issue with respect to, for example, Radium transport in the ground water system.

In terms of Thorium, generally the daughters grow in -- well, the daughters -- even if the Thorium-232 is the only material disposed of, they'll grow in in 45 or 50 years, but in terms of depleted Uranium, you may be looking at daughter in-growth occurring over very long periods of time, a million years or more to reach equilibrium with the parent. So, that's one area of concern.

Another is that various concrete vault disposal systems may delay releases for long periods, but the timeframe of this degradation is uncertain.

So, a specific arbitrary cutoff in time may, in fact, allow an analysis simply to say, well, I've done an analysis, and my vault is going to last 10,000 years, and therefore, we don't have to analyze the impacts on ground water or other -- of any possible releases from that facility, because we know it's going to last a certain period of time.

The other important point in terms of should there be an absolute cutoff time is that the sensitivity of release and transport, the travel time issue, for a number of parameters with significant natural variability may be very large, and by selecting, one can essentially manipulate the analysis by just tweaking this variable and that variable to push a peak dose beyond any particular timeframe, and so, from a regulatory standpoint, one wants to know what's the impact of that dose, not, well, we met it for 10,000 years or 1,000 years or 500 years, so therefore we don't have to look beyond that timeframe, because of all the variability of the transport parameters, the range of values for transport can range from literally tens of years to thousands of years before you see the impact of a release occurring.

[Slide.]

MR. CAMPBELL: This is an important point that we've obviously been talking about, is that Performance

Assessment is not a prediction of future risk, that the modeling assumptions and uncertainties preclude a precise prediction of facility performance for dose over either the short or the long timeframe.

The focus here is that PA is a bounding calculation to demonstrate compliance that takes into account current knowledge limitations.

Thus, by providing protection to individuals under a reference set of conditions and processes, some reasonable measure of protection is provided to future generations, and so, the staff has developed a position that basically looks at timeframes in terms of a focus on the engineered barrier performance, and we basically looked at this first thousand years in terms of developing site characteristics that will impact site and facility performance and evaluating the processes and events, consequence analyses and sensitivity analyses over longer times.

Up to about 10,000 years, what we're recommending is that other possible processes that could occur in this timeframe, such as geologic processes that may be occurring on a longer time-scale than just 1,000 years, be factored into the analysis but that, beyond 10,000 years, one use those processes, conditions, and events as your reference basis set for the analysis.

We have suggested that people go to peak dose for a number of reasons. One is that, because of the uncertainties in terms of travel time, peak doses can occur over a fairly broad range. If one just simply says, okay, we cut here, then one is faced with the situation that one may be seeing a dose occurring here just a short time later that would be significant in terms of one's analysis.

On the other hand, clearly the issue of what's happening at this period of time in terms of the inventory left in the facility is an important point. I mean, clearly, a lot of the assumptions that you have made in developing this reference basis set for analysis may very well become invalid at these very long timeframes.

So, we're kind of -- what we're trying to focus on in terms of the timeframe is a set of conditions, processes that provide some reasonable protection over the long run without getting into trying to characterize every single process, condition, and event that could conceivably impact performance.

[Slide.]

MR. CAMPBELL: Treatment of uncertainty -- what we have found through the test case analysis is that, because of the complex interactions of various system components, a priori determining what constitutes a conservative parameter value when one is faced with a range of values that are appropriate for that parameter are very difficult to say, well, I know that, if I select the mean value or the most conservative -- the highest value for a particular parameter, that that's going to result in a dose that is conservative.

What we have found through the analyses is that one has to actually go through the process of looking at the impacts of the various ranges of parameters in terms of the final consequence, because some surprises really come out from looking at the various combinations of parameters.

The highest flux of water does not always give you the highest dose, because the combination of releases and dilution may, in fact, lower your dose. If you have got a lot of water going through the cover but not going through the waste, you may have increased dilution from that effect.

In fact, very low fluxes of water sometimes do not result in the lowest dose because of the fact that there may not be very much dilution. So, dilution, it turns out, has an important role in this.

So, in that one example, simply saying, well, I'm going to use this flux value for the facility, without exploring how does that range of flux that could reasonably occur at that site, could end up with a non-conservative analysis.

If we're looking at the future state of the system and conceptual model uncertainty in terms of -- and this gets to the issue that John Starmer was raising earlier of multiple conceptual models and possibly the scenarios. Rather than trying to assign probabilities to those, in terms of parameter we're recommending that people look at distributions of parameter values.

We are using a stratified Monte Carlo sampling routine, Latin hypercube sampling, but there are certainly other ways of looking at the parameter variability and the uncertainty associated with that.

So, that basically sums up the approach.

The one area of concern which Director John Greeves mentioned earlier was what one ends up with, presumably, in this type of approach, is that there may be some portion of the distribution that exceeds the dose standard, and one of the questions that we're wrestling with in this approach is is there -- can one specify a particular percentile of the distribution that can exceed the standard and still provide reasonable assurance? What we've recommended that people do is look at the central tendency of the distribution.

Now, this distribution would apply to the conceptual model that will give you the largest doses which cannot be ruled out from consideration at this site because of the collection of additional data at this site and consideration of processes occurring at the site, cannot reasonably rule it out, but it has to be a reasonable level. It has to have some basis -- have some scientific and technical basis for assuming that model or using that model.

So, what we have focused on is, in terms of the parameter distribution, one should understand how this central tendency of the model is affected by the ranges in parameter values.

What we recommend is that, under all circumstances, the mean or median of this distribution, whichever is higher, should -- there should be a higher degree of confidence that it's below the dose standard. So, at a minimum, the mean of the distribution must meet the standard.

We initially thought about specifying the 95th percentile with a 95-percent confidence interval in terms of some percentile of the distribution that can exceed the standard, but the problem that we ran into with that approach is that one may not have enough information really to do a full-blown statistical analysis of the probability of exceeding -- you know, whether or not one has a 95-percent confidence that one will -- that the distribution is below the dose standard, and so, what we've done is we basically left this part of the distribution open.

The applicant is going to have to look at what is driving the model in this region that distinguishes it from the model in this region and try to come to an understanding.

Is one looking at simply combinations of values that are unlikely or physically impossible to occur, or is one just simply looking at some reasonable distribution, or do these just simply have a lower likelihood of occurrence?

MR. POMEROY: Andy, one could have a lot of discussion about that, whether it should be the mean, the median, the 84th percentile, plus or minus 1 standard deviation.

We may want to look at that a little bit later on in the discussion period to talk about in some greater detail, but I'm not sure that it fits right here now, but John has a comment on it.

MR. GARRICK: Well, the only comment I have -- I hope we adopt the lessons learned from the years of discussion on this from the ACRS, which was not much.

MR. POMEROY: Bob?

MR. BUDNITZ: I believe that, when the analysis is done, that distribution, which is a density distribution of dose, should properly represent your state of knowledge of what the dose would be, and as such, I believe that the decision-maker ought to stare at that distribution, stare at the whole state of knowledge and what you know about it and why, and make a decision based on that, rather than using a single figure of merit like the mean.

That single figure of merit can obscure or lose information which is part of the state of knowledge of the analyst, and therefore, I guess I was a little surprised by your comment that the mean ought to be used as a red or green light, and I'm not sure that that is, in fact, the regulatory position in Part 61, is it?

MR. GREEVES: John Greeves.

I would point out this is a draft document.

MR. BUDNITZ: Of course.

MR. GREEVES: We've laid it on the street in its imperfect state. This is healthy discussion. I'm enjoying this.

In fact, it reminds me -- in reading Dr. Garrick's paper that you shared with us, he showed the usefulness of Performance Assessment in -- presuming you set the models up, etcetera, get the data right, going through a pass process, and I think, Dr. Garrick, in your paper, it shows that you really don't know what the mean value is if you did the single pass process, but if it is conservative and defensible, you can stop, and then, if you find you don't have enough information, he recommends to go the second pass, even the third pass, and I think what I see here today is communication.

The Technical Position is imperfect communication in some areas, and yet, I'm frankly enjoying this conversation, and I hope, with the feedback you give us, we can improve that product and have a workshop and communicate even more clearly.

MR. CAMPBELL: Let me back up just briefly, because you've been left with a mis-impression, getting to what John is talking about, communication. We do not say the mean is okey-dokey.

MR. BUDNITZ: I didn't think so. I didn't see it anywhere.

MR. CAMPBELL: As you go through the position, what we say is that, as a minimum, the very least, there must be a high degree of confidence that the mean or median is below the standard, but we say you also have to evaluate this upper portion of the distribution, and it's going to have to be a determination, if you will, on the basis of knowledge of the system that you're analyzing and the process you've included if any of that distribution can exceed the standard.

So, we have not given a gift to anybody in saying that, oh, the mean is okay or the median is okay. What we've said is that one should use this as a tool for understanding how the system is performing, both for the central tendency of the model and the tail of the distribution, and that the determination of what will constitute reasonable assurance is going to have to made on a case-by-case basis, basically getting to your point about the state of knowledge, what is the analyst and the regulator -- the regulatory authority is going to have to be looking very carefully at this as saying how conservative is this model, you know, has the applicant adequately addressed the uncertainties, and this presentation here does not mean that you can stop at the mean or the median and everything is done, and that is not what it says in the BTP.

If that's what people are reading into it, then we need to rewrite the language, because we've tried to distinguish those two.

MR. POMEROY: Bob?

MR. BUDNITZ: I guess, just to react, if, at the very least, you want a high degree of confidence that the mean isn't exceeded, you may be asking too much.

There are plenty of distributions out there of states of knowledge of things that you think you know a lot about where the mean exceeds the 98th percentile, and it could be that, in that case, the mean exceeds the 98th percentile because everybody in the world thinks the parameter is 1 except one guy thinks it's a million, and of course, the mean is going to -- if there are 100 people, the mean is going to be a 100th of a million, it's not to going to be the other, and you have to be very careful, especially in areas where experts disagree, about even making such statements as high degree of confidence the mean isn't exceeded.

The fact is your state of knowledge may not allow that statement, even though every sensible person would agree that your state of knowledge would be opposite.

MR. POMEROY: Scott?

MR. SINNOCK: Scott Sinnock, TRW.

I would like to follow up on the concept of state of knowledge. I agree with what you're saying. We need to give the decision-maker a representation of the best science can do in representing the state of knowledge, but I think, when we slip into probability, we have to be very careful that we don't become overly conservative.

If you require only a probability distribution for your most conservative conceptual model, you are not, indeed, representing the state of knowledge, you're representing a very biased view, and with showing a distribution, you're giving an impression that you're representing a broader state of knowledge.

So, I think we have to be very careful by extracting the "most conservative," and this will go back to my point earlier of what's a conceptual model versus a parameterization.

I can parameterize a geometric grid -- sand lenses, homogeneous median -- to give me a worst representation, but I don't think the intent of your position paper is to get me to parameterize my grid in the worst manner possible and then do a distribution on that.

So, I think we have to be very careful that, if we go to the probability route, we indeed try to capture the full range of knowledge, which may include alternative opinions and likelihoods, relative likelihoods of alternative models that we cannot eliminate but we may know are quite unlikely.

MR. POMEROY: Andy, can we go forward, and can we finish up quickly here?

MR. CAMPBELL: Yes. We're nearing the end.

[Slide.]

MR. CAMPBELL: This gets to an issue that was discussed earlier in terms of updating the performance assessment during operations when significant changes are made. I pointed out earlier the real versus a hypothetical inventory, possible design modifications.

One may have in place demonstration units that one can look at the as-built properties as opposed to the design properties and the fuel performance.

For example, a demonstration unit for a cover may be able to provide 30 years of data in terms of the performance of that cover as it was built in the field, and then, one could use this information for updating the Performance Assessment for closure with the site monitoring data from the operational period as well as some of this other information.

[Slide.]

MR. CAMPBELL: So, to sum up, the draft PA has been sent to the Department of Energy, the EPA, and the USGS, sited and host agreement states for comment. That was in mid-January.

Comments received to date are from the DOE Performance Assessment Task Team, the National Low-Level Waste Management Program, the U.S. Geological Survey, EPA, New York State, and staff has also had some of their contractors look at either the whole document or various portions of the document to provide some feedback.

I will say that, in terms of staff capability, we have been working with contractors on various components of both the test case and the document. However, the document itself represents staff effort in terms of putting all the issues and policies together and coming up with the positions that we've come up with.

We have used the contractors for providing, if you will, peer review of particular sections, particularly in the technical areas, and so, in that sense, we have used those resources to help us out, but the document itself was produced by staff.

Similarly, in the test case, we are using the resources of contractors to provide ancillary analyses of particular areas, but the test case model itself has been developed by staff internally to the NRC and is being exercised by staff internally.

We begin formal evaluation of the comments in April. We're awaiting some state input on the document.

We plan to have a workshop sometime in the summer, with revisions in a Federal Register notice hopefully by the end of the fiscal year and some management decision on the policy issues after the public comment period, and at that point, I'm going to stop.

MR. POMEROY: Thank you, Andy.

Are there any further questions from the group?

[No response.]

MR. POMEROY: If not, I think everybody wants to go to lunch.

You will have noticed that we're approximately an hour behind schedule now. If we proceed at the same rate, we'll be adjourning at about 7:15 tonight. I would rather not do that. So, perhaps we can find a way to increase the speed of this process, but we will take an hour's break for lunch and return here at 1:25.

[Whereupon, at 12:25 p.m., the meeting recessed for lunch, to reconvene this same day, Tuesday, March 22, 1994, at 1:25 p.m.]

AFTERNOON SESSION

[1:25 p.m.]

MR. POMEROY: The next item on our agenda this afternoon is an overview of TA modeling technical issues and recommended analytic approaches. Fred Ross will be the presenter.

Fred, do you have a microphone on? If you will put that on, we will be ready to proceed.

MR. ROSS: It has already been mentioned, but I am going to talk about the technical issues and some of the approaches that we recommend for resolving the issues.

Also, I know we are behind, so I would like to be able to keep it going. I hope not to dwell on thing too long unless there are some real problems.

We don't have problems; we have approaches that everybody is going to agree on.

[Laughter.]

MR. POMEROY: Please proceed.

[Slide.]

MR. ROSS: We've already seen this, but I put into on to remind everybody that in performance assessment we are dealing with a number of modules. We talk about the infiltration analysis; the engineered barrier performance; source term; the different pathways, air transport, groundwater, so on; dose demand; and we have talked about each of these sections independent.

[Slide.]

MR. ROSS: With respect to the infiltration analysis, the main issues have to do with the transient behavior of certain processes that effect infiltration: changes in site conditions over time, changes in how the engineered barriers change over time, particularly those in the cover system, and then there is spatial variability.

Even though it is a cover system, it is man made. There is still variability with it. As far as natural systems are concerned, there is even more variability.

[Slide.]

MR. ROSS: In terms of infiltration analysis and our approach, we divide the analysis really into two parts.

First, you want to deal with the amount of percolation that actually enters into the cover. This is one of the more difficult areas in hydrologic science. I think most soil scientists agree that determining what the actual percolation rate in the soil is is highly uncertain phenomena.

Once percolation rate is established, we use that as a boundary condition for the flow through the cover, which is a much easier problem, I think. That was also mentioned this morning from the gentleman from Texas who made that same observation.

Because the purpose of the analysis is primarily to get the flux into the disposal unit for the source terms so we can get a release, but we also use it for getting recharged to the water table and getting any additional dilution factored into the analysis.

[Slide.]

MR. HINZE: Fred, while you are on that point, on page 48 of your document you talk about the steady rate of water flux to the water table. Over what period of time is that?

MR. ROSS: It is a steady state analysis. The amount of flux will vary as you vary the input parameters, so it is over the entire time of the analysis. But for each iteration it is a steady state value or a single value.

MR. HINZE: So this is just a constant value that you are using? You are not really talking about it being a steady state because that is not a steady state.

MR. ROSS: No, it is not. Well, the problem is that this process up here is all dependent on precipitation run off as to what the cover is at the time.

MR. HINZE: Snow melt? The whole bit?

MR. ROSS: Yes. It is very variable. People said that hourly values are sometimes necessary to actually get a percolation. That is why we divide the problem into two parts to deal with this separately. Once this is determined, or a range of values is determined to the percolation, then the flow aspect of it is much simpler. But to lump the two together into a single analysis in which you are looking at all these transient processes is probably more than most people would want to deal with.

[Slide.]

MR. ROSS: So basically, as I said, we divided it into two parts. We use this analysis to determine the steady state flux into the disposal units. We recommend that you sample a range of percolation rates over a very large value to account for the transient behavior, and also, to some extent, that would also account for large changes between wet and dry years and so on. It help build some of the variability into your analysis.

A lot of people have tried to sell the idea of an annual water budget where you have -- if you have more evaporation than precipitation therefore it means you have a net loss, and that is not necessarily true.

Then what we have to do is we have to look at how the system is going to behave over time, and we recommend reanalyzing at different time the account for degradation of facilities.

I want to talk next about how the facility is evaluated over time.

MR. STEINDLER: I'm sorry. I guess I got

confused. If you have more evaporation than you have rainfall, you don't have a negative?

MR. ROSS: You see, what happens is the process is so -- the transients in the process are so important. In other words, if you have, for example, high intensity rain storm, that will have --

MR. STEINDLER: Oh, I see.

MR. ROSS: You know, you get run off. All right?

MR. STEINDLER: Yes.

[Slide.]

MR. ROSS: In engineered barriers the main issues relate to permeability and durability of the materials. And actually, the durability aspect also relates to the permeability because ultimately that's the value that we use in the analysis, the permeabilities.

It is an issue because there is no relevant long-term data on the permeability of the engineered materials. They are not independent of each other because a lot of these materials work as a system except with drainage layer where you have two layers, one of higher and lower permeability. So you get a permeability contrast to cause lateral drainage. They work with each other, not independently of each other, so if you degrade one, you change the whole function of those two layers as a system.

There are limited models for prediction. You get into the problem of the macro -- the micro and macro, and lab data versus field behavior. So there is a lot of uncertainty.

Durability is even more of a problem because we just don't have information on how these materials are going to behave over the long term. Then we have to assign properties to them. Once we understand, if we do understand, how they are going to degrade then you have got to somehow decide what is an appropriate property to represent that degraded state.

MR. STEINDLER: Your definition of long-term is how many years?

MR. ROSS: We are talking hundreds to thousands.

MR. STEINDLER: Hundreds of thousands?

MR. ROSS: Hundreds to thousands. Actually, the thing is it starts almost immediately once the -- if you have a concrete vault with a cover on it, once that is built and in place, the degradation starts, to some extent, probably immediately.

[Slide.]

MR. ROSS: In trying to deal with this problem, there is a lot of engineering judgment and expertise that is going to have to be applied. There is no other way around it. I have listed all of the things that you have to consider in dealing with the materials. A lot of them relate to the design, the construction, of the facility; the QA, the QC systems; operational requirements are involved because you have to design around the fact that you are going to be putting waste in this facility.

The interactions of materials I've mentioned, there is a whole slew of considerations. We point this out because these are the things that people are going to have to consider when they begin assigning values to these systems.

As I said, expert judgment can make a definition of what the properties are to a great extent and what they will degrade to. And we point out to people that it is probably going to be subject to a lot of peer review, because you are also dependent on the expert judgment in this area.

That is why we recommend -- we went into this 500 year recommendation where we are saying that, for one, if you don't need it, why try to justify the performance of some materials that you don't need necessarily to demonstrate that you have complied with the requirements.

So when you are going out on a limb, as you extent yourself out into time to try and justify all this, you are going out on a limb which you may not have to crawl out on.

But I agree. If you wish to go ahead and do that, why be our guest. But, again, you are going to be subject to the period you process when you try to justify all that.

[Slide.]

MR. ROSS: Source term is another major areas of uncertainty, and I think the operative word is variability because we've got variability among waste types, classes, waste forms with respect to the distribution already on nuclides, the activities, the release rates and mechanisms, and the geochemical environment.

Of course, variability in the geochemical environment then affects your solubility limits, your rates of diffusion from solidified waste forms, the amount of sorption, corrosion rates, what have you.

We also have to consider the variability of the lifetimes of containers, anywhere from the HICs, the high integrity containers, to the steel containers which don't have a very long lifetime.

[Slide.]

MR. ROSS: Trying to resolve some of these uncertainties, I think the most important thing is having a good description of your inventory, what kinds of waste types and forms, et cetera, you are going to have, the types of radionuclides associated with each type of waste, and so on.

Then we would recommend doing -- it doesn't show this, but we recommend a screening analysis before you go further in your PA where you use some very simple release models in order to eliminate a lot of the radionuclides from the analysis, because it is complicated enough and if you can eliminate a great deal of the various radionuclide species from the analysis then you can proceed further. So we do recommend a screening analysis to do that.

Once you do your screening analysis, you can augment your analysis by including things such as dissolution release, diffusion release for cement waste forms, and Kd release, say, for ion exchanges, for ion-exchange resins.

Of course, you get into the problem of having to justify some of these things, and, of course, we recommend being conservative as you do them. It is quite obviously, I think in most cases, that a rinse release is flat-out too conservative to demonstrate compliance with. Although, as I said, it is useful in screening analysis.

[Slide.]

MR. ROSS: We recommend not attempting to simulate individual containers. I don't think there is enough data in the world to be able to do that, but if you look at an individual disposal unit and you try to allocate as a percentage the particular release mechanisms along with different waste types and so on that you have in the unit, and do it that way.

Geochemical modeling is okay. It should be used or could be used to evaluate your solubility limits and so on in the rest of the geochemical environment where you can if you need to.

MR. POMEROY: Fred, before you leave the source term, I noticed the statement in the BTP that said a licensee should provide a complete description of all low-level waste to be disposed of at the facility.

And it seemed to me that that was a little bit hard to do.

Later on, I think, you provided the guidance that specific inventory information for performance assessment should be obtained, essentially, but a survey of those present-day generators and from projections of changes in waste streams over the lifetime of the facility.

Is that a realistic thing to do from your perspective? Do you think people -- and I realize that some of this has been done as it has been done in Texas as we heard this morning -- but is it a realistic thing to get? By doing what you are suggesting, does it give them a realistic picture of the source term?

MR. ROSS: Obviously, initially it is hypothetical but I think most people would agree that they should try to do something like that.

MR. POMEROY: Right.

MR. ROSS: They did in Texas. I think they wanted a fairly good representation of what it is that they are actually going to be disposing of, and, of course, the requirements later on. You are required to keep records, keep track of what is being disposed of at your facility. Of course, we would use that later on to refine the analysis if need be.

I am not an expert in the source term area and I don't know all of the facets that go into the manifesting and so on.

Phil, if you would like to address that further?

MR. REED: My name is Phil Reed. I'm with the Office of Research, and I was one of the persons responsible for putting together our entire inventory composing of individual radionuclides by Class A, Class B, Class C, and then breaking down the Class A, B, and C into waste forms and waste streams.

With the information available today, it is probably a pretty good reasonable effort to say that you can get good data specifically if you do the inventory based on contacting power plants and contacting the waste generators within your compact, i.e., the utilities, the industries, the hospitals, the universities, and things like that.

We found that it was to our advantage to look at waste stream data taken from the management information system that was already brought up that DOE is developing with regard to INEL. The problem we ran into is when we first started this the utilities changed waste processes, and that is the most difficult part to predict.

But in answer to your basic question, yes. We think you can do it but if things change down the line -- for example, when we started, we assumed a large fraction of the waste would be solidified in cement for BNC.

Well, about six months ago, maybe a little bit beyond that, the industry changed. That is no longer being an option, and everything is going into high-integrity containers. The same thing for other long-lived radionuclides, particularly like some of the uranium isotopes and natural analogs. We are seeing a lot more of that where we had not anticipated.

Predicting into the future is very difficult, and it does provide some hazards, but if you aware of some of these things, you certainly can try to anticipate when you are putting the inventories together.

I hope that answers your question.

MR. POMEROY: Yes, it does. Thank you. Please go on, Fred.

[Slide.]

MR. ROSS: With respect to groundwater flow and transport, I think the major issue is how you conceptualize the site and how you get data on the site and begin to use that to develop conceptual models.

Conceptual models should include the relevant processes and features that are important to demonstrating performance of the facility.

Another issue, of course, is spatial variability. That is in all the hydrology problems.

Other issues that we tried to address are about the assumptions of who gets dosed from groundwater and under water conditions, so we provided some guidance on the receptor location for groundwater use and also the relationship between groundwater system and surface water system for the surface water pathway.

We believe the model should be as simple as possible and still show the important, relevant processes at the site. Well location should be at the disposal site boundary. That should give you the maximum dose to groundwater. It should be done in a site-specific way. You should look at how, in the region of your site, wells are designed, how groundwater wells are designed and utilized, and consider those as assumptions into your model for groundwater use.

Obviously, there should be a pumping well, a water supply well, which is sufficient to meet this hypothetical individual. But, again, his needs are tailored to the site-specific needs. We don't want to make up things that aren't realistic for the particular facility at hand.

MR. STEINDLER: Do you consider the current practices in the area to be sufficient for extrapolation to whatever time limit you have previously indicated?

MR. ROSS: Yes, I would think so. Some of those may not change very much. If the climate is suitable for growing suitable crops, we would have an irrigation that would be built into the groundwater use, so the pumpage would relate to how much would be used to irrigate. You would have to really change things significantly to change the pumpage rate.

The usage for just domestic supply, that is fairly constant. I mean, if you assume a person is living there, he is going to drink the same amount of water through all time. That aspect of human life won't change. So I think we'll pretty well hold it constant.

As far as the hydrology is concerned, I don't think we changed the hydrology very much. We are not going to assume that the aquifers all of a sudden yield more water in the future than they do today or less in the future than they do today.

MR. STEINDLER: Really?

MR. ROSS: Yes.

MR. STEINDLER: Talk to some of the people that live in our neck of the woods. The bottom is falling out of their wells.

MR. ROSS: I understand that. That if an area of an aquifer is overdeveloped, the groundwater system changes in terms of what wells will yield and so on, but I don't think we are going to get into that in our analysis, or we need to.

MR. STEINDLER: I guess the problem I'm having is that I hear what you are saying, and it seems imminently reasonable.

I would hate, however, to be the person who says those very same words in front of the licensing board and then become subject to cross-examination about where you get your hard data to substantiate those fundamental assumptions you are making.

MR. ROSS: Well, I think --

MR. STEINDLER: Which is the difficulty in trying to move out in time to this hundred to thousands of years that you were indicating.

MR. ROSS: I heard what you are saying, but I think our assumptions kind of hold steady in terms of when you look at how a person would get dosed, he is only going to drink so much water from the well.

Now, you would have to change the whole hydrologic environment to change -- and that wouldn't just relate to how the water well is used by an individual, but also relates to way radionuclides would travel to the well and all these other things. So I think it really complicates the analysis tremendously.

But we can think about that further, I'm sure.

MR. POMEROY: Bob Budnitz has a question.

MR. BUDNITZ: Fred, I'm not sure what you directed or suggested as the assumption for the dose pathway in terms of foodstuffs. Is the assumption that the person, not knowing it is there, puts a house up, drills a well, takes water out?

MR. ROSS: Well, he is off-site.

MR. BUDNITZ: But he is adjacent?

MR. ROSS: Yes.

MR. BUDNITZ: Then does he eat all the lettuce that he grows?

MR. ROSS: We will look at that in the dose models. All I was trying to show was consistency between the groundwater-used model and the way a well is pumped and used for irrigation.

MR. BUDNITZ: But you are really going so far as to say what is in the water that comes up?

MR. ROSS: Right.

MR. BUDNITZ: Then there is another piece to cover.

MR. ROSS: There is another piece to that in the dose assessment where you look at what people eat and how much they eat.

MR. BUDNITZ: But your fundamental assumption is that technology will not change from today in terms of the way that pumping is --

MR. ROSS: That's right. That's correct.

MR. BUDNITZ: Without arguing that none of us knows that, but that's just your assumption for the purpose of this analysis?

MR. ROSS: Right.

[Slide.]

MR. ROSS: Surface water issues: when we looked at the different disposal alternatives, above ground versus below grounds vaults and so on, we realized that for the above ground vault there is quite a few issues related to surface water environment which could be fairly complicated because you could be dealing with erosion, over-land flow, transport, sediments, then sorption on the sediments, and how the sediments would accumulate in streams, and so on.

Fortunately for the terms of the technical position, since we were dealing with the below ground concepts, the issue boils down to dealing with the connection to surface water with the ground water flow path because we believe that is the path that radionuclides would take. They would go down to the water table and then travel to the surface water body.

[Slide.]

MR. ROSS: So as I already said, that is our approach. We consider the pathway. The most important transport mechanism is surface water through the groundwater transport pathway.

What we do is then take the concentration of radionuclides and you would go to the nearest point of discharge to the surface water body and dilute that with whatever the flow rate in the surface water body is, and that would be your concentration.

[Slide.]

MR. ROSS: Air pathway: the main issue there was actually whether the air pathway was even important or not. There has been a lot of debate over the years as to how important the air pathway actually is with respect to off-site. On-site might be another problem.

Also, it is not clear how much gas is going to be generated over what period of time. It kind of makes the issue a little bit more complicated, but if it is not really an important pathway anyway, maybe we don't need to worry about it.

[Slide.]

MR. ROSS: So here is a case where we recommend the bounding screening analysis just to get some relative idea of how important the air pathway might be. Then, if it needs to be reduced further, you can do some more detailed analysis. I suppose it is possible that you might even begin then to have to consider things like what is going on in the waste itself in terms of gas generation, and then how the gas might flow through the cover, and how it would be transported off-site.

But I think for our purposes today we found that simple screening models will pretty well take care of the problem. Anywhere from just simply releasing all the inventory at one time to maybe waiting 100 years and then releasing the inventory.

[Slide.]

MR. ROSS: Dose modeling: the main issue there is identifying all your different pathways. Because we talked about air and surface water and ground water and so on, but then you have all the interconnecting linkages that create pathway demand. You've got water to soil, to plants, to man. That sort of thing.

Then, of course, use of the proper dose models: there is a lot of question about what the proper dose models are. Our approach is to recommend pathway identification based on actual site; not to use generic pathways.

And also for your different factors, to use factors that are really important to the site. Not take factors that are already in a model, that are generically emplaced, or that are appropriate for some other site. To really look at what is important for the site, what could actually be grown at the site, if you are dealing with eating vegetation, or with water, how water is actually used, application rates to the specific vegetation, that sort of thing.

Dosimetry: we are recommending Reg. Guide 109 models, the JREG-5512 transfer factors, and using site-specific usage factors, what I already said, and we are recommending the ICRP 2630 methodology.

MR. BUDNITZ: Bob Budnitz. Now you've come to the dose question that you ducked three minutes ago because you said wait three slides.

MR. ROSS: Okay.

MR. BUDNITZ: I am not clear about what you are recommending there but suppose that this farm is in a wheat area.

MR. ROSS: Yes.

MR. BUDNITZ: Are you going to recommend that all the wheat they consume comes from their own thing rather than get shipped to Battle Creek where Kellogg's makes it into cornflakes or what?

MR. ROSS: Well, we aren't talking about -- I don't think in our scenarios that we are talking about a large wheat farm. We are talking about dealing with the dose --

MR. BUDNITZ: I understand. There is a family and they put up this farm that is right at the edge -- the scenarios -- it is right at the edge of you zone, and they grow something.

If they grow carrots, do you assume that they are going to eat those carrots?

MR. ROSS: Yes.

MR. BUDNITZ: Rather than sell them to some big conglomerate and buy carrots at the Safeway like most people do? I'm just curious. It is a completely non-trivial point which I think is worth you thinking about.

What is your guidance?

MR. ROSS: I was going to let Chris or Bob answer that.

MR. McKENNEY: Chris McKenney, NMSS.

MR. POMEROY: Could you talk closer to the microphone, please.

MR. McKENNEY: Chris McKenney, NMSS.

Current guidance is that the individual will consume. They will be most self-sufficient rural, sort of, farmland using typical values for the region.

The EPA suggests in their newest draft guidance for the public -- for the pubic dose using typical values for ruture time periods.

In our current -- for test case dose is not -- the pathway factors are not as dependent on the agriculture and the food us as they are on the water. Drinking water is the fundamental pathway for a dose in our test.

MR. BUDNITZ: You mean the amount of dose from drinking water out of the well completely dominates or is most of it and not the carrots that they might grow, in which case it doesn't matter? In which case these assumptions don't matter about if they are growing something for commerce whether they sell it or eat it or what.

MR. McKENNEY: Right. Currently the dose limits for 61.41 are an individual dose. They are not a population dose.

MR. BUDNITZ: No, no. I understand exactly, that is just where the point comes, exactly right. If the guy is a carrot farmer and if he and his wife and children eat more carrots because of that than I do at Berkeley, how much more can he eat? Those are completely nontrivial points when you are doing individual dose, which is the limit.

MR. McKENNEY: Correct.

MR. BUDNITZ: Maybe there is a trout farm and they love fish. I don't know. The problem with individual dose as a limit is that really the dose is the wrong concept, it is the risk of the dose that is their probabilities of these various doses which you have to factor in.

MR. McKENNEY: Then you would have to go to the probability scenario in the first place, that would have to be factored into it.

MR. BUDNITZ: That is why I am asking how you have recommended handling that in the modelling? You have just said, the heck with it, it is going to be the water.

MR. McKENNEY: No. Using Reg. Guide 1.109 with the transfer factors and stuff, on a nuclide basis has been mostly that the water has been ending up contributing to most of the dose except for a couple of nuclides. Otherwise situations like that would have to be banded like that in your application for an individual for various concerns for the area.

I mean, if there is an area that you don't use irrigation, then you are not going to be having irrigation in your pathways analysis. If you are in a desert, you are going to have a much higher component for your irrigation pathway. It is very site-specific. It can't be said, well, every person is going to be evaluated on 10 pounds of carrots per year, 150 pounds of beef, and so forth. It has to be dealt with on a site-specific basis.

MR. STEINDLER: Is it correct that there is no NRC-wide standard for dose calculations independent of the actual source of contamination in the groundwater; is that correct?

MR. McKENNEY: Not a real standard.

MR. STEINDLER: So you are using something different than high-level waste folks might, that the uranium mill-tailing folks might?

MR. McKENNEY: That is why we based it back to Reg. Guide 1.109, which a lot of models are based on. In the instance, I did compare my spreadsheet models with some of the other models by putting the same values in for data and came up with similar results to GENII and a couple of other codes. But there is no standard throughout the NRC that this is how residual radiation will be --

MR. STEINDLER: Recognizing that the scenario is different if you are in a wheat farm area or if you are farming carrots, all those other things aside.

MR. THOMA: Right. This is John Thoma. I wanted to interject one thought here, though. Don Cool's branch over in the Office of Research does do a lot of this work on doses, that type of thing, and we have been working closely with his branch, and he has been interacting with high-level as well as with other activities to see if we can come up with some kind of standards. So we are relying -- we are not trying to go out on a limb and say, this is only for low-level waste. We are trying to do what the agency is approaching from that, and that is mainly from the Office of Research right now.

MR. HINZE: Before you do that, the last transparency on dose modelling pathway identification sed on site, this is based upon an arbitrary decision that hat a certain pathway may not be important or significant?

MR. ROSS: That's right. Well, I don't think it would arbitrary. I think if the applicant or developer would --

MR. HINZE: You mention in the BTP the word "significant" the first time without any identification and that is on page 10. Then on page 12 you state something about 5 percent or more of the total dose exposure. Then further on you point out that all of em will have to be analyzed in order to prove that is less than 5 percent.

MR. ROSS: You may have me on that.

MR. HINZE: What you really need to do, if that is the case, that they have to be shown to be less than 5 percent, then all pathways should be identified regardless of the site, that they have to be evaluated.

MR. ROSS: Okay, but you are talking about two things. First, to decide whether a pathway even exists or not, and that should be site specific also. That is what I thought you were referring to initially. Some pathways just might not be realistic. For example, desert environment, certain agricultural pathways just aren't realistic, so you didn't do those. So that is important to identify those important pathways.

Now you are getting into the specifics of, once you have identified a pathway how significant is it. I will have to defer again to Chris.

MR. McKENNEY: Again, this is like the air pathway where you say you use a screening model or something like that, you can do a simpler model to try to get the relative order of magnitude of the various pathways, and then on your more detailed path you will only have to do the ones that are greater than 5 percent, which was the values. Similar to, like, in the new Part 20, you only have to consider N.

I guess my concern here is the use of the word "significant" because, if you are going to have to evaluate it and it is identified as even a possible pathway, then you are going to have to evaluate it. So then all of them become significant whether they are less than this 5 percent threshold or not. I think in reading the document that there is confusion there, there is a constant change, a moving target of what significant really becomes of the identified pathways.

MR. McKENNEY: Some of that could be, when you start dealing with pathways, you start dealing with circular loops or multiple pathways like you will deal with irrigation to plant to man, and then you can also deal with irrigation to plant to ground to plant to man, and you can start adding steps in the pathway for the pseudo-biotic environment while another pathway may actually capture and actually contribute most of the dose. The more and more steps you put in the pathway the less is going to result in the final product.

MR. HINZE: I guess my evaluation of it is that all pathways, if they are present, are significant and should be involved in the evaluations.

MR. ROSS: It sounds like something we need to look at. There is no question.

MR. BUDNITZ: Just quickly, but you made a present day assumption so that if somebody raises his arm in the back of the room and says, but what if they start farming carrots at Ward Valley, that is out, right? It is out because nobody is farming carrots in Ward Valley or any place near Ward Valley now. Am I right?

It is out to assume that Las Vegas springs up at Ward Valley for this purpose?

MR. ROSS: Yes. But if you think it is going to happen, let me know, because it might be a good time to get in.

[Laughter.]

MR. BUDNITZ: I didn't know that Babbitt was putting that land up for sale anytime soon, but there is a buyer, if he is.

MR. POMEROY: Maybe that is an alternative for Mr. Babbitt.

Please go on, Fred.

MR. ROSS: We are almost at the end. I would like to talk about the status of the PAM, but only in one particular area because I think this is the area that is going to be new and might be the most promising.

It was mentioned this morning that EPA, NRC and DOE are working on a decision support system for low-level waste. Right now this system is being developed for the remediation of sites that are already contaminated, and it is a system that is used to optimize well location. What Sandia currently has is, they have a graphical user interface or somebody sitting at the terminal and he can access a geographical information system which is essentially your database. If he takes the database, he can input problem assumptions and so on, and pull codes out to run simulations with.

Also, there is an uncertainty analysis driver built in and then he gets an output. They are trying to modify it for low-level waste. They will put more flexibility into it. They will put more codes into the code section so that there is a choice of more codes. It is not a black box where their system necessarily chooses the code, but it helps you decide on what code is appropriate for your given conceptualizations, and they are going to build in a conceptual model manager. I am not sure exactly how that is all going to work.

What it should do is, it should do two things. It should make building a systems model a little bit easier because a lot of the interfaces will be done within the support system, so you don't have to worry about how one model will interface with another. You should worry about it, in a sense, but I mean you don't physically have to go do it each time you want to run a different model.

I think this conceptual model manager will also help you to document your decisions so that they don't get lost, and I think that is an important process of building confidence in what you are doing is that as you make different decisions that they are documented somewhere so that you can use them to support your application.

I don't know when this work is going to be done, but it is interesting.

MR. STEINDLER: Let me ask the question that some intervenor might certainly ask you, and that is, if you have a suite of codes on the right-hand box is there someplace that somebody can go to define what the assumptions are in each of the codes that have been used to construct this arithmetic operation?

MR. ROSS: If you are talking about assumptions in the code, I am not certain about that. I think that the purpose of this conceptual model manager is to keep track of assumptions about the models that you are putting into the system, as far as the assumptions in the particular code.

MR. STEINDLER: The assumptions and simplifications are all in one bag. Does your staff have a catalogue, if somebody were to call you up on the phone and say, I am using XYZ Code, or I am planning to use the XYZ Code for such-and-such a task, can you tell me something about the underlying assumptions?

MR. ROSS: We don't.

MR. STEINDLER: You don't.

MR. ROSS: It might be a particular code that we are familiar with and I am sure then we can do that. We don't have a vast catalogue of codes.

MR. STEINDLER: I wasn't even looking for a vast catalogue, I was just looking for a little catalogue.

MR. GREEVES: Can you rephrase the question to ask if they have an understanding of the underlying assumptions of the codes they have been using? They have been using a set of codes, and I think a good question is, do you know what the underlying assumptions of those codes are?

MR. STEINDLER: I didn't want to put it quite in those terms because, if the answer is no you are in trouble.

MR. GREEVES: It is a bit of a risk-taking exercise.

MR. STEINDLER: I think that is fundamentally the question.

MR. GREEVES: I think that is a fair question. We have been working with codes. What level of understanding do we have about the underlying assumptions.

MR. STEINDLER: It isn't each individual code taken on its own, but what I am looking for is that most of these analyses involve the use of multiple codes, and where do they run into conflict where the assumption of one is the fundamental basis of the rejection of the other, et cetera, the interactions.

MR. McCARTIN: I will try to answer it in part. Tim McCartin with the Office of Research.

The DSS, in terms of that, the model manager, the attempt will be that any time you run a simulation it will produce a listing at the beginning of that simulation that lists all the assumptions you are now making for all the conceptual models you have invoked. It is hoped that it would not allow you to select models that are in conflict with one another.

Say, for example, a one-dimensional flow model in a transport model that possibly had two-dimensional dispersion, and part of the managing part of it, you would say what you want to do, and it would try select the codes, but it would produce this file giving all the assumptions. You could choose to ignore it, but it would be produced as a written record for that simulation.

MR. STEINDLER: I think that is a great leap forward.

MR. McCARTIN: Now having said that, I would say --

[Laughter.]

MR. McCARTIN: It still is a research project. The proof will be as it comes in and, hopefully, the first version of the DSS will be in hopefully at the end of this year.

MR. STEINDLER: This calendar year?

MR. McCARTIN: This calendar year, hopefully. That would be the first version. It will have a limited number of models. It will be used by the staff to try to give feedback back to Sandia as to other features we would like. It is the type of thing that EPA and DOE also are involved in, and they are adding some of their models, so there is a fairly large collection. As time goes on, we see the need to add more models. They will be added to the system, but it will be more limited version, hopefully expanding over the years.

MR. STEINDLER: That sounds most encouraging, I might add. But the corollary may not be so. For example, is it also true that at this point in time that performance assessments that use significantly complex models or a large number of different codes don't have the benefit of somebody doing the analysis to see whether or not in those applications conflicts are resolved at the assumption level?

MR. McCARTIN: For now, speaking for the NRC staff, I will say in my opinion, when we pulled the models, the ones we have used, we looked very hard, at least in our mind, as to the assumptions and what is allowable with the conceptual models we are trying to simulate.

It isn't an explicit output from those models. You have to understand the computer programs and the concepts they are doing. Does everyone do that, probably not. The worry is that as computer models get easier and easier to use as the age of computers increases, people just take up models and run them, and sometimes some of the users know the assumptions they are invoking.

That is one of the reasons Sandia suggests that this type of procedure, especially for our assistance to the states, now you could get this and at least you could look at the front end and see all the assumptions being made and whether you agree with them.

MR. STEINDLER: Thank you.

MR. POMEROY: John Garrick?

MR. GARRICK: I am sure the modelers know this, but sometimes it much more illuminating to not talk so much in terms of assumptions, which is kind of a negative connotation, but to talk in terms of the scope of the model. Then you can be extremely explicit. As a matter of fact, if you talk about the scope and you incorporate the notion of uncertainty and propagating it through the model, very often there is very little to talk about in terms of assumptions.

In fact, I had an old professor that hated the notion of assumptions. He said that is a cop-out. What you really are trying to tell people is that you are uncertain about it, and why don't you just go ahead and put in the uncertainty and why don't you go ahead and define the scope, and I think there is an important point there.

If these models tell us exactly what the scope is -- for example, this model doesn't consider episodic events, or this model doesn't consider a certain kind of flow, or what-have-you, then it becomes a more direct process of indicating what you are doing rather than this long list of what you are not doing.

When we have reviewed other PRAs, for example, we adopted that notion of having a clear understanding of what the scope was. We didn't consider external events. We only took it to this point, et cetera, et cetera. While you can call those assumptions, the thing that really makes progress is when you start getting to a point where you can compare models of same scope. I think that more of that kind of language would help this process.

MR. McCARTIN: The advice comes at a good time in that Sandia is still in the development stage of this.

MR. GARRICK: Mostly what we are talking about is scope.

MR. McCARTIN: Yes.

MR. STEINDLER: John, there are also mathematical assumptions that have to be made in order to be able to fit this thing into a PC, for example, if that is what you are doing. I would like to pull all of that together, lay it up there where somebody can see it so that you don't have column mode failures.

MR. McCARTIN: Assumptions in scope, we are at a time now where we are certainly making use of the more then matching funding from EPA and DOE. We are approximately a tenth of the financial burden of this, and so we want to make use of as much information as we can put in there to help people know what they have when they get the final results. It is a benefit. We will be more in a workstation environment rather than a PC, for what that is worth.

MR. POMEROY: If there are no further questions, we should probably move on.

MR. ROSS: I am just about at the end of the line.

[Slide.]

MR. ROSS: I hate to bring this up. I am going to talk about the dreaded "V word" for a moment, issues in defining model validation. This might change. I know that we have worked independently of the high-level people up to now and I know that is changing very shortly. They are working on a project and attempting to define model validation. I raise these issues because they are going to have to deal with these issues just as anybody will when they try to define model validation. So I don't think whether we come up with a definition or not it negates what I have on the slide.

One of the problems with model validation is, there is no accepted common definition for it. From what I have read, the definitions seem to fall into two sides. There is sort of the scientific concept where you have a model that says the answer is ten, so you go out in the field somewhere in space and you measure ten, by God, it is a valid model.

The problem with that, of course, is that that doesn't happen. So actually how valid the model is becomes subjective. In performance assessment, a lot of people agree, at least from a dose point of view looking at the whole system and the times we are dealing with and the complexities and so on, that that concept is probably not achievable.

[Slide.]

MR. ROSS: So that gets you down to the next concept, which is the so-called regulatory concept. There the issue is, are the models adequate for the purpose they are being intended for. In this case, it is to make some sort of regulatory decision.

Determining its adequacy, of course, becomes also subjective. It could be intentionally misleading in that it may appear that regulators are trying to have it both ways, saying, for example, that they have valid models, yet we are saying up here that validation -- or some people would believe validation is not possible. So you get into that sort of confusing argument.

So what are we doing. What we are saying right now is, we are trying to build confidence in the models. If that is validation and you want to call it that, then that is fine with me. Basically, we are saying, the iterative approach we are doing that integrates data collection, site characterization, the modelling and uncertainty together to improve confidence, that is one aspect of confidence building.

MR. GREEVES: You might want to mention, these are the last two slides on the general observations and conclusions.

MR. ROSS: You don't have them in this package. It is in the last package.

MR. GREEVES: He was afraid he wasn't going to get to his topic, so he slipped it in.

MR. ROSS: We get back into the alternative conceptual models. If you are not sure about a model, look at it, see what kind of values you get from it. Be open-minded about what could be going on, emphasize conservatism. If you have to focus on refuting the conceptual models to give you the bad results. You may never prove the models, that you have the right models, but maybe you can refute some of the really bad assumptions that give you trouble.

Formal treatment of uncertainty, or at least treating the uncertainty builds confidence. There is no point running away from it, I don't think. Include as broad a range of conditions and data as possible. Again, don't try to duck anything, be open about it, be upfront.

Perform auxiliary analysis and tests as needed, infiltration tests like they did in California to demonstrate, in fact, that water didn't percolate very deep. It is better to do a deep measurement than to do a model, if you can measure something directly.

Water budget studies, real water budget studies, they can augment the problem. Any other specific detail modelling you want to do on a particular subject. If you think you have the data and you think it is worthwhile doing it, do it if you need to. Make the process as open as possible. We heard this morning about holding things back. We would suggest don't hold back, if you have got it show it.

Also dealing with the public openly and bringing them into the process, we think it is a good idea. I think Illinois, the process there, showed that maybe if they had done some of these things, they wouldn't have had the problem they had, although they did have a hearing board that was tough.

So if there are no questions about model validation --

MR. POMEROY: Nice try.

MR. GARRICK: I hope you are saying that the scientific method is not achievable in performance assessment, literally.

MR. ROSS: Not the scientific method, I said a concept where you think that you are going to get actual results. I just don't think that performance assessment leads to that.

The other concept, if you want to use it, it is fine. If you can get over the fact that you are going to have to caveat what you mean by validation and tell people that your answers aren't real answers, and if you can get that across, then call this model validation, if you will.

But, first of all, there was a talk Sandia gave some time ago when they were talking about model validation, and all the time we were talking about not actually predicting dose but just showing that the dose limit is not exceeded. Right away just taking that approach alone is suggesting that you are really not even attempting to do this. You are not attempting to be accurate in that sense. You are trying to do something else. All you are trying to show is you are not exceeding the regulatory limits. So right away you are backing off accuracy.

It gets to be a real semantic argument, and that is why we just dumped it, frankly. I think what we wanted to show was, regardless of what you think of model validation, these are all things that we are promoting that lead to confidence. I say, call it what you will, that is what we think leads to a good performance assessment.

MR. GARRICK: Isn't it true that as we progress towards risk-based regulation these differences disappear given that what we mean by risk is logic-based regulation, et cetera, et cetera. So I would think that this is kind of an academic discussion in reality.

MR. ROSS: Frankly, I don't know enough about risk and what risk-based regulations look like right now. I cannot really address your concern.

MR. GARRICK: I am not too comfortable with these two slides. They do not seem to me to be too relevant. We will let them go.

MR. POMEROY: Validation, just to throw another thought into this, validation is a very real question to a lot of people, and it will be thought out, I am sure, in the context of the high-level situation before it is finally -- it never will be resolved, but finally adjudicated, at least.

Fred, thank you very much.

MR. ROSS: Thank you.

MR. POMEROY: We will move forward.

This presentation is by a number of speakers on the status of test case analyses. I believe it will be led by Mr. Cady.

I would like to just say, while you are putting on the microphone, that we would be especially interested. We understand that during the course of doing the test case you have had difficulties at times in certain areas. And we would like to know if we can something about the lessons learned from those areas, if you can.

[Slide.]

MR. CADY: I will be going through starting out essentially defining what the problem was for the test case.

And then we will start launching into individual sub-areas with discussions by the individuals around here. I will flip the slides and let them provide the moving target.

[Slide.]

MR. CADY: One of our main objectives was to really get everybody up to speed on what performance assessment is, what performance assessment should mean to them in the context of their particular discipline. And so that is one of the incentives for doing this thing in addition to helping us with some of the regulatory issues that we were having questions about such as the time frame, inventory limits and that sort of thing.

One important thing, at least from my perspective, was this trying to focus people on the important processes. We can all sit around in our own disciplines and argue particular aspects of a problem. The bottom line is how does it affect the consequence.

I think we are probably a little bit slow out of the starting blocks getting to the sort of consensus where people felt that they knew what things were -- where we were all headed and that sort of thing. I think we have made considerable process in the last year, year-and-a-half or two years. We get to this thing in the sort of conclusions about the conceptual models and I will describe them. We may bring some up in the process to help you through our little semantics ab ut what individual conceptual models are.

And, finally, we really wanted to test the feasibility that we put into BTP. That is why we were sort of doing it in parallel, trying to test out things that got into the BTP. There may be a little more that's in there than has truly been tested out at this stage, but we are well on our way. And we certainly have jumped head long into the sensitivity and uncertainty analyses segment of it.

As Andy mentioned in his discussion on the BTP, for our problem here, we are not going to deal with the intruder. We are going to deal only with peak dose. And I guess -- let me just call it peak dose. I won't talk about effective dose equivalent or any of those things that I don't understand.

[Laughter.]

MR. CADY: So it is this poor guy that has drilled his well just off -- right on the site boundary. So we are going to try to estimate dose to this individual.

[Slide.]

MR. CADY: The lay of the land for this little test case is essentially slightly rolling topography, a humid subtropical coastal plain environment, precipitation about 50 inches a year, very little runoff typically. Most storms just infiltrate entirely.

Here is the outline of our hypothetical facility. And down here there is a small spring that feeds a small stream.

[Slide.]

MR. CADY: We'll move into some cross sections here.

As I mentioned, it is fairly typical coastal sediments with layered silt, sands, clays. This area is categorized by essentially four hydrogeologic units. In our analysis we are going to be dealing with these upper two.

This silt and clay bed, we're down south of that disposal site near this small discharge area for the stream. So as we come back up flow direction, this thing sort of disappears and becomes muddled. But for our analysis, given the dimensions of the problem, we are dealing only with these two; we don't expect any significant impact of having this lower unit there at all in our analysis, particularly the way we are analyzing the problem at this stage.

[Slide.]

MR. CADY: And a slightly more detailed cross section showing again the upper zone, zone one, to there's this lower unit that seems to be consistent across the site. Really, we didn't have at our disposal sufficient data to even come to these sort of conclusions. And we will talk about that when we get into the conceptualizations.

Essentially, there are a number of different water tables here. But they are all similar, about the same sort of level. Silt, sands and clays interfingered.

[Slide.]

MR. CADY: A sort of a layout for the site -- I cannot get it all on. I will show you the top of that.

[Slide.]

MR. CADY: Essentially, it is 3,200 feet wide, 5,000 feet long and it is broken up into 60 class A cells and eight B and C cells.

Here is a north arrow, and we are presuming regional groundwater flow south toward that stream.

The A vaults have a wide dimension, a wider in the direction of groundwater flow, pretty similar to the B-C normal to groundwater flow.

[Slide.]

MR. CADY: Looking in on one of the B-C diagrams, the dimension is 165 feet. Groundwater flows in this direction in our presumption.

[Indicating.]

MR. CADY: And it is 25 feet wide. In the class A cells, my recollection is 95 feet wide and 142 feet long, similarly aligned perpendicular to the groundwater flow direction.

The rest of this diagram is essentially an engineered cover and they essentially slope to interior drainage ways between the covers.

[Slide.]

MR. CADY: A schematic for the engineered covers as conceptualized is essentially three or four feet thick top soil zone, number of filtered layers isolating a gravel drainage layer with a very substantial three foot thick clay zone. There is a geomembrane in the design. It is not necessarily something that we are going to consider.

Below that is essentially a capillary break layer with a conductive layer above gravel which is going to hopefully function as a capillary break and divert water through this unit number five.

And below that, there is essentially the concrete vault with some bentonite panels that were also not really considered in a lot of the analysis.

[Slide.]

MR. CADY: This section really focuses in on the vault itself. So it is a concrete vault, a little slope on the roof, 30:1 slope, and this would be the capillary break, the gravel layer, whatever, that essentially would hopefully drain off anything through this silt if the capillary break is functioning well.

And with that, we will start through the individual sub-areas for the conceptualization and approach that we have used in the analysis. And Mark Thaggard will provide that.

MR. THAGGARD: My name is Mark Thaggard. I am going to talk about what we did in the infiltration analysis.

First of all, I want to mention that we had two primary objectives which are highlighted on the overhead. The first objective was to determine the amount of water reaching a typical disposal unit. The second objective was to determine the amount of water reaching the groundwater system.

We needed this information to help determine the amount of water which would be available for our diluting the contaminants within the groundwater system. And as you probably know, we need the first information to feed into the source term analysis.

As I pointed out earlier, we wrote the analysis up according to the different time scales. We felt that analyzing the transient processes such as precipitation, evapotranspiration and things of that nature. It was important to consider the transient nature of those processes.

So we use a daily water balance analysis covering a period of 29 years to get a handle on what we considered to be a mean or long-term percolation rate. This 29-year water balance analysis gave us a range of percolation rates which we felt kind of bound the percolation rate at the site, considering that we had a number of wet years in there and some very dry years in there.

Once we attained the range of percolation rates, we sampled from that range and the sample value for a particular run was used as a constant flux boundary for the top of our flow analysis. We used a quasi two-dimensional steady state unsaturated flow model that was developed by NRC staff to analyze the flow through the cover system. We sampled hydraulic properties of the cover materials to feed into this model.

From the model, we obtained basically two values. One value we determined was the flux rate through the clay barrier.

Can you put the other overhead back on now?

[Slide.]

MR. THAGGARD: One value we obtained was the flux rate through the clay barrier. And this value we used as the recharge rate to the groundwater system.

The second value that we attained from the flow analysis was the flux through the capillary barrier which we compared against the saturated hydraulic conductivity of the concrete vault. The lower of those two values we used as the flux into the facility for a particular run.

When the cover and the vault was assumed to be degraded, we sampled values, hydraulic property values which we assumed represented the greater condition. And we also made the assumption that the capillary barrier was no longer functioning at that point.

So what we did was we compared the amount of water reaching the top of the clay to the amount of water -- to the saturated conductivity of the clay and the lesser of those two we compared against the concrete. We only did that when we assumed that the capillary break was no longer functioning.

You can put the other slide back.

[Slide.]

MR. THAGGARD: Just to kind of summarize the approach that we used, we used a 29-year water balance analysis to determine the percolation rate at the site. From that we sampled from a range of values to use as a constant flux in our water flow analysis.

We used a quasi two-dimensional steady state unsaturated flow analysis to model moisture movement through the cover. We sampled hydraulic properties of the various materials which was fed into the model that we used. And once we made the assumption that the cover was no longer functioning completely, we assumed that the capillary barrier was also no longer functioning so we changed the analysis slightly.

MR. HINZE: How did you establish the time for the degradation of the cover?

MR. THAGGARD: Someone in the engineering group can talk about that. They gave us a value. The way we are doing the analysis, we can sample that value, we can specify a range of values. But for the particular analysis we did, we used a particular value, and I will let the engineering group speak on that.

MR. POMEROY: Mark, could I ask you, ultimately this model was used to analyze a period of 500 years, I assume, as well as to the 10,000 year time frame. Does it worry you that you have 29 years of actual data, or are you happy that you've got 29 years of actual data?

In other words, I am thinking of things like in other parts of this agency people use 100-year floods or 300-year something or others and use those as a bounding range.

Do you think the 29 years, for instance, gives you a sufficient range of percolation rates?

MR. THAGGARD: Yes, I really do. A number of reasons.

First of all, we only had 29 years' worth of data. That's why we used it. But the other reason is we had a wide range of variability in the climate data over that particular period of time. We had some very wet years in there and some very dry years.

And in addition, the way we are doing the analysis, because we are only sampling a particular value, we are making the assumption that that value we are sampling remains constant through time. So that, in itself, is a little bit conservative.

For example, if the percolation rate that we sample is on the high end, we are assuming that you are going to be getting that continually throughout time. So that, in itself, is providing some amount of conservatism. In addition, we did auxiliary analysis. Since we did not have additional data, we randomly generated some data and made some comparisons to the values that we came up with and they were fairly close.

I feel fairly confident that the values we got were reasonable.

MR. SINNOCK: I think you answered my question. You do use the same value of flux throughout the 500-year simulation. Did you consider that there might be processes involved in periodic pulses of water that themselves may contribute to a different type of behavior considered in sort of a steady state kind of analysis with a constant flux? For example, things like fingering, perhaps, through your capillary barriers.

MR. THAGGARD: Yes, that is correct. Now, one of the reasons that we believed that you need to use a range of values because to actually try to analyze all of the different types of things that could occur on the very short time scale, the analysis could get extremely complicated. The information that we had reviewed indicated that to really do a decent water balance analysis, you really need to use hourly data. You cannot really use -- you cannot really do an hourly analysis in a PA that maybe covers a couple of hundred to several thousand years; it would get to be very unrealistic.

What we are hoping to do is by selecting a range of values, we would incorporate different things that may occur at the site. We would hope that the range would be broad enough that it would pick up some of those things.

MR. POMEROY: John.

MR. STARMER: John Starmer. I am interested, you sampled, you mentioned several times, and this has come up earlier and I did not ask the question, but you said you sampled from a range?

MR. THAGGARD: Yes.

MR. STARMER: What was the distribution that you assumed for these various variables?

MR. THAGGARD: For the percolation rate, we assumed normal distribution for the percolation rate, simply because it was a pseudo log normal distribution. But for practical purposes, it was a normal distribution. The reason being is because the water balance analysis which we used, which is the health codes, the same analysis that the Texas people use, it calculates mean and standard deviations. It is assuming a normal distribution. So we used the output that we got from that model.

Now, some of the other values that we are sampling, like some of the hydraulic properties we assumed a log normal distribution. And there again, I have to put the emphasis on the engineering group. We got values, ranges of values from the engineering group and basically most of those were log normal distribution.

MR. STARMER: Just to follow on, I assume that based on the approach that you have adopted for addressing uncertainty that you were doing the sampling to address uncertainty in the single value to come up with some value of output and then apply something like standard deviation or some measure of uncertainty to the result?

MR. THAGGARD: Well, that is correct. But it was not just on this particular -- I mean, we are sampling not only in this particular set of analysis but in all the analyses that you're going to be hearing about, like source term data. They are sampling different parameters. It is particular parameters that we have some measure of uncertainty.

And obviously we have some measure of uncertainty in the percolation rates. We wanted to get a range of values for a particular run. What we are doing is we are sampling an assumed distribution. And that value is remaining constant for that particular run.

When we go through another run, and as it was alluded to earlier, we make 30 runs, 100 runs or whatever. The next run it goes through and it selects another value. And so you are getting distribution doses based on the distribution of different parameters. It is not just in the infiltration area, but the other areas that you will hear about.

MR. STARMER: The last question is, how certain are you that these assumed distributions have any validity? In other words, you have got an uncertain certainty, I believe, is something that you are using now to quantify uncertainty. Could you explain how that works?

MR. THAGGARD: Part of it would be hopefully sensitivity analysis would help us in terms of figuring out which of these areas -- which of tnese parameters are really important and which are really critical. And those are the ones we would maybe spend a little bit more time on.

The other item is that some of the items in the infiltration area I think we can be fairly comfortable with because we do have data and we have a large amount of data. Obviously, some of the other ones, you know, there's going to be some measure of uncomfort.

But you've got to keep in mind that the site that we are analyzing is a site that we kind of put together for the purpose of this analysis. And so we didn't really have the luxury of being able to go back and iterate and get more data and build confidence in some of the values that we came up with. We wanted to have some measure of comfort that what we were doing was reasonable. But you've got bear in mind that this was just a test case; we weren't actually trying to analyze a particular site.

MR. POMEROY: I think that is an important point. This is a test case. Some of the -- it is the lessons learned here that we are really after.

And my first question, for instance, was not a very valid one. We are just looking at the longer term question here.

MR. McCARTIN: I just want to say in terms of the distribution, you're right. The selection of a distribution is certainly going to affect your final results. But for the test case, I guess we have the benefit that we're not applying for a license or we don't have to defend a particular distribution.

But, certainly, when you do select a distribution, you are once again making some assumptions about what the data is telling you. And somewhere you are going to have to -- whatever you do, you have to at least give some rationale for that selection, just like the end points of the ranges have to be defended.

MR. STARMER: I would point out that you are giving guidance to a prospective licence applicant to do this. And yet you are reluctant to give a basis for doing it. You should be able to tell people how you are going to do something if you're going to tell them to do it.

MR. McCARTIN: Well, you have to look at the data. Many people would believe that hydraulic conductivity is log normally distributed. Whatever data they collect, if you have no idea of anything, I would say uniform distribution. You just make two end points and let it just sample in between. But then, again, :hat drives the numbers a certain way as compared to a normal distribution.

Whatever you do, I think the bottom line is you have to be aware of how that translates into your results and defend it. But to state it simply, what you are really saying is that these distributions represent your states of knowledge about those parameters.

MR. CADY: Bob Shewmaker will give the engineering overview.

MR. SHEWMAKER: I am Bob Shewmaker. I am in the low level waste area and in the engineered barriers. You have to remember that the term encompasses many things. In the low level waste area, that is really described and addressed in Part 61, somewhat different than Part 60

For our particular test case that we devised in order to exercise this methodology, there were really two elements that our group had to focus on, the cover and the concrete vault. And for both of those, the characteristics that were important and that we felt were important were the permeabilities and the permeability with respect to time; in other words, the durability.

And I would like to point out here that, say, taking concrete as a material that someone might select as an applicant to use as an engineered barrier, that may be utilized in several different manners in a disposal facility. It might be utilized to provide stability which, you've heard already this morning that that was not part of what we're doing in a performance assessment in looking at stability. We try and address that in other ways.

But that material, concrete, could be used to address stability. It can also be used to function as a barrier to water flow and mass transport. In addition, it can also be utilized, people are looking at it, as a reactive element in some sort of a buffered or geochemical environment for the functioning of a low level waste facility.

In this specific area that we are looking at for the vault at this point in time, we are looking at the question of flow transport. So we are looking at permeability.

First of all, our job was really to try and define what range of permeabilities with respect to time should we be looking at. One of the first things you find out is that in the area of concrete there is no standard test for permeability. So you start out, you try and look at the data that are available in the literature that people have developed, and all of that data in many cases is developed using different test methods. You can't even compare numbers. So that is a hindrance to start out with if you're trying to come up with a number.

The other thing that one finds out is that most of those tests that are available and the results that are available have been performed on the matrix of the material, a small sample.

We are looking at an integrated facility that is built in stages. It has joints, it has many other things in it that you have to be able to describe how they are going to function if you are going to address the question of vault permeability.

We have seen this before in the engineering area.

We have addressed the issue of peer review and judgement. We think that it will be necessary in some of these areas to focus on those aspects.

In the engineering world, the people who are directly involved with liquid containing structures, et cetera, do not really worry too much about permeability through the matrix itself. It is the basically the leakage through all of the other places, like joints, cracks, et cetera, not the matrix flow that becomes important.

So what we had to do was to try to come up with an integrated permeability for this facility with respect to time. The same was true with the cover. I will try to explain. I hear the question come up as to: How did you determine how long one of these barriers would last?

In terms of the cover, the main element that we were looking at was the clay, since it is the most impermeable section in the multi-layered system. The element or characteristic that was determined by the people that we had working on this -- and we did have some research and tech assistants in this area -- who believed that root penetration will probably be the cause of the failure in the clay layer.

Based on some studies that have been done in arid as well as other types of sites, including humid sites and depth of penetration, the judgement was arrived at, that we were looking at something in the 700 to 800 year time frame for penetration of that boundary.

In our modeling work, we were using 500. So, this is part of that conservatism that is built in after some consensus or judgement was reached.

In terms of the concrete -- and I might say in terms of that clay, we also gave a set of bounds of what the permeabilities might be. Again, the process was one of performing many runs in the computer simulation with Latin Hypercube sampling in that range of values.

In the concrete, the same type of approach was used. We know there are many models available for theoretical extrapolations and projections of lifetime. They are basically based normally on various degradation mechanisms. But again, as I pointed out, most of the flow is not through the matrix, but it is through other areas like joints.

[Slide.]

MR. SHEWMAKER: So, in the actual test case, it was the working of these two barriers that would be the main controls or limits on the flux that was getting into the vault to the waste. We would work with the "as-built" hydraulic conductivity of the concrete as well as the cover.

In our case we were working with a degraded time frame on the concrete of 100 years with a 50 year ramp to degradation. At that time, since the cover was still functioning, the covers permeability would actually then begin to control the flux into the vault once the concrete had degraded.

MR. STEINDLER: How did you rationalize the time for degradation of joints to be 50 or 100 years? My basement leaked a lot faster than that.

MR. SHEWMAKER: Well, this again, one of the things that we have tried to describe in the methodology is an attempt to make a clear definition that there will be a requirement for testing these facilities before they go into operation.

So, you are left at the front end. You are in the assumption stage. So you want to be somewhat conservative in your assumption. You have to verify at what points you start out. Granted, what you have observed is exactly what we or anybody else bringing one of these forth will face with the general population, in my belief.

People see things like concrete being replaced all the time. To get people to believe that it is going to last 12,000 years is, I think, stretching the situation. What we have tried to do is to look at the history of water stop and joint performance.

There are many failures that you can point to that have happened, as you say, at the outset. The first time that particular joint was tested it failed. There are other cases where a joint like that will perform for 50 years.

There are cases where joints are used on a continuing basis. They will accept the failure because it is in a position where it can be repaired. We only have that capability in this type of facility up during the operational and monitoring phase.

MR. STEINDLER: I guess in my mind that was only a facetious comment. It turns out that my basement doesn't leak all that much.

[Laughter.]

MR. GARRICK: You had better take your contractor off the bid list.

MR. STEINDLER: It wouldn't be bad idea.

But if I had to build an underground vault where the requirement was that the basement doesn't leak, there are a half a dozen perfectly acceptable well-established techniques that will allow you to pour concrete at joints where the joints do not leak, they can't leak because they are constructed -- they are engineered so that they don't leak.

So I am a little confused as to just what it is that you are doing when you say, "Well, there are two ways into this vault. One is through the matrix and the other one is through the fracture." The high-level folks have heard this a million times about tuff.

Then you make some assumptions that maybe the fractures are going to be more important than the matrix which doesn't come as a great shock. But you don't take into account -- and maybe that is an assumption you want to use for conservatism, and that gets me into this question about what do you do for assumptions in the model.

You want to take into account the fact that these folks are not building in your basement or mine. They are building a low-level disposal vault. They can and probably will be held to certain standards on construction. That is a lot different than what we are currently used to.

MR. SHEWMAKER: Let me just relate a little bit of my background. I came up in design and building of nuclear facilities, containments, et cetera. At the time in the '60 and '70s when we were building reactors and power plants, the highest level of level in the concrete area was being placed in those facilities.

I happened to be personally involved in shutting down numerous projects because of the problems. There were many problems that were not necessarily caught exactly at the time of construction. So, I just am afraid that one can always back in and say if something happened, it was a quality problem.

In the water retaining structures that are built from concrete, they leak. The question, then, is: How much do they leak?

MR. POMEROY: Okay. Shall we go on then?

MR. CADY: Kim McCartin will pro·ide an overview of source terms.

[Slide.]

MR. McCARTIN: Okay. In the source term portion of the work, there are a number of aspects to the source term that we felt had the potential, at least, to impact the final dose. For the test case we wanted to include a number of aspects that could be easily included and potentially justified in a PA.

If you look at that first slide, certainly you have heard of the waste classes, "A," "B," and "C." They were treated separately. Then, of course, there are release mechanisms. Three release mechanisms easily came to mind.

The first, obviously, being the most conservative, the rinse release or the wash off. Basically as soon as the water contacts the waste, it is immediately available for transport.

There is also a diffusional release which for the cement solidified waste, you had basically a diffusion co-efficient to control the rate of release from the waste form. Then for activated metals, we had a dissolution rate, which is similar to a general corrosion rate that typified that release.

Next there were three container types. Once again, carbon steel drums, typical for Class A waste. We have steel liners for activated metals, Class B and C, and the HIC containers -- three drastically different containers in terms of the potential for the lifetime that would be envisioned to keep water out.

For carbon steel drums, we assumed a zero lifetime. We assigned no credit for anything being in a carbon steel drum. For the liners, I believe it was a 5 to 50 year range that we sampled over. For the HIC containers, we used a 300 to 1,000 years.

There wasn't a whole lot of that, obviously, to support any of those numbers other than the carbon steel drum which typically everyone knows they leak very rapidly. The other ones -- it was something that we want to give some credit to see. Did we see an impact in our results as a result of that?

Finally, one of the things that is going to reduce your releases is solubility limits. We actually had -- and this would be a case in terms of conceptual models. We would view this as two different conceptual models, certainly using the exact same computer models.

But one was based on the groundwater chemistry existing at the site, some solubility limits. Then we wanted to play the "what if" game. There is the potential for concrete to keep the pH significantly higher than what it would ordinarily would be. A high pH could reduce the solubilities for some nuclides.

Did that have an impact on the result? That, we would view, as a different concept model. Obviously in terms of testing requires very little additional work because you are talking about changing the solubility limits, leaving everything else the same.

[Slide.]

MR. McCARTIN: With that, in terms of the implementation, we used two programs that were contractor-developed. I don't know if this gets to Dr. Garrick's question very early on to John Greeves in terms of the development of the programs and the review of programs, et cetera.

Knowing what we wanted to do, these two programs, at least in our opinion, were the easiest ones to use and implement and also contained features that were extremely beneficial.

Obviously BLT was developed for us, and not too surprising, it has rinse release, diffusional release, and a dissolutional release. It was relatively easy to use. As was mentioned by Ruben Alvarado, it also employed the FEMWATER code. We did not use that part of BLT.

But we made use of NEFTRAN II which was developed for the NRC under the high-level waste program. Although we didn't develop both programs, there is now sort of a hybrid code that we combined in our mind the best features of these two codes.

BLT is now implemented within the NEFTRAN code. One of the main reasons we used it is that it is one of the most efficient computer models for simulating chains of radionuclides.

It was developed obviously in the high-level waste program, as I said, for the situation where you are doing the Monte Carlo sampling and you need a relatively efficient program. So it made sense to adopt that together with --

MR. HINZE: Does that mean you don't have access to the computer time? Couldn't you have used another code and just had more computer time?

MR. McCARTIN: You could. There are other codes that do a few of these features. There aren't a lot of codes that do multiple chains. NEFTRAN is relatively unique in terms of doing multiple chains. It is incredibly efficient. It is just solves the equations very quickly.

MR. HINZE: That does not impress me very much. I mean, just the fact that it does it fast.

MR. McCARTIN: Well, without a sacrifice of quality. I mean, it has been used for the last, I will say the last 12 years or so, both in benchmarking and international arenas, in terms of transport problems.

It typically has always performed quite well in terms of the accuracy of the predictions. In terms of the efficiency, the CPU time, it typically is many, many times faster than just about everything else out.

When you are doing Monte Carlo analysis, one of your considerations has to be, if I have a code that takes two or three hours to do just one part of the problem, then when I add that in, in terms of the total system code, it would be something that takes 10 hours. If I wanted to do 100 realizations, it does become a factor. You have to consider that.

I agree if you are sacrificing quality for efficiency, you are a loser in the long run. But in the past 12 years, NEFTRAN has been used in, as I said, in international efforts. I have not seen it produce results that you really had to be skeptical of. But it has performed quite well.

MR. HINZE: Is there any other code that would do the same thing, but with somewhat different scope, assumptions?

MR. McCARTIN: The only thing that makes NEFTRAN different than a lot of other transport codes is the way it handles chains. It uses a distributed velocity method to account for dispersion.

It is quite similar. I mean, I have to hand it to the people at Sandia that developed it. As I said, it was done 12 years ago. I have yet to see a code come along that was significantly more efficient than it.

It is a pipe model in that it connected pipes, if you will. But you can give them any properties. If you had a three-dimension flow field that could be resulted by a number of kinked pipes, then you could have a quasi-multi-dimensional code. But it is a series of 1-D pipes.

[Slide.]

MR. McCARTIN: With that, in terms of from we learned in using those particular features, where would we want to go next in terms of the source term? First and foremost is speciation solubility data. We saw that. There is no question of that.

As we can improve the solubility data for some of the nuclides that are important the pay-off in terms of final doses, that would be our largest pay-off.

Some of the release characteristics -- at this stage we were very conservative in terms of what we put in as a rinse model. A lot of the waste ended up as a rinse, which means it is all available for release solubility. Those are the only thing that slow it down.

You could see the three mechanisms that we had.

One was cement solidified. The other was activated metals. So everything else was a rinse release. It would be nice to get some more information on some of the release characteristics.

Then also there is going to be other chemical factors in the disposal units due to contamination waste. How will that impact the release? That could add an interesting aspect to the chemical part

MR. STEINDLER: But your entire field of view is fundamentally solution chemistry? You didn't address culverts?

MR. McCARTIN: No.

MR. STEINDLER: You didn't address secondary mineral formations?

MR. McCARTIN: No.

For now, the thought was in terms of the test case. I think we did use it to an extent, was the iterative approach. We started out relatively simple to try to reduce the number of nuclides that are important to a smaller subset and then look at some of the assumptions with those nuclides and say, "Gee, can we do a better job on those?"

Hopefully there is some aspects of the waste streams or waste forms for specific nuclides or inventory loads.

MR. POMEROY: Okay.

[Slide.]

MR. CADY: I will provide the overview of these next two segments. Rather than read you through this, I will put up this little conceptual diagram and hopefully cover the same points in it.

We are presuming potentially water coming in at the conduit. We are sampling these activities for the vaults as well as the covers and deriving a flux through the vault, as well as a flux through the cover.

Conceptually you are going to have uncontaminated water separating these individual plumes coming off individual vaults. So when we really get into the crunch is what happens at this well.

Rather than simulating a concentration at a location in the aquifer at some coordinate, what we are trying to do is dry the concentration coming out of the well. So, in this particular instance, how that well mixes is for our conceptual model the primary mechanism.

People might say, "Well, we are using this stream tube approach," which can be a three-dimensional approach, defining what that stream tube looks like in three dimensions. You can then extract what sort of interception you would have of this well, let's say, with this particular vault and how wide would this interception be, how thick would it be.

You could do that for the purely deterministic flow field analysis, let's say. Maybe you want to run it every time you run a simulation. But you could extract what the stream lines are between this well and that vault and come up with some sort of a contributing area from this vault to this vault, as well as the intermediate intervening water.

So we are not drinking simply leachate coming out of one little plume. There is a mixing going on because of the geometry of the system in three dimensions.

If you want to worry about dispersion, let's temporarily step back and look at this figure.

[Slide.]

MR. CADY: There is this figure. There is the closest vault. There is not a lot of room for dispersion laterally considering that the capture zone, if you will, for this well is extremely narrow. Dispersion would happen at the edges.

Yes, it might be significant when you step way back, but in closest proximity to the vault, you would have minimal dispersion outside of that stream tube, the stream tube coming from that well to the vault.

In the vertical sense, you would have small amounts of dispersion from this plume, or out of the steam tube into this intervening water. But then you are sucking it right back up again.

So how much is that really going to buy you unless these plumes are really separated by considerable distance? Even at that point, there is going to be a fair mixing of that water.

So we don't really believe that dispersion is the problem with this particular type of approach. We are handling dispersion along this stream tube. That shows up in some of the analyses.

MR. STEINDLER: Before you take that off, there is a considerable amount of information in the literature on both the Hanford leaky tanks as well as leaky tanks in industry. None of the plumes look like yours.

MR. CADY: Well, I could refer you in the literature to plumes in fairly humid environs where they would be very shallow. They are not going to spread the entire thickness of this aquifer. They are not going to just come down, hit the water table, and disperse vertically.

They tend to layer like this. I mean, it is a mass conservation. There is a conservation of mass going on here which is driving this. If you want to say that there is dispersion that is going on, then these things are going to sort of co-mingle and eventually disperse into some sort of a hybrid bloom of all three of them.

MR. STEINDLER: So you believe the literature would bear you would as this being a fairly realistic picture?

MR. CADY: Well, not as precise as this because I am dealing only in streamlines.

MR. STEINDLER: No, I understand that.

MR. CADY: But I can show you plumes. I mean, if you see a plume in the literature that looks oval, check the scale. They are typically thin relatively to their thickness, particularly with very short travel times.

Another thing to realize is that we are not talking about a great deal of recharge here. We are not talking about a lot of water massively pouring through the system.

MR. STEINDLER: So then they are old. Is that what you are saying? The plume, in fact, is old?

MR. CADY: Old?

MR. STEINDLER: Yes.

MR. CADY: Well, I think groundwater velocity -- it is a fairly reasonable groundwater velocity. The higher the groundwater velocity, the more they bend this way, and the thinner they become.

MR. STEINDLER: I see. Okay.

MR. CADY: The lower the groundwater velocity, they will mix.

MR. STARMER: Did you do any two or three-dimensional modeling of this system? Do you have any slides of that?

MR. CADY: Analytical?

MR. STARMER: No, not analytical. We have virtually no data. I mean, I have done this model analytically in three dimensions, yes.

MR. STARMER: With three dimensional dispersion?

MR. CADY: No, just simply this model flow, okay, the flow field, not incorporating this version.

MR. STARMER: Okay. Do you feel that you have characterized this site adequately?

MR. CADY: No, I mean that was not the intent. If we go back to the second slide, we are not talking about a site. All right. We are talking about a process. I mean, we are not saying that you have to do it this way. That is not part of this analysis.

We are saying that you want to think through the approach, make a reasonable attempt at matching the scope.

MR. STARMER: Is this what you would suggest that a license applicant submit this to you? This would be adequate?

MR. CADY: No, I am not saying that at all. I am saying that if I were on the outside, my first cut would probably be something like that.

[Slide.]

MR. POMEROY: Just to clarify here, what we are doing here is talking about the conceptualization of a test case that was used to, as I understand it, to simply try out all of the techniques that were currently available within the NRC to see what the pitfalls were.

I wonder. Perhaps we can absorb some of the conceptualizations fairly fast if you can give them to us. I would think that the Committee wants to concentrate on your lessons learned and your conclusions more. So, if we could move a little more rapidly through the conceptualization, that would be useful to us, I think, at this point.

[Slide.]

MR. CADY: All right. For surface water, it was equally simple, perhaps even more simple. We essentially looked at the volume of water again that is involved in the sort of massive stream tube for this entire facility, presuming that it is going to make it to this discharge point, and also presuming that a significant portion of the water that infiltrates between the facility and the surface water, also discharges.

Then if we are still not at a reasonable stream discharge, we dilute it up to a reasonable stream discharge for surface water use.

And now to DOS.

[Slide.]

MR. McKENNEY: I talked about the conceptions before. It's just a rule system. We found after using the usual typical values doing the irrigation and drinking water and household use water needs, one of the most important conclusions in this part really is that water use became a very important factor in the other parts of the model, too.

The approach used was Reg Guide 1.109, which is the basis of a lot of DOS programs out there and with some modification to account for leeching and the root zone, leeching in and out of the root zone during irrigation, and used regionally specific data and then transferred factors from the NUREG-5512.

For any questions on the nonstandardized approach, Research is working on trying to put in 5512 for residual contamination of a site together. It is not just in code form yet. It is out in NUREG, so there is an attempt in the future to have a pseudo-standard for this sort of modelling.

[Slide.]

MR. CADY: All right, so to wrap it all up into one little package, taking each one of these conceptual models, trying to cast those into codes, either fine codes that do fit or create some linkages of our own, this is essentially the flow diagram with the Latin Hypercube sampling driving this entire portion of the analysis, going through the infiltration into flow field simulation.

Once we get the flow field, using the modified NEFTRAN that Tim talked about to determine the source term release rate and then using NEFTRAN again to transport these contaminants down these stream tubes both to the well as to the surface water, at this point then you stop playing the geometric games for the mixing of the individual stream tubes at the well to determine a concentration, in that water pumped from the well doing a similar sort of thing with the surface water and then using a concentration from both ground and surface water, incorporating the dose conversion factors that Chris went through for the entire time series of these concentration and scanning it for the peak dose, going back and doing it. However, many times is necessary.

This thing represents little FORTRAN routines that scatter throughout here in addition to these other models that actually set some of the data up and then there's an old DOS batch file that runs the whole sequence, so it is not as though you are losing something from NEFTRAN. NEFTRAN is still running in its entirety, creating all the output it normally would. It just saves a lot of typing. Regardless whether you were to go through this in a Monte Carlo sense or try to work with a dozen people and come up with reasonable results and go through a number of iterations, it was easier doing it this way, linking things together rather than trying to manually do it.

In summary, this is pretty much where we are at at this point. We have some input data using sort of a composite of real data as well as engineering judgment to get values for the engineering properties and an inventory using the Richland '89 data.

Each of our teams has gone through and developed conceptual models for the site and then we took that and tried to couple the whole thing using different codes to go through the integrated thing as well as allowing these, performing the sensitivity and uncertainty analyses.

At this point we have done too many iterations as well as many, many individual realizations, trying to adapt the approach that is listed in the BTP and determine sensitivity -- to parameters as well as to the multiple conceptual models and we will deal with some more of those multiple conceptual models, if you wish, in Lessons Learned.

MR. POMEROY: Okay, Scott?

MR. SINNOCK: Thank you, Ralph. You have a nice suite of codes together. Do you have any visualization techniques for the site that you have thought about using or developing?

Sometimes these codes get presented as very abstract kinds of graphs, et cetera. If you could actually show some visualization of the plume moving through the site, it may be very useful for interested parties in seeing what the code is actually doing by expressing a plume.

MR. CADY: We are waiting for Sandia to come in with its little DSS. All of this stuff was essentially done by two or three people. Yes, we thought about it but that is as far as it went and that is probably about as far as it will go until we get a link-in with some of the technology that is available on the high-level waste side.

MR. SINNOCK: So no color, 3-D, GIS movie yet?

MR. CADY: Gosh, no.

[Laughter.]

MR. POMEROY: Let's go on now.

MR. CADY: The final two slides in this presentation and then we will move over to the error analysis.

[Slide.]

MR. CADY: This is essentially a wrap-up of the individual efforts by contractors in support, performing sort of ancillary analyses we call them, supporting analyses, feeding into either the data selection or conceptual models, testing some of the implementation of the different codes, that sort of thing.

These provide a reasonable list of those that actually performed ancillary analyses and then continuing with some ground water and surface water contractors as well as overall dose assessment at Oak Ridge.

Phil Reed has a short presentation on sort of bounding analyses for the air pathway.

MR. HINZE: Well, before you do that, let me ask you to go to your first transparency. There are two bullets here particularly in terms of the purposes and goals to develop a better understanding of important processes and to examine the consequences of different conceptual models.

Has that been achieved? What are those, if indeed that has been achieved?

[Slide.]

MR. HINZE: Third and fourth bullet.

MR. CADY: Yes.

MR. HINZE: Have you developed a better understanding of the important processes as a result of this?

MR. CADY: I certainly have. Yes, I believe that we have. At the start of this everybody was all over the place as far as what was driving. What was most important to my little part of the pie. Certainly when we started this I mean that was the only thing that I had any feeling for, and so evolving through this process those sorts of things come out.

MR. HINZE: And what are those important processes?

MR. CADY: We can get to those in the conclusions.

MR. HINZE: I'm sorry if I am getting ahead of the game. I am just curious as to what you had achieved here in terms of what you have learned.

MR. THOMA: That is the next presentation, after Phil Reed.

MR. HINZE: I'm sorry, I thought you were moving to another topic.

[Pause.]

MR. STEINDLER: One other quick question. How many people and how much time have you all spent so far at this?

MR. THOMA: I understand. I took a look at just the test case and the fact that we were all working on the test case for a couple of years at the same time as the BTP. We have total FTE, around 6 to 7 FTE to get to this stage. Contractual dollars I do not have a feel for. That is roughly what it would be costing us so far.

[Slide.]

MR. REED: My name is Phil Reed. I am with the Office of Research in the Waste Management Branch. I am going to be talking to you about the atmospheric transporting pathway and dose estimates, gaseous source terms.

[Slide.]

MR. REED: This is our conceptual model that we used We show the waste forms. We show the radionuclides released from the waste forms travelling up through the interior of the vault. The gaseous radionuclides are then transferred through the soil cover to the atmosphere where they are released and dispersed down-wind from the site.

We are assuming Gaussian distributions and I see that you are missing one slide or one viewgraph. Let me put this in.

[Slide.]

MR. REED: This is the screening approach that we are taking we are assuming basically that the entire inventory will be released for Carbon-14 and we are going to assume the inventory is released over one year.

We are not going to be taking any credit at all for any of the waste streams that would be in the bulk of what would have the tendency to perhaps decompose and release gaseous waste forms. We are not going to take any credit for any sorption or any partitioning, no Henry's law calculations, and we are not going to take any credit for any soil interactions.

We are not going to take any credit at all for any other pathways. We are going to do the calculations, two types. One, we are going to use a simple point source, and the next one we are going to use an area release, using an EPA model. We are also going to use simple transport exposure. We are going to use a single transport line, straight line, and also we are going to use a 22.5 degree sector. In an advanced case we are going to use a multi-directional classical wind-rows or dose-rows, 16 wind sectors.

We are going to calculate the inhalation dose and if we were going to calculate the dose for Krypton-85, of course that would be submersion dose.

MR. STEINDLER: Is your tritium in the form of water?

MR. REED: It could be. There's tritium present in the 21 waste streams that we analyzed. Tritium is present as some water. It's absorbed on ion exchange resins. It's distributed in DAW-type waste.

We are making no distinction as to what the chemical form is, as the HT, HTO. We are just assuming that the maximum is going to be released.

MR. STEINDLER: But it is not tritiated methane?

MR. REED: I don't think so. I don't think we have too much methane in the tritium.

MR. STEINDLER: The Carbon-14 is CO-2.

MR. REED: We are basically assuming in an oxidized form it would be CO-2, yes, although we are not making any distinction between CO-2 or CH-4 or any other form.

The computer code descriptions that we're going to use I've listed three of them and I have listed also the GENII code for calculating dose.

The first code is a real basic. This is the type of code where you would do the back of the napkin calculation. This code only calculates the chi over Q values. It's the same type of equation that we use in reactors where we calculate the chi over Q based on routine or accidental releases.

You have to supply the breathing rate, the total activity, and the dose conversion factors and essentially this can be, like I said, either on the napkin or you can do it on a spreadsheet.

The second code that I listed up here is CAP88-PC. This is an EPA code. This is a pretty sophisticate code. If you are a meteorologist, you call it a meteorology code; if you are a health physicist, you call it health physics code. It incorporates the entire NRC Reg Guide 1-109, the pathway analysis. It incorporates site meteorology data. I shouldn't say "site" -- I should say it incorporates a database that includes the meteorology data from most major cities within the United States and it also allows you to incorporate your own meteorology data.

It calculates doses. It calculates risks. It includes vegetation data. It includes data from milk production and other types of information on cattle, et cetera, et cetera. It also calculates the doses on the basis of the 16 wind-row sectors, so it is a very easy code to use in that aspect.

The third code was mentioned this morning. This is a series of codes that EPA has put out. This is PRESTO-II but we also use the PRESTO EPA code. This incorporates an atmospheric transport code that is the sister essentially of the first code. They were both developed by the same individual at Oak Ridge National Laboratory. It is single sector code and one can calculate the release points down-wind.

The third code is not so much an atmospheric code as it does provide, it does do a little bit of atmospheric releases but the nice thing about it, it does calculate the wind-rows pattern so that you do get the 16 point sectors if you are interested in this particular area.

There is a slide that you are missing and that is the parameters and the code input that I used in the particular calculations.

[Slide.]

MR. REED: Basically, very quickly the

calculations were done with Carbon-14. The curies that you see up there are the actual curies taken from our inventory. They are the sum of Class A, B and C. We did not distinguish between classes.

The other data that was supplied to us by meteorology was the wind speed, which is 3 meters per second, forward down-wind, and also the stability class. All of the other parameters in the CAP88 were calculated by the model for that particular location.

[Slide.]

MR. REED: The results of the calculation are shown in this viewgraph, the X axis is the distance down-wind from the center of the facility; the Y axis are the doses. This is the effective dose equivalent. The vertical dash line that you see is the line that is 100 meters from the facility boundary and the horizontal line that you see is the NRC dose limit.

The top two lines are the calculations based from the very simple model. The first line is the actual straight line. The second line is the 22.5 degree sector. I might mention that these are also surface releases but the models do have the capability of varying height.

The third calculation is the calculation that was done with the CAP88 that provides wind-rows type sectors and it will allow you to essentially disperse or dilute these values in the first two curves.

As you can see from the curves, most of the data that we calculated at the 100 meter is well below the NRC limit of 25 millirem.

In addition to the 7,000 curies released per year we also did other calculations ranging down to releases of about 10 to the minus 3rd curies per year.

We have compared some of these calculations with the calculations that Oak Ridge National Laboratory did as part of a technical assistance contract and an assessment. In all cases the results agreed.

[Slide.]

MR. REED: For Krypton-85 and tritium we can do the calculation. We did it for tritium but there is an easier way to do it. The reason for the easy way to do it is to take into account two things: the half-life of these individual radionuclides and also the good engineering that will be done and also the good cover design.

Krypton-85 and tritium have very short half-lives, as we say. Krypton-85 has 10-year half-life; tritium has a 12.3 half-life. The activity initial values that you see are the actual activity values in our inventories and essentially all we did was decay the values down to the point of about 300 years, which is the lifetime of our facility, a good engineering design facility, and from then you can see that the activity levels are very small, so much to the point that we could probably disregard them.

If we went out further and if we had a good facility design, in 400 years this line would essentially go down to zero.

For this particular case we feel that this is a good approach and we would probably not consider tritium or Krypton-85 further.

We are in the process of looking at Radon-222.

[Slide.]

MR. REED: Unfortunately, Radon-222, as was mentioned this morning does cause some concern about determining the actual activity level. Radon-222 is a daughter product. It is daughter of Uranium-238. Uranium-238 decays into Uranium-234 which decays later on into Thorium-230, decaying down into Radium-226 and Radon-222 is a daughter product of Radium-226, the short half-lived daughter of a long parent -- therefore it is always in secular equilibrium.

In addition to that, to complicate the problem we have some Radium-226 as a source term or as the inventory, so the question is what value Radon-222 do we use?

Well, we are going to go out to the 1000 year, look it up in the graph, and find that we have approximately 5 curies of Radon-222. That is the point that we are going to work with. We have not done the calculation yet, but if you were taking some reasonable estimates and seeing some ball park numbers, you might want to say, well, we have got 5 curies. We have got a volume of anywhere from 10 to the 5th or 10 to the 6th cubic meters, on the metric system. That works out to be about 5 maybe to 50 nanocuries per CC.

When I was doing a Radon-222 that used to be the limit of detection but I suspect now it's probably a little higher. However, if you look at 5, maybe 5 to 50 nanocuries per CC and you compare it with the EPA limit of I think it is picocuries per litre now, we'll see that we have maybe three, four, five orders of magnitude lower rate on 222 than what we might expect if you were to do a comparison to EPA standards.

Although we haven't done the dose calculation, it is reasonable to expect that for off-site purposes that Radon-222 may not be a problem. On-site it's a different story.

[Slide.]

MR. REED: The conclusions that we can draw from our analysis are, number one, we think the screening process is effective. We think simple models are acceptable. We think single sector direction is adequate. We think point source models are adequate. If you want to use an area model you will get more resolution, and finally, we think that deleting or decaying Krypton-85 and tritium is an acceptable way to determine whether or not we have a major problem with these two isotopes.

That concludes my presentation. Are there any questions?

MR. POMEROY: Thank you, Ralph. I'm sorry, Phil.

MR. STEINDLER: You indicate your models are acceptable, adequate, appropriate and effective. Compared to what?

MR. REED: Compared to the manner in which we did the analysis and in comparison to our dose limits.

We made an effort compare most of our calculations to our dose limits of 25 millirem. Therefore, that is one way.

The other answer would be that we believe that the amount of Carbon-14 that we have in our facility is quite excessive, perhaps compared to some of the other inventories. I noticed that looking through the Carbon-14 inventory in Texas it was much less. We think we do have an advantage in that aspect and I think the other thing is that we have released everything within one year. In reality, I don't think we are ever going to see a release rate of 7000 curies per year so with that approach and comparing it to our dose limits we think that is a reasonable acceptability.

MR. STEINDLER: Are there any data from either

U.S. sources or otherwise that would allow you to determine whether or not gas transport rates, for example, that you are using, are realistic.

MR. REED: There are some data that have been developed for the West Valley site, which is in New York, which closed several years ago. They have determined Carbon-14 releases at the site as well as tritium. However, it should be kept in mind that we do allow releases.

NRC allows releases up to the acceptability. However, the problem is at the site of West Valley one of a kind. Those conditions are no longer going to be used. The methods of disposal are no longer adequate. It is a site that is much different than any of the other sites.

I suppose you could use those numbers perhaps as a maximum release or a bounding condition. Certainly the numbers are there and we could always use those numbers.

MR. STEINDLER: Have you tried to model the West Valley site?

MR. REED: No, we have not. The West Valley release numbers are extremely small. The values, if I am not mistaken, are in the range of 10 to the minus 3 or 10 to the minus 4 per year, plus the fact I think that there are inventories much less than what we have here so even if you took that and integrated that throughout the entire year, your release rates would be much less, I believe, than 7000 curies per year.

MR. STEINDLER: I understand that, but you are exercising composite modelling here and now you have an opportunity to compare that to a situation in which you have actual release data, however small I assume to be reasonably accurate. It may well be that you have enough basic information from the attributes of the geochemistry and geology of that burial area in West Valley to be able to determine whether or not your models will give you the right answers, so to speak.

MR. REED: Well, we had planned, and of course in a screening process it is a tiered approach, we did this maximum. The next step would be to go down and look at the waste streams that could be composed and the next step would be to go down to look more at the mechanistic approach and to look at actual numbers to see how they would vary.

If it was determined that the dose calculations were fairly close we would make every effort to do that. We have not done that but it could easily be done.

MR. CADY: If I may chime in here, Mr. Chairman, we were able to do a back of the envelope comparison of the West Valley release rates as part of this whole process. We did look at West Valley.

You would have to assume that there is an extreme degree of biodegradation occurring at West Valley, which would be appropriate for comparable disposal systems. Given the high pHs that might occur at this system you have to keep that in mind, it may not be, but if you scale West Valley for our inventory, which is rather large, 7000 curies, you are looking at a release rate on the order of 4 or 5 curies per year. As Phil has pointed out, this bounding calculation will release the entire inventory of 7000 curies in one year, so based upon just that simple comparison of kind of the actual release rates going on at West Valley with the type of inventory released still we can demonstrate compliance with the standard.

MR. STEINDLER: I guess I am not getting my point across but it is five minutes to 4:00 and I am not sure I want to continue, but my point was that you are using a model, a hypothetical situation, the 7000 curies, et cetera, but you have got a live site for which you have release data for which you also probably have some decent geochemistry data.

Now the question is, why not take that model, look at the West Valley site, compare what you get with the actual numbers that somebody has measured at West Valley? That is my only point.

MR. CADY: We looked at the numbers, Koonz and other papers where they evaluated the releases. For radionuclides from West Valley is answer is less than a few curies per year or on that scale.

MR. STEINDLER: Does that match with the analysis?

MR. CADY: For the West Valley situation if you scale that type of release rate to our inventory of C-14 and assume it is all available, then you get a few curies per year.

MR. GREEVES: I think you are asking the question, it's almost a validation of a model at that location, not using the 7000 curies.

MR. POMEROY: Let's move on.

MR. CADY: We would have to use --

MR. STEINDLER: You don't have site specific data?

MR. CADY: We would have to go down and do the model for West Valley.

MR. STEINDLER: Exactly.

MR. CADY: We have not done that.

MR. STEINDLER: That was my question.

MR. POMEROY: Phil, thank you and I apologize for the misnaming.

This is an appropriate time to take a break so we will reconvene at five minutes after 4:00.

[Recess.]

MR. POMEROY: Let's reconvene, please.

We are now going to move on to the next topic which on my slide grouping anyway is listed as general observations and conclusions from the test case studies. And Ralph Cady is going to lead that discussion also, I believe.

[Slide.]

MR. CADY: These are some examples of what we have been referring to as conceptual models, multiple conceptual models. For example, we are handling the cover performance out past some 500-year time frame. And in one case we're allowing that cover with its all its intricate layers to be fully functional. Except that we have modified the permeabilities of each layer. That being one conceptual model for the performance of that cover in some sort of a degraded state.

Another conceptual model of the same thing would take no credit at that lower capillary break. Essentially saying the capillary break fails and the only thing that you have is the diversion on top of the clay in that upper drain and then percolation directly through the clay.

A third conceptualization of how that thing might perform would limit percolation, totally ignore those upper and lower drains and the capillary break and limit percolation for the sort of degraded conductivity of the clay. So in that sense, we have been calling them conceptual -- different conceptual models of how that thing would perform.

I don't know which one's right. We know which one we would like to be right depending on which side of the aisle we sit. That is one possibility.

On the other hand, similar to the -- I guess Tim probably referred to it earlier talking about the solubilities, varying solubilities from a concrete buffered state to a groundwater buffered state. Or including some modifications to account for organic complexity.

In addition, we might imagine three ways to handle the mixing at the well. And you can do the -- so to look at the geometric gains, that first figure, and then constrain that by sort of a well stream, say, is 10 feet long and if a plume is a foot think and interplume is two feet thick, well then you're going to have a few plumes potentially intersected by the well. And so that would define some sort of a mixing capability just due to the vertical geometry.

And then, full blown, you would look at the capture zone from a three-dimensional flow analysis. So that could be three conceptual models and there would be the fourth, there would be the full-blown invective dispersive model for flow and transport to the well.

So we have tried to essentially touch all three of these with different analyses, just to play games, see how important they turned out to be. And that's the sort of thing we're referring to as conceptual models.

MR. POMEROY: As I understand it, you have done these analyses; is that correct?

MR. CADY: Yes.

MR. POMEROY: So for your cover performance in its degraded state, could you tell us, you know, are there several orders of magnitude difference between the specific cases you've looked at, or is there no difference? Is it -- does the cover performance make a difference?

MR. CADY: In certain cases, if you treat the cover -- if you assume that that capillary break will function for all time, it works great. I mean, it diverts a lot of water away from that vault.

The problem you get in when -- if you feel you have to go out hundreds and thousands of years, well, soil morphology, soil genesis is telling you that things are going to change in long time frames. I mean, soils will evolve with time, particularly if they are moist. So things are going to change, hydraulic properties are going to change, moisture characteristic curves will change. We don't really know what they are going to evolve into.

So that's sort of why we were driven down to this lower conceptual model as being the most conservative.

MR. GARRICK: I guess this is an example of where I would begin to dislike the concept of assumptions. Now in a real performance assessment, what we really want to know is how will the cover perform. In other words, the emphasis ought not to be on assuming one life versus another. The emphasis ought to be on assessing the integrity of the cover as a function of time.

And I hope -- you know, I hope we're not losing that. I hope we're not just -- what we're trying to do, it seems to me, is to understand how good a repository is by way of performance assessment.

And I understand this is a test case and we've got other goals and other objectives. But I am also trying to put myself in the position of the applicant and ask him the question, what is this going to mean in terms of what I have to do in order to comply. And I guess one of the things that I am anxious to see with respect to this whole test project is what you have learned about two categories of mechanisms, transport mechanisms and retardation mechanisms. And how that is going to be translated into something that is going to make you a better regulator or how is it going to be translated into something that is going to provide guidance, genuine guidance to the applicant. And a key element of all of this is analyzing the effectiveness of these various barriers as a function of time.

MR. POMEROY: If I can go on with that just a little bit, sensitivity analyses imply to me that you take some system, some relatively physical system, and you vary parameters in such a way as to find out whether or not that variation is going to be significant to you, whether it is next year or whether it's 500 years from now or 10,000 years from now.

What I am asking here is, if we have done all these sensitivity analyses, what do we learn in that context for these sensitivity analyses?

MR. CADY: In that case, that is a perfect lead-in for this next series of slides.

MR. STARMER: Before you leave that one, I am being sandbagged by the chairman.

The implication of your second bullet on the solubility of radionuclides is that you do not now have the capability of considering the interaction between concrete and the path through the concrete by groundwater and the groundwater constituents. So you are not looking at mineralization, for example; is that correct?

MR. CADY: No.

MR. CAMPBELL: What we are doing is looking at -- and this is part of an ongoing technical assistance contract with PNL -- is looking at the geochemistry of a concrete buffered system and its interaction with groundwater and the effects that would have on radionuclide solubilities and also possibly absorption parameters within the facility.

As part of that analysis, one will come out with the formation of secondary minerals that will precipitate out of the solutions. So as part of this analysis we looked at ongoing work done at Harwell Laboratories in Great Britain for some of the systems that they have worked on. We have also looked at other work in other European countries.

We used, as part of the test case, the database developed by the Harwell Laboratories as a starting point because it was an internally consistent database where they did a fair number of experimental projects to try and confirm the modeling.

In terms of what the staff is doing, we have asked Pacific Northwest Laboratory to look at these two different models, if you will, one in which you have essentially the groundwater of the site controlling solubility, which might correspond to a very high flux of water through the facility perhaps in an advanced state of degradation and also to look at the effects of concrete buffering and cement buffering.

And the problem that we face in trying to mesh the two of these into a single model is the uncertainty with respect to how long and at what point in time does one make the transition. And the mechanism of implementing that within a code is fairly severe.

And so what we ended up doing was looking at these two possible effects and then PNL is also going to be looking at the effect of mixing of the two, the groundwater coming into the facility, interacting with the reactive components of the cement and the effects that might have on solubility. And then the lechate possibly coming out of the facility and further interacting with the groundwater.

There are big contrasts between the groundwater at our hypothetical site and what might -- what lechate composition with a very high pH and high ionic strength -- the groundwater at this site is very low on its strength, the fluid has a fairly low pH, there is not a lot of carbonate in the soils in our test case.

So that is the kind of approach they are looking at. And it's just -- the work isn't completed at this point in time.

MR. STARMER: Fine, thank you.

MR. CADY: One point I would like to make about the conceptual model is not that we are adopting this because we have no information. We have performed a sensitivity analysis to see how important that element of the system truly is. That element, the cover, is an amalgam of a number of parameters.

So we were trying a series of reasonable concepts to see does that truly have a severe impact on the ultimate consequence.

MR. BUDNITZ: Just to follow up on John Garrick's comment, suppose this is a real design submitted to you by a nonagreement state and it looked like you showed us. Do you now have the capability to model that realistically or not? And if so, what did you learn and if not what did you learn? That's a fair question.

MR. CADY: The point is not to model it realistically. Our guess is --

MR. BUDNITZ: Okay.

MR. CADY: When we get down to the actual sensitivity analysis, the significance of individual components, it's going to sort of drive you to look at the performance in the long time frame for this cover. These engineering properties in the long time.

And, no, we don't have a model for how these things perform over a long time. That's going to be a fairly significant uncertainty in anyone's analysis.

MR. BUDNITZ: Okay. Just to follow up, John, you had said that you thought that one of the important objectives or outcomes here ought to be the best realistic model one could come up with for a performance. That's what a performance assessment is, from which you gain insights. And I was springing from that to ask the question I asked.

Now, you have said, no, no, no, you're not pretending here that you're modeling the performance of that cover as a piece of the performance of that repository, correct?

MR. CADY: That is correct.

MR. BUDNITZ: That's fine. You can't do everything all at once. That's fine. I just misunderstood.

MR. THAGGARD: We did see some auxiliary analysis where we tried to model the cover as realistically as we possibly could. That was a separate analysis outside of this here. And I would probably anticipate that somebody preparing an application might do something similar to get a flavor of helping them with the design of the cover.

I would consider that being more of a design analysis as opposed to what we are trying to do here, which is a PA analysis. There's probably a slight difference between the two.

And I also want to just point out that the analysis that we ran when we tried to simulate this thing as close to reality as possible, we were using computer codes that were running in real time, almost what the gentleman from Texas alluded to in terms of to simulate one bay took almost a day to do the analysis. So the computation --

MR. BUDNITZ: Not 500 years.

MR. CADY: If somebody knew that the degraded state was, how those things degraded, yes, we could do an analysis maybe in real time. We could do it.

At this point, that is the problem. What is the degraded state, what does it evolve toward? That is perhaps a research item.

MR. GREEVES: ..n this discussion I think you are entering the round table almost. I would offer the question. We looked at an interdose process earlier. And it appeared to me to be an upper-downed approach and if you release at all any air and it seems to fit your criteria in terms of a regulatory environment, should you ask the licensee to spend --

MR. BUDNITZ: You walk away from it.

MR. GREEVES: Why should you expect the licensee to spend more money chasing reality.

MR. BUDNITZ: That's right, sure.

MR. GREEVES: Sometimes you're asking these questions about do you know what reality is and it is a good question. But I think we as regulators need to be mindful. Let's chase after the decision process. Sometimes we need to leave the real answers to somebody else.

I hope we are communicating.

MR. BUDNITZ: I will truncate this, Mr. Chairman. I want to make sure there's no miscommunication here.

MR. GARRICK: I appreciate what you're trying to do in terms of establishing the sensitivity of these various areas. But in the end when it comes to licensing time, I think we also as regulators have got to appreciate that even though item A may be much more sensitive than item B, when it comes to performing the fix, when it comes to performing the design or doing the design, it may be much easier to achieve the less sensitive one than the more sensitive one.

So we want to be able to have a mechanism here where there is credit for what you can achieve and what you can do rather than just looking at it on the basis of esoteric parameters and how important those different transport stages are in the overall scheme of things. That's all. I know what you're doing and I think it's valuable.

MR. SINNOCK: Very much along those lines, I think you answered my earlier question about the alternative conceptual models are basically what they are and parameters. And I am still not real comfortable. I think many of tnose differences can be parameterized and evaluated in terms of their effect.

I agree with you, early on you want to do sensitivity studies and see if it even matters if you want to look at the reality. We have to be very careful to distinguish test cases and sensitivity analyses early in the game from guidance that may show up in a generic or branch technical position with statements to the effect of we have to use the most conservative conceptual models that we can't eliminate.

We have to be very careful to keep those distinctions in mind in doing sensitivity studies to see if we even want to consider a model from saying we must take out of the 27 possible combinations there the most conservative of those 27 combinations as our decision basis.

MR. POMEROY: Let's move on if we can, Ralph.

[Slide.]

MR. CADY: I guess I can cover this one rather well. During Bob Shewmaker's presentation, there were a couple of little equations that talked about cover flux versus the flux into the vault. This is the result of 100 different runs. And the real point of this slide is that there is that little model, there is that equation, that says the flux of the vault can be no greater than the flux through the cover.

And if you didn't see that upper limit, that straight line, your conceptual model and result, you know you've got a problem. And that's one ploy fo doing multiple realizations, to see if the thing is working.

And we'll havc Andy talk about the chemistry.

MR. CAMPBELL: This is an example of a plot of the relative contribution of iodine to total dose for the concrete buffered system. If you took a similar plot of technetium 99 for the unbuffered system, it would be a straight line.

And in general what we found is that those radionuclides that were identified years ago in the EIS, carbon 14, tec 99 and I 129 are consistently dominating the analysis when you begin to take credit for reasonable retardation values in the geosphere, even ignoring -- even if you do a rinse release model.

Many radionuclides are simply screened out by looking at what amount to reasonably conservative retardation values in the geosphere, just because of decay.

What we have ended up with is an analysis that is frankly very conservative and so we haven't put doses up there. We have a very large inventory of technetium relative, for example, to the Texas inventory. We're looking at over 110 curies of technetium in B and C vaults.

The reason we have a high inventory of technetium is that's what's reported on the manifests that were received at the Richland site in 1989. And when you scale that up to our facility, that's what you end up with in inventory.

We know that those inventories are based upon, if you will, lower limits of detection scaling factors. More realistic estimates of inventory based upon actual measurements or better models would probably reduce those numbers by about two orders of magnitude if not more. So in comparison to the Texas inventory, we have about 2,000 times more technetium in our inventory than in theirs.

The result, though, if you begin looking at the effect of high pH and reducing environments, technetium itself forms a TcO2 species which is relatively insoluble compared to the protectnate ion which, under more oxidizing conditions, is dominant. And, in fact, that was the basis for the design of a chemical barrier to the migration of technetium for the Savannah River site, the so-called Salt Stone Facility, where they purposefully put a blast furnace slag in a grout mixture to maintain a reducing environment and the grout mixture maintains a high pH for long periods of time to hold up technetium.

So we feel -- we then looked at the effect of reducing the inventories of technetium and iodine. We initially just tried reducing them by an order of magnitude. And the net effect is actually more than an order of magnitude reduction in our consequence or in the dose.

So we feel that through developing a better database for technetium and iodine for these facilities will be an important factor in a performance assessment.

Another important point is that for carbon 14 if you do not take credit for -- and, again, we have a very large inventory that is partly a result of scaling from one year's worth of data at Richland '89 to fit into our facility -- if you cannot take credit for the fact that under high pH conditions you precipitate calcium carbonate and tend to hold that up in the facility that it essentially acts as a sponge as you go from releasing calcium hydroxide in a cementatious matrix, you get a high pH and you can precipitate calcium carbonate in that environment.

If you do not do that, then you are faced with much higher order of magnitude increases in dose from carbon 14.

So what we found, though, is that this is an important factor. What we don't have is a very specific realistic model which would require a detailed design for a facility. Now, we do note that most of the facility designs now are going to concrete overpacks for all waste, both class A as well as class B-C waste. And that in the interior of these concrete overpacks, the intricacies of the empty space, the void space, the plan is to put grout.

And so we don't think that this is completely unrealistic but it is different the way low level waste disposal is occurring in the US than, for example, the British system which has the entire facility as one giant block of grout. So there are some conceptual differences between, say, some of the European concepts and what we are looking at. And that will be a source of uncertainty in a performance assessment analysis.

The other point, and Ralph has got this slide up here now, is the whole issue of time frame, how far out do you need to go in time. And one of the interesting results of being able to look a: a large number of realizations as opposed to a few analyses or compartmentalizing it but being able to look at the entire result is to be able to look at the effects of the different combinations of parameters and how they affect dose.

And this is for the concrete buffer case, so most of the so-called consequence on the left axis is due to iodine 129. As peak doses occur further and further out in time, they get smaller and smaller, and that is an effect of retardation or the combined effects of retardation and lower flux rates at longer time frames.

So, in essence, for a large number of radionuclides you probably do not have to go out for very long periods of time, hundreds of thousands of years, and capture the peak. You may very well capture it within a relatively short period of time.

The one exception to this would be the in-growth of daughter products associated with uranium. We looked at the in growth of radium, we carried a calculation out to 100,000 years. And it didn't continue growing forever.

We were looking at radium in the groundwater. And so we were looking at the well, not the on-site person but the person at the site boundary. And it didn't continue to in-grow for a million years. What happens is eventually you begin washing out enough uranium just through leaching processes that the rate of in-growth from the daughter products is balanced by the washout of uranium. And somewhere around I think it was about 30,000 it peaked.

The interesting result was that peak consistently in our analysis tends to be less than the early peak from the original inventory of radium in the facility. So, again, the practical experience of doing the test cases indicated to us that we are not looking at a million years down the road for a low level waste site. Now, of course, we have 300 curies of uranium in our test case inventory. If you are looking at thousands and thousands of curies of uranium, it might be a different story.

But for this particular test case, we actually would feel comfortable with some sort of truncation, you know, probably 10,000 or 20,000 years, given the fact that we have looked beyond that period of time and we don't see a significant problem.

MR. STEINDLER: How did you get to retardation? You used iodine as a species?

MR. CAMPBELL: For our site, we have a fair amount. It is a southeastern site. We have specifically taken advantage of data developed for the Savannah River site. They measured iodine retardation and a variety of soils under a variety of conditions.

The fact of the matter is iodine is retarded to some degree. I have worked with iodine, iodide, in the laboratory. It certainly is a sticky species when you deal with it.

It doesn't mean that it is -- it is moving like chloride, but it is sticky to some degree. Now whether or not that data is completely accurately wasn't the point of our test case. There is a fair amount of data out there. We took advantage of it. It is an issue that ultimately in documenting the test case, we will have to compare that.

I think in general people assume iodine moves like chloride. From the standpoint of a chemist and a geochemist, that is basically not correct. Iodine is a different beast than chloride. It doesn't behave in the same way chloride does. Iodine under oxidizing conditions likes to sorb onto organic matter. It sorbs onto other surfaces as well.

Now for regulatory purposes we often treat iodine as having no retardation or a zero Kd, or a retardation of one. But in this particular case, we have a fair amount of data.

The other thing to keep in mind is there is a lot of non-radioactive iodine in the environment. You have isotopic exchange processes that are driving that. So, we use the data that we had available to us to do that.

One final point is Chlorine 36 was a radionuclide that we didn't think much about. We included it because it is there in the inventories. Because it has no solubility limit and no retardation, if an applicant can take care of the iodine and the technetium they are still facing a problem in dealing with Chlorine 36.

Now, whether or not it would be appropriate to put -- and it appears to be, at least in our inventory, the reason we use Richland '89 is we could go into that database which is rather extensive in terms of the waste streams and the waste forms and where it came from and so on.

What we found was in our database the original source of that Richland, most of that Chlorine 36 was coming from industry, maybe 80 percent from industry, 5 percent from hospitals, 15 percent from universities and colleges.

Other databases may show that utilities as they decommission will have some Chlorine 36 because it is an activation product. So, as one develops a database, those are, if you will, the red flags to be aware of in terms of the impacts on those.

[Slide.]

MR. CAMPBELL: As a part of the bottom line, these first three bullets are: What is the dose most sensitive to? For all of the runs that we have done, it is the flux of water that gets into and through the vault. So, the cover is a significant player there.

So, the better you can make that model, or a more appropriate model, interesting the next one is percolation through the cover. But that happens to be negatively correlated because that forms that mixing volume of water.

What doesn't get into the vault and can go around the vault and separate individual plumes is going to tend to mix with the contaminated water and dilute it.

Third, is the solubility and retardation for those fairly critical radionuclides.

One point that I might bring up is the point about conservatism. Early on we were worrying about the time of failure of these engineered structures. We just had a little step change for the engineered cover. It went out to 500 years and just failed it.

MR. CADY: So a few of us were talking, and "Well, could we delay that failure over a period of time?" "Yes, no problem doing that." Obviously I figured that that is going to lower our doses and delay the failure, stretch it out. It is going to make things better.

The way our conceptual model works, doesn't work like that. Percolation starts increasing as you fail that cover. It gets to a point where it is equal to the flux into the vault. That is where the peak is. Anything beyond that is going to lower the dose.

I was certain before I did this analysis that I was going to find stuff lower. The conceptualization proved me wrong.

Do you want to talk to this one?

MR. THAGGARD: Yes, a couple of items that we found in the infiltration analysis is that we found out that the clay barrier, the amount of water getting to that clay barrier obviously may have some implications in terms of its long-term performance.

Although we were not trying to analyze the cover design, per se, we starting realizing that if you reduced the amount of water getting to that clay below its saturated conductivity, it may cause the clay to start drying out. It may cause it to degrade a lot of faster.

This is something that PNL has documented. Also some of the people in some of the European countries have found the same problem. So that was just something that we kind of highlighted as something that came out of the analysis.

Also, we kind of anticipated at the beginning of the analysis that in calculating the percolation rate, the recharge rate for the site, that it would be highly sensitive to the timing over which the analysis is carried out.

The analysis that we have done has basically proved what we anticipated. So, we basically found out what we anticipated in that instance.

MR. BUDNITZ: Over what time interval?

MR. THAGGARD: Well, one of the things that we found out is that obviously if somebody goes out and does like Ross mentioned and go out and do these water balances, these annual water balances, for example.

You do something like that out in the arid area. You come to the conclusion that you are in an arid area and your ET is higher than your rainfall, so you can't get any recharge. That is a very poor assumption because it is all very dependent upon the time interval that those processes are occurring. They occur over a very short time interval.

So you really have to take that into consideration. That is something that we were trying to point out.

MR. CADY: Some of these additional conclusions are probably fairly obvious to us. I don't know. I can try to put as many up as I can and see if anyone has either a problem or a question about any of these, in the interest of time.

[Slide.]

MR. POMEROY: I hear none, so why don't you proceed?

MR. CADY: That is the end of our presentation.

MR. POMEROY: Before you go away, there must have been other things you learned, many other things.

MR. CADY: Yes.

MR. POMEROY: We probably would like to explore those a little bit.

Stop me if I am wrong on this one, but I heard you were having a lot of trouble with the models that you were using in the test case to get your conceptualized repository to meet the standards, basically the final dose standards. In fact, that was one of the reasons that we postponed this from October of last year until now.

I guess I would like to know how you resolved that, if that is a proper characterization of part of the problem. How did you resolve that question? Did you look for different models that gave you better answers, or different answers? How do you know that the answers are correct?

MR. GREEVES: John Greeves. They didn't resolve the problems. They go back to John Garrick's paper that we looked at earlier on.

If you have a real site, you will take your state of knowledge, do what you can with that state of knowledge, perform your modeling, and as he suggests, conduct a first pass.

If your first pass shows that you clearly meet whatever your industry or your regulatory regime is meets a standard, then you can stop. You don't have to spend any more effort chasing that down.

In the test case, we don't have that. We don't have a site. I think what we have done is a first pass. What would happen then -- and basically you are standing in the shoes of the developer at that point.

What would happen then is if you didn't meet the standard you started answering yourself a whole series of questions: Do I need a new design? Do I need a different design? Was I too conservative in this set of parameters?

So I would say what we have done is what I believe Dr. Garrick described as the first pass. We don't have a site that we would go back with the second pass.

So, again, I have come to this thing in the past few months. But my observation is it was no point in meeting a standard with the test case. It was more: Can we put these models together? Can we learn some things like the conclusions that you saw up there? If we had a real site, we would be going through the second and third pass.

MR. CAMPBELL: If I may add here, what I was alluding to earlier with the technetium and the iodine is if I were a developer, the first thing I would go back to is the generators and say, "You need to come up with better numbers for these." Simply giving me a lower limit of detection is a problem.

Another feature that -- those radionuclides right now are driving this analysis. Another aspect that really hasn't come out is there are a large number of radionuclides given enormous ranges of solubilities. In some cases, we have plugged into the models. There did not seem to be problems.

An example is: Unless we are missing something completely, we do not see plutonium being a problem. We think we have captured the peak from plutonium. We have used seven or eight decades of range of solubility for plutonium, which encompasses concentrations, if you will, for plutonium in the leachate comparable to what occurred at Maxie Flats. In fact, it bounds that leachate concentration.

In some cases -- I mean, obviously as we work with PNL in the geochemical modeling project, we will come to a more refined set of data to use in the analysis. But the bottom line is going to come down to these mobile radionuclides and how you handle their release.

In many other cases you can deal with just using reasonable assumptions. You can deal with the radionuclides. But i' is the four or so very mobile radionuclides. As I pointed out, the Radium 226 and perhaps other daughters of uranium, are potentially a problem for sites that are anticipating large inventories of uranium.

So, to a large degree, we attempted an initial pass of that simply by reducing the inventory by a factor of 10 for iodine and technetium. What we saw was more than a factor of 10 reduction in dose.

We worked with inventories more like what we see more realistic estimates, presumably from Texas, Nebraska, and so on where you have millicuries of technetium as opposed to a hundred curies of technetium.

The scale of the problem is completely different. So, we are not -- at this point that is what we would do. If I were the developer, I would look at those numbers in a much more -- go to the generators and say, "This is an area that needs to be focused on."

The NRC NMSS has an on-going topical report review of the Vance model which specifically is a model designed to address that issue.

The more realistic numbers of technetium and iodine as opposed to these, would amount to bogus numbers that are based upon, "I can't detect any less than this, so, therefore, my inventory contains this amount" sort of thing.

Now, Chlorine 36, you know, that is kind of a new one on us. It may be just simply because we are modeling as a rinse pulse release. We don't have any sprouting out of that plume in time that we are grossly overestimating the potential for release of that.

That would be another area that we would invest some more time in, in looking at: Are there mechanisms that would give you more realistic release?

We know that rinse release models are conservative. That is why we use them. There are many radionuclides that are perfectly acceptable. You can still demonstrate with compliance for the standards. So, the iterative process has now focused us down on these radionuclides.

The flip side of that is: Is there a process that we haven't though about? I think as we go through the documentation of the test case, we will certainly consider that, not only in terms of source terms, but other areas as well.

MR. POMEROY: Okay. Fine. Thank you. That was very helpful.

MR. REED: My name is Phil Reed. Can I make a comment with regard to that same area?

I think initially you heard that we were going to go into a Phase II. Well, the initial Phase I only looked at some very simple wash-off type mechanisms. In reality, a lot of the radionuclides that Andy was referring to are actually ion exchange resins.

What is important in solubility is not the fact that you have solubility. The important thing is: How long does it take to reach solubility? We have not built into our models yet the ion exchange capabilities for which one would then considerably retard, reduce, or slow down many of these mechanisms that we talk about in just simply wash-out.

For example, we have 21 different waste streams. In looking through the waste streams, Carbon 14 is represented in just about every one of them. The same thing with Nickel 59. Yet we know that Nickel 59 in an activated metal is different than a Nickel 59 in an ion exchange resin or some other ion exchange resin.

So in the Phase II we were actually going to go into several of these waste streams, measure dissolution rates, and get releases from the actual waste streams.

If you lump everything under a "wash-off" mechanism, you get everything in one large sum. Therefore, you always will see a large dose.

So you have to put some of these specific streams in perspective with regards to their actual availability in a low-level waste site. Many times if you generalize, you are going to over-estimate. So you have to be very careful about that.

MR. POMEROY: Thank you.

Are there other questions for Ralph?

[No response.]

MR. POMEROY: Hearing no other questions, thank you, Ralph.

The next item on the agenda belongs somewhat to the co-chairman and to Mr. Gnugnoli, namely a summary of future directions for NRC low-level waste performance assessment.

I am going to take the liberty of condensing this quite a bit unless some member or expert wants to discuss particular areas.

I guess I would like to address to John Greeves, though, first, two years or so ago we wrote a letter with regard to the low-level waste performance assessment program. One of our specific comments related to the development of a strategic plan, in essence.

I wondered if you would talk briefly, John. To go back, we have talked today a little bit about strategic plans. I wonder: Is there a document that is going to outline completely a strategic plan for a low-level waste performance assessment? Do you contemplate anything like the strategy plan or not?

MR. GREEVES: Let me just say that I would direct your attention to the Commission paper we put out back in '92. We called it a program plan. The Commission asked us for a program plan. That is what we gave them.

In some ways that is a strategic plan. We updated that document in '93. We are updating it again even as we speak, a '94 version. It contains the strategy in terms of where we have been, how far along are we, and where are we going.

So, when asked that question, I point to these document. There is no other document called the strategic plan. These are the documents that constitute the strategy. What you are seeing here today is the results of that process.

I would hope you can see that we have come a long way since '92. You identified in late '91 a number of questions. I believe a lot of those questions have been addressed and answered, I hope, to your satisfaction. We have found some additional things that we need to look at.

I like the comment that was raised here earlier. It made some conclusions in what is it that we have missed? So, I hope as a result of this briefing, if you see something else that we have missed, we can hear about that and get it into the plant.

This is a bit of, and appropriately so, a moving target process. If you look at two years ago, nobody was thinking about the SDMP sites. They were thinking Phase II would move on and be more test cases, et cetera.

I have to tell you that having been back only a few months, I can't afford to do any more test cases. So the strategy is changing. The strategy that we are going with is to take these tools, apply them to SDMP sites, and let's get some early pay-off for the Commission, and basically the public, in using these tools.

So it is a bit of a moving strategy. It is best defined in these Commission papers. I would enjoy whatever your comments are on that. I currently have no intention to develop an additional document that is called a strategy. But I would be interested.

If you think we are missing something, I would appreciate hearing that so that we could factor it into our thinking.

MR. POMEROY: But you are planning to upgrade the program plan periodically to reflect these changes such as the SDMP?

MR. GREEVES: We've got a commitment to once a year put together a program plan and update it each year. I think you are gong to find year-to-year a little bit of the correction factor.

The principal one we are making this year is let's move in the direction of helping ourselves over in the licensing case work arena. Next year maybe we will have something that is a little bit different.

Now, these all come at a little bit of a cost. You know, you talked about schedules. It took us a year longer than maybe people thought in '92 to come up with this branch technical position.

If you read the '92 version, you will see something about doing a NUREG for a branch technical position. I will have to tell you. I don't think we can afford to do a NUREG. This branch technical position -- it is a work-in-progress. You have heard where we are on it. I hope to hear what your comments are on it.

Personally, I would like to think that some version of this that gets out there will serve the purpose and we can move on to doing licensing work as opposed to spending a number of "x" number of years turning what is a perfectly adequate branch technical position into a Reg Guide. I don't think we can afford to do that.

So, this is the thinking that I have had, that I have been formulating over the last few months. I would appreciate feedback from you, if you want to suggest some additional insights that you have.

This pattern is going to repeat itself once a year. I hope that we come back here at least once a year and have a session like this, if not more often. We had a lot of material here to cover in one day. I was sitting here wishing we had a little bit more.

MR. POMEROY: Certainly we could have used more time to do that, although I see Georgio wince a little bit over the concept of doing it once a year.

From the last item on the agenda here, there are eight sub-items. Listed are staff resources and other low-level waste PA projected needs.

I think we have a fairly good idea of what we are talking about there in terms of hardware/software and staff resources.

But do you want to add anything to the discussions that have taken place today, John?

MR. GREEVES: I don't think I could add to it. I personally was pleased with the presentation that the staff provided to you. I think as best as you can do in one day, you got a good insight as to what the staff's capabilities are, what their resources are.

And as I said, I have been back only a few months. I see more people work in this issue than the FTE that seemed to pop out when you press the button, which pleases me by the way. It is a little bit loaves and fishes, maybe. I don't know.

But I am pleased with the resources. I can assure you that the Federal Government in general is not in an expansive mode. So, if I can just keep this level of resources and the capability that is here, refine it, and use it in the licensing arena, I think we have done a lot, as far as resources.

Other PA needs -- I think they were on the last set of charts there. We have a few areas that we need to look into. The one about: Are these real inventories of Technetium 99?

Anybody that has been in this business knows that they look inflated. If they cause you a problem, let's chase it back and see whether it is real or not for a particular disposal site.

Coordination efforts with others -- I would hope that the presentations that you heard convey to you the reality which is we are working closely with a lot of the DOE groups, the international groups. This was a comment you made back in '92.

As I say, since I have been back, I think the staff has clearly demonstrated to me that they have made those contacts. They are directly involved. In fact, they have taken a leadership role. We are frequently asked to go out and give presentations to groups to the point where we have to refuse on occasion because we've got to get the work done, too.

With that, the summary and conclusions I would offer is the BTP is a little bit of a work-in-progress. We are looking forward to your comments, states, EPA, DOE, et cetera. We would like to refine this document and get it out for a larger set of comments and basically start offering it for implementation.

There are those four or five policy issues that were in my slide that still need some attention. So, to the extent you have a chance to think about those, I would value the input that you could provide for us.

MR. POMEROY: All right. We certainly haven't forgotten those, John. We have kept them clearly in mind.

What I would like to do now is to turn to our round-table discussion, basically. I would like to return, first of all, to the issues that we have left for further discussion.

Is there anybody that feels honor bound to pursue any of those? John Garrick?

MR. GARRICK: I will make a few quick comments and then lay low.

I want to go back to the earlier presentations where we were talking about capabilities, the branch technical position and what have you, and just make a few observations that came to my mind as we were going through them.

We talked a lot about training, training and modeling or training and probe training. And I guess I just want to stress the point that I hope also in that training process is the matter of how to develop very meaningful scenarios.

I would much prefer a modeler understanding what the physical process was and what constitute a very good structured set of scenarios of the repository than necessarily just knowing, for example, how to operate a code. Because what that does is drive them to understand the code and the scope and assumptions associated with that code and relating it to reality.

I think also on the matter of training I would observe that I was impressed with the meetings that you attend, the training that you receive. And I think all of that is very much appropriate and in the right direction.

I was struck a little bit by the absence of identification of some other institutions that I think are very relevant to the whole performance assessment business, and I am sure they are part of it. I know this isn't considered to be an all-inclusive list, but I am thinking of societies like the American Nuclear Society, the Society for Risk Analysis, for which I am prejudiced because I was once its president, and things that are going on this week like P-SAM out in San Diego.

It turns out that I pushed for this and I am happy to see it. There is a session in that conference now on performance assessment. And the center stage of that will be the work going on at WIPP.

I think these are activities that are very important, especially as performance assessment takes on more and more a risk-based look to it.

I think, on the branch technical position, a question that we got very close to and I just will mention in the interest of stimulating your thought processes on its architecture, and that is I have to ask the question of the compatibility of the branch technical position with the movement toward more and more risk-based thinking and risk-based regulation.

And I am still reminded of some of the discussions of last week at an executive conference here in Washington on that subject, which were very, very interesting. And it seems to me that it is clear that there is movement in that direction and that the branch technical position ought to be compatible, if not stimulating, with respect to that. And I just wanted to mention that.

One discussion that came up that we need to probably discuss among ourselves one of these days is this issue of when do you start doing PA. I happen to be of the school that you start doing it immediately, that you are never in a position where your state of knowledge about a particular site is zero. You always know something. And it is very healthy, in my judgement, to start structuring the problem and systematizing the problem. And I think performance assessment does that.

To be sure, one ought not to take the results to serious early in the process but it does give you -- begin to give you a benchmark from which you can see how you're progressing.

We talked a little bit about some specifics like central tendency parameters and what have you. And I have to agree with my old friend here, Bob Budnitz, that if you have the whole curve, you use the whole curve. But I am also very sympathetic to the fact that in this time when we're trying to embrace the public and stakeholders and bring them into the arena, we have to use -- if these kinds of abstract presentations don't communicate, we have to do something else.

And something else very often is to use a point estimate of some sort. And the only point estimate that carries with it any impact from the whole curve is the mean. So the mean becomes a useful parameter for communication under those kinds of circumstances. But given the option with respect to decisionmaking, the more information the better.

And the only other thing I want to say is I realize that we are here primarily to see to it that the public safety is protected. And that ought to be first and foremost in our whole process of inquiry.

On the other hand, I also like to evaluate these things from a standpoint of guidance to the applicant and what progress is being made to make the applications for repositories, for example, as useful and meaningful as possible.

And one impression I got today, and that's an impression that's not unexpected given that it's a test case and given that I'm a believer of something that John Greeves has already referred to, namely the method of successive approximation. But one would conclude that there is a lot more effort given to mechanisms of transport rather than mechanisms of retardation.

And I think that we want to be careful when it comes to our capability and our training to not be able to deal with that application where things aren't so clear cut with respect to compliance. And that means that you really do need to give some attention to retardation mechanisms beyond perhaps what we heard today and we even saw the ones that were excluded. And that's fair enough.

So I think that's a little bit of a summary of some of my points.

MR. POMEROY: Great.

John, before we run around the table, are there any points that anybody would like to discuss further from anything they have heard today?

People must be getting tired.

[Laughter.]

MR. POMFROY: Perhaps we can start to go around the table if there are no other -- there are none of the issues that you want to pursue further at this point in time. And perhaps we could start down at your end, Scott, if you don't mind.

Can you give us any impressions or thoughts or ideas?

MR. SINNOCK: Thank you, Dr. Pomeroy.

Scott Sinnock, TRW.

I certainly would like to compliment the Staff on what I think is obvious and very significant progress since I was here last in I think it was November of 1991. It is obvious that the team is now starting to speak with the experience of having applied a performance assessment rather than from a theoretical basis of what one ought to look like. I think the test case has been very instructive for you, I am sure, in some of the problems and capabilities and limitations of applying a performance assessment.

I would also like to say I am very encouraged by a movement toward what I would call probabilistic approaches. When we were here over two years ago, I believe the statement was, we will stick with deterministic approaches.

And now we are talking about stochasticaly sampling within parameter space.

I would encourage you to continue the movement in that direction and that perhaps we will learn to deal with this alternative conceptual model issue in what I hope is a more realistic way of accounting for perhaps relative likelihoods, perhaps based on expert elicitation and judgment about some conceptual models that cannot be eliminated but perhaps can be considered less likely than others.

That's one of the three concerns I have. Following further, I would hope that on the second one, besides the treatment of alternative conceptual models, that the exclusion of certain scenarios, sort of a priori such as glaciation, climate change, also be treated as an assessment of what we know. And if there are, indeed, scenarios that we can't evaluate then, perhaps, yes exclude them if you can't say anything.

But I think, for example, climate, considerable knowledge can be had about what the effects of climate might be at a particular site without a tremendous investment on the part of the operator/developer in a site characterization program. I think these could be treated from some fairly standard knowledge in the area. So I would encourage the progress toward probabilistic approaches in that arena also rather than a priori exclusion.

And, finally, along that line, I would encourage a reconsideration of the BTP of eliminating reliance on a barrier, engineered barrier, after a given period of time and leave this to the owner/operator to assess what they think the relative allocation of reliance on various barriers should be in meeting the objectives of the rule.

These three points lead to me, by excluding certain conditions like climate that may be very influential, excluding reliance on an EDS and perhaps what I think is artificially distinguishing conceptual models from parameters what I call a very stylized type of analysis in which we are defining a basis for comparison, perhaps, to a standard but not, as you said, assessing the reality of the situation.

I think that is all right if that is the approach that the NRC wants to take, a very stylized type of analysis that's used across sites perhaps as a basis of comparison to others to see where we fit in the world with a particular site. But we have to be very careful that we are not implying that this in some way is assessing the risk to populations that may live in this area sometime in the future.

And I would just encourage the Staff to give thought to what the purpose of the evaluation of a site is.

Is it a comparative basis or is it really an attempt to get at what that site -- how it's going to behave over time, in which case I think more and more will be brought into the probabilistic assessment.

But again, I want to thank you all for a very enlightening presentation and great progress over the past two years.

MR. POMEROY: Thank you, Scott.

John.

MR. STARMER: I also would like to congratulate the Staff on something that I had thought was needed for about eight years. I am very happy to see it coming to fruition.

I have a couple of observations. And one of them might be that at times the document seems to be somewhat prescriptive in terms of what Staff would expect to see, particularly in some cases where it seems like they would expect to see things that are not normally now done and have not been done for sites that are being licensed by states. One example of that is if we look at the multiple -- what I call the multiple scenario requirement, multiple scenario, multiple conceptual model, development of multiple data sets, I think I am getting a little bit better idea of what's meant by staff particularly toward the end there where it was explained a little bit more clearly than I found it explained.

But in the document there is a request or a statement that, one, the license applicant should consider multiple scenarios and multiple conceptual models. And I guess my feeling today is, after hearing what you had to say about it, is that these aren't really so much multiple conceptual models as nuances on particular conceptual models.

Take the example that was used with infiltration. The performance of the cap or the degradation mechanism was presented as three different conceptual models. I would tend to say that they are nuances of one conceptual model.

If you had no cap, a layered cap, that might be a somewhat different conceptual model. But it was differences in how that model behaved.

Possibly if this was explained up front, it might make a little bit more sense. But I think what might be a little more disturbing if I were sitting here and saying, gee, I just wrote my license application and when I did my performance assessment I, one, didn't really talk about multiple conceptual models but I certainly did not document my consideration of all these models. Because that was very early when I was developing these models.

I understand John's point about starting performance assessment as early as possible, and I think it is posrible at a conceptual state. But to look at the diagram which was this diagram here, I also see multiple parameter sets on top of multiple conceptual models and multiple scenarios.

And I think that if you really think about what you do, this isn't, I don't feel, representative of how this process would work.

I also said, as I mentioned, in some cases it seemed that the Staff was saying, well, this is how we think you should do it. And I think Staff should remember that while, as regulators, you always say, well, guidance is not the regulation and so nobody has to do it. As soon as someone says, this is the way we think you should do it, that is the way the license applicant will do it, mainly because they really don't have time to mess around and do a lot of other things.

Another formula for providing guidance, which can get you to the same point if you know where you want to get to, is to provide to the applicant nonprescriptive guidance which tells them how to provide what you would find acceptable and what justification you would find acceptable for that guidance, for that approach. That's just a sort of a thought.

In other words, rather than telling a person how many monitoring wells to put in, one up gradient and two down gradient like a certain federal agency does, I think it might be more appropriate to say that you need to place a number cf wells in a manner which will give you background information and will intercept any plumes that might develop from your disposal facility.

You can take either approach. NRC in the past has always tended to take a nonprescriptive approach and put more of the weight on the license applicant.

I think something else that struck me during our discussions was -- and I didn't bring this up, but I would kind of like to emphasize it and I guess I noticed it and I didn't quite see what was wrong, there were several cases where positions are taken. Basically, again, from talking to people and hearing what was presented here, I am pretty sure that Staff has a pretty good basis for the position that was taken but it's not explained so well. And it's always easier for someone to take a requirement or a suggested approach to something if you understand why that approach has been written down.

An example was that there is some discussion of the 500-year barrier, why one would only get credit for 500 years for barriers. And even what one might, after 500 years, take credit for. The fact that the barriers really are still there in some respects, they could chemically condition that the groundwater, for example, and you could take credit for that sort of thing.

But if you -- well, Ruben took credit for 300 years. You suggested 500 years. I might suggest 100 years.

But the point would be there is certain basis. You mentioned that the major failure mechanism for concrete barriers, for example, would be cracking. When does cracking start? When does it -- how does it develop?

There was a mention of a 50-year ramping period for degradation. If some of these things were brought out based on your experience, based on the work that's been done for you by contractors or based on your modeling, it might be a little bit easier to take.

The same way with the 1,000 years. I find the length of time and the approach to the length of time used for analysis to be rather convincing. But I know there are some people who would argue that if, as in the DEIS/EIS for Part 61, it was found if you take the inventory that they assume for a low level waste site, that really after 500 years the only thing you have to worry about is intruders, you wonder why you would look for 10,000 years. And perhaps some examples of some of the work that you presented there right at the very last brought up front as a backup or an example or presented in an analysis might be useful.

Possibly, and it sounds as though this may not take place, it is a documentation of the work on your test case and reference to that here as one of the references of the document might be very useful in providing some of this backup. In other words, what did you do, what was your experience, what was your contractor's experience, how did that lead to coming to the requirements or the -- I haven't figured out what you call it -- the guidance that you're providing. Because they always look very much like requirements to me.

And then one last thing, and I guess this is back -- I am going to somewhat take issue with Scott. I am very disturbed that we are going to a probabilistic approach for low level waste. I do not personally believe that in any case that we have an inventory equivalent to a high level waste repository, we're not dealing with population doses but individual doses, there's no way that we have 70,000 metric tons of heavy metal to deal with.

And I think there are other approaches that can be taken, just taking best parameter estimates and then doing perturbation on that and a few simple means would be perhaps better than taking some computer, generating a bunch of what-ifs, which may not actually ever generate the best estimate set of parameters that you would put in your model in the first place would perhaps be a very good approach to take.

MR. POMEROY: Thank you, John.

Bob.

MR. BUDNITZ: I was going to start saying something else, but I have to say I couldn't disagree more with the last six sentences from my colleague on the left, John Starmer.

I believe that the value of probabilistic analysis is that it enables you to look at scenarios separate from the base case.

By the way, the base case is I am going to drive to Dulles and I am going to fly home safely. And then I am going to drive home from the airport safely, which are the two dangerous parts, and then I am going to go to bed tonight in Berkeley.

MR. GARRICK: The latter part is the most dangerous.

MR. BUDNITZ: It will be about 4:00 in the morning your time; I'll think it's 1:00.

Now, if I was thinking about the safety of that thing, I couldn't do it by analyzing the base case; I've got to do it by analyzing the what-ifs. And that can only be done probabilistically because there are a lot of probabilistic things that probably won't happen, some are 10 to the minus sixes and some of [illegible]ich are 10 to the minus threes, per trip. You know, [illegible] co the minus one is something that happens that's a delay that isn't a safety problem but just is a nuisance.

You have got to use probabilities to understand things that aren't the base case. Whereas, to do the main base case, you don't necessarily have to use a probabilistic approach. And so I just have to disagree very fundamentally there.

Now, let me go on to my comments of which I have a bunch.

First, I am a newcomer to this arena. The last time I thought about low level waste in the context of the Nuclear Regulatory Commission was when I was on the Staff, I was actually the director of research and we were developing Part 60 and 61 in parallel. Mike Bell was the branch chief at that time, late '70s, early '80s, '81, '82. I left in '80.

And there was a terrible problem that we had. We meaning it was NMSS but I was in research. Which was to try to figure out how to cast a regulation in place without having had very good analysis of any of the six sites that were running. There were six sites -- well, Maxy Flats had closed down and maybe even West Valley by then, and maybe even Morris. But we had six sites that were running at that time, ultimately became three and now of course only two.

Without that analysis to know what the realistic behavior was, and we didn't have it, research didn't have it, NMSS didn't have it, nobody had it, and the Department of Energy didn't have it, it was ERDA then, in '77, for their sites either. It was very difficult to understand how to write a regulation.

So now here comes my pitch. We now have some realistic analyses of some of the operating sites. We have some reasonable performance assessment analyses of cooked up sites like the one you did and a few of the, for example, on Ward Valley. And there is a lot more we could do along those lines if we wished.

It strikes me as almost the most important thing you can do right now in this Staff except to provide aid to the dozen or so grievance state groups, is to use these analyses to challenge Part 61 and found out where it's weak and where it's strong. And I want to say that in the deepest way.

I want to remind you, I haven't thought about this much, except -- by the way, I have my Ward Valley hat which I am telling you about. But I haven't thought about it in terms of the adequacy of Part 61 in all this time. It could easily be that Part 61 is weak in some areas that you can strengthen. It could easily be that you have found where it is very strong and that is where the concepts of 1979 and 1981 are admirable and you can strengthen them, either with exhortation or with help to the agreement states that have to implement it. And I want to urge that because that's one of the roles that the Agency must continually do.

You can't let it go for 25 years without challenging a regulation you wrote in the old days, especially when you're smarter. Excuse me, you're not smarter; you're more informed. You might even be smarter.

So I think that is a crucial one, and that's just where probabilistic performance assessment has a role to play which is separate from and different from the mainstream analysis of the expected case.

Let me make two or three other points.

First, we mentioned earlier, and I believe it is important for you to recognize that as good as the branch technical position is, and I was surprised how good it is and how thorough it is and how comprehensive and how much it covers and what the advice is and all that stuff, it's great, it is important for you to go through every page and find where the recommendations are or the suggestions.

By the way, there is a hierarchy of must, recommend, maybe, suggest. You know, there is a whole hierarchy of those things which you have in some cases clearly and in other cases you have befuddled them a little bit and there's nothing wrong with that. And for each one, see if you can identify if you know what the criterion is that led you to support whether it's a recommendation or a requirement or a suggestion or only a kind of a -- and by the way, there is the negative of those. You can, you know, not recommend it or suggest against.

And wherever that criterion isn't clear, write two sentences to make it clear so that it's clear why you are strongly suggesting in one area and only weakly suggesting in another area and in some areas requiring and in some areas almost forbidding or saying, you know, don't do that unless.

That will, in a few sentences here and there, strengthen your backup in a way that I know is in your mind but isn't always in the document. Although, by the way, it's often in the document and that's great. But it's not always. And we came to some of those this morning, for example, on the rare events like the volcanism.

Secondly, and I know Starmer said some of this earlier today, it is very important to take care about thinking about the performance assessment as a unit. That is, it's the integration of the pieces at which stage the full comprehension and understanding of what you've got and what you didn't have emerges. And it's real important for everybody working on the pieces to think about the whole, not the parts. In other words, think about how the part fits and makes the whole.

You know, it's not the camshaft in my car that matters. It's that when I get in and turn it on, I drive smoothly. Although the integrity of the camshaft is important.

And I didn't see much that would lead me to believe you weren't doing that. But the guidance document, the technical position, doesn't exhort the user out in one of these state regulatory agencies or perhaps what I'll call a supplicant, you know, the developer, to think about it that way. And you could probably help yourselves and them a lot by the exhortation along those lines. It sounds like exhortation but it could probably be valuable.

Last -- no, I've got two more. There is a long eight- or nine-page section on uncertainty that is great. I thought it was very thoughtful dealing mostly with parameter uncertainty. Only short and I consider inadequate treatment of model uncertainty. You don't have to write nine pages, but there is more you can write than you did write.

If you want to really know what to write, you can go and copy some stuff that's been written elsewhere. For example, with your colleagues in Part 60, who have some very nicely thought out guidance for our Yucca Mountain supplicants on that stuff which you can crib from and probably easily bolster the comprehensive scope of this document in that area.

Last 10,000 years, I am just quoting from 61.7A2, it says, "Site characteristics shall be considered in terms of the indefinite future, and evaluated for at least the 500 year timeframe," and that was stuff that was all written a dozen years ago.

It seems to me that one of the major things that you can do, you, the staff, can do with this performance assessment activity, not only yours but some of the other work that is going on, is to evaluate what in the world you mean by evaluating what you mean by consider, because I can assure you that when hearings come up in states where Agreement State regulators and public and supplicants are all in a hearing together, something we avoided in California, by the way, because our process didn't have it, but it is going to be in other states, those words "consider indefinite future and evaluate for at least 500 years," the words are going to be contentious and, in my view, the whole process with these dozen new depositories coming along, we hope soon but certain if not in five years, in 10 or 15, is going to hinge in some cases on those words and their interpretation, and you could do everybody a benefit by writing clearly what you mean.

How do you do that? You use performance assessment insights to help you understand what you meant, what this means, what the Commission meant, or what really Mike Bell must have meant, or whoever it was. It was Dale

Smith, okay, and Jack Martin, and you know it went up the chain, but it was really written in an ambiguous way because it was 1981. You think it came down the chain, okay. I was in research, all I did was concur.

[Laughter.]

MR. BUDNITZ: We didn't know what we meant. I am being honest, we did not know what we meant in 1980, whenever it was. Probably you will never really know, except on a case-by-case basis, but you can learn a lot from these performance assessments about just what "evaluation and consider" means and give some guidance. That is my last comments.

MR. POMEROY: Thank you, Bob.

Bill?

MR. HINZE: One of my basic rules is never to follow Budnitz, for many reasons, including the fact that he has already covered everything, but let me touch on a few things that I picked up as I read it that might lead to some confusion. One of the terms is expert judgment. Expert judgment is something that we have spent a lot of time on. It is used in several tough places in the report. I think it should be made clear whether you are really suggesting that this be explicit or implicit expert judgment. That is a minor thing, but every time I read it it kind of was scraping fingernails across the blackboard in terms of where it was going.

A similar type of thing that came to mind was, I remember the days when we were worried about mixed waste as part of the low-level waste problem, and if that problem hasn't gone away, I think we should recognize the fact that performance assessment is something that may have to deal with the provisions of the RCRA as well as Part 61.

Another topic that hit me was the lack of consideration of some of the facts that might involve the above ground vault that are in the recent changes to 61. We may very well see a lot more of the above ground vault coming in as the design for our low-level waste sites performance assessment has to deal with those in its entirety, I think.

There are several places where I think that there needs to be some real tightening up of the recommendations and the definitions. One of them that I alluded to previously was this pathways, and when they are significant. Another, in reading through it, when are the engineering barriers of concern and what role do they play. This business of 500,000, 10,000 is touched on in several places. It would be good early on to deal with those issues.

[illegible]ree with everything that has been said about dealing with things like global change. We do have the RCMs, the regional climate models now that are trying to define smaller areas. I don't think that is solving the problem, but I think there has to be a recognition that there are those things. I think it is important that we suggest some means, perhaps, as Bob has suggested, using criteria to define when these items are neglected or not considered any further, and that would go to some of those features which are concerning the stability of the site.

I guess I will leave it at that.

MR. POMEROY: Fine.

Marty?

MR. STEINDLER: Well, being last has certain advantages. In theory, I don't have to say much.

Let me see whether I can organize what to me was a very interesting day along the lines of what I thought we were asked to do. I thought we were asked to do several things. One is to determine what the branch technical position looks like in terms of its adequacy for whatever is its purpose.

Two, I thought we were going to look to see whether or not we can assess the staff capability in the area of performance assessment.

Finally, whether we were asked or not, it seemed to me that it was worthwhile to ask the question, how is the staff doing with the customer, the customer presumably being external to the agency.

In the case of the branch technical position, you have heard a lot of comments. The staff here has heard a lot of comments about this, that, or the other thing. Let me simply say that I had a little bit of difficulty early on trying to find out who the reader and who the customer for this document was. At first I thought, well, this is obviously a generic document aimed at the world at large out there to give them, as indicated in the very early pages, some guidance on how to do performance assessment and what things to consider, and things of that kind.

Indeed, as has been said before, it does an admirable job in many instances. On the other hand, it also turns out to be a non-generic document and provides conclusions or gives guidance in a particular direction that it strikes me if those guidances are, potentially at least, sufficiently site-specific so that you could no longer call them generic. I think that is an issue that is pervasive throughout the various chapters of this document and perhaps rereading from the standpoint of whether things are generic or whether, in fact, the assumptions or conclusions or guidance, tends to be specific, or too specific, might be worthwhile to make it more readable.

Let me address the staff capability, and here I have kind of a mixed signal that I am getting. It sounds as though the staff capability is aimed not at actually doing performance assessment, but being able to evaluate other people's performance assessment.

It isn't very clear to me why the staff, other than for what I would call esoteric reasons, why the staff would even want to do a performance assessment if it weren't for the fact that you can't really expect somebody to evaluate a complex document done by somebody else unless you have some practical experience in the business.

If that is the case, then the exercise that has been gone through here is, I think, an excellent example of starting down the road of having experience in doing a practical case.

The difficulty that I found was that the so-called test case wasn't testing very much except the capability of the staff to pull it altogether, and that is not normally what I guess I mean when somebody says test case. I guess I have that confused with validation and the sundry other words of that kind, and perhaps that was my problem and not the staff's.

I found it impressive, I might add, to listen to the staff in various directions, and particularly in areas that I thought I knew something about, to learn that, in fact, the critical item, namely the staff's ability to understand what is in the literature and, therefore, evaluate either assumptions or actual data are being used by a potential applicant or supplicant, as Bob put it. It sounded to me as though the staff was well versed in what is out there, which is a necessary, but perhaps not sufficient, but certainly a necessary prerequisite in doing an evaluation of somebody else's exercise.

I conclude from that that the staff's ability to actually do a performance assessment that is or will be subject to severe scrutiny as in a licensing adjudication, that has not been demonstrated, nor do I necessarily believe that is a requirement to be able to answer the question which we have been asked, namely is the staff capable. I think, however, there is reasonable evidence that the staff is certainly a great deal better off than they were the last time that we talked about the subject.

Finally, the access to the states and the ability to interact usefully with the states, we have limited evidence. We were very pleased to hear what Texas had to say to us, and I thought it was gratifying for several reasons.

One is, being one of the few if not the only Macintosh person in this room, I was pleased to see that you can do this on a Macintosh as well as some of the other machines that you folks use. It was a portable.

The other one was the notion that, in fact, the staff served a useful function as Texas was going through this exercise. So I think, in that sense, interaction with the customer sounds like it is well on the way, and it seems to me that the staff understands quite well what the customer is in the need of.

I was impressed by the litany of things that the staff is doing to pull itself up by its own boctstraps, and the training exercises that they are going through sound like they are moving in the right direction.

I am not sure that it is worthwhile to comment on too many other things, with one minor exception. We heard a exhortation to reexamine Part 61 in light of the experience from the existing facilities. It is clear that we have made that comment from time to time, perhaps not as loudly as before, but somewhat softly here, and it was pointed out to us repeatedly that the existing sites were not licensed under Part 61 which didn't exist at the time they were either put in place or decommissioned.

As a consequence, the notions that I have gotten in the past and perhaps subject to reexamination is that that exercise may not be as useful as one might think.

On the other hand, if the staff elects to test models that they have either developed on their own or that they know somebody else is using and can find adequate data in those sites, looking at it not from the licensing standpoint but from the physical model validation, my term but not somebody else's, validation standpoint, there it would be nice to be able to pull out the migration to tritium at Maxie Flats, and see whether or not the models that people are using have some reasonable relationship to what you actually find out in the field.

It is going to be very difficult for somebody to stand up in an adjudicatory hearing and answer the question clearly asked by members of the public, how do you know this thing really represents the real world. There it would be very nice to be able to say, well, we have looked at the real world, and here is what we have done, and here are the results.

I will quit here.

MR. POMEROY: Thank you, Marty.

I guess before I start out, I would like to strongly second that last remark. It certainly is going to be clear, when you get to an adjudicatory situation, that you are going to be asked exactly that question, and it would be nice to have a few cases, and perhaps that can be done through, possibly through the SDMP, but it would be nice to have a few actual cases that were associated with low-level waste as well.

I only have a few comments that haven't been covered very extensively by somebody else, but I would like to mention them. The first thing is, it is easy to read this document and not get a feeling that you are talking about iterative performance assessment. I stress the iterative there. I really would like to encourage you to at least bring the word up more often.

Iterative, as John pointed out, starting at the beginning, iterative through the process up to licensing, and iterative as necessary through the operating stage, through the closure stage. It really could come through clearer. It is certainly there in places, especially in Section E, but it could come through more clearly.

The branch technical position, you have heard lots of good things about it, and I would strongly second those. You will certainly see some of those, I suspect, in our final approach to this problem.

There are a few things that I would like to just mention. One of them Bill brought up. You specifically excluded consideration of above-ground vaults and deeper than 30 meters burial, and I wonder if that is really necessary and whether you couldn't take another look at that, particularly the above-ground vaults.

There was also a question of your using what I would consider to be the maximally exposed individual in your dose calculations. If you can clearly identify him in all cases, that is easy, but I wonder what you feel about using a critical group approach, which is the international approach, by and large, to this particular program rather than the maximally exposed individual.

The expert judgment question, somehow I don't think you quite, as Bill pointed out, made it clear enough, certainly both in the screening process and in where you specifically call out the use of expert judgment, which is in a number of the key areas. You should perhaps provide some further input to people or guidance on what you mean by expert judgment in that context and in the screening context as well.

John, you asked two questions that I wanted to end up with, perhaps three questions that I wanted to talk about. The first was the uncertainty approach. I like very much your approach on uncertainty. As Bob pointed out, your parameter uncertainty discussion was very, very good, and I don't think I could even make a suggestion on how to improve that, but I would second Bob's comments strongly that you need to expand the discussion on model uncertainty to some extent. But, as an overall statement, though, it is a nice job.

The systems approach for performance assessment, I think you have done a pretty good job in outlining. I still perhaps -- perhaps it is just me that is confused, but in the modular approach that you are taking, the interfaces between those modules and the potential substitution of other models within those modules, I wonder if you could talk a little more about how that system works for you, and how you envision it working for people that are actually going to be preparing a license application and revie/ing and making licensing decisions on the basis of some of this.

Finally, the timeframe for the PA analyses, I must say I am still not clear in my mind about, and I don't know enough of the justification for some of the numbers that you used and I think I understand the concepts pretty well, and I am sure it is really hard to find justification for the numbers, but it is one of the things that invariably will come up any time somebody begins to look at this and somebody says, well, the NRC said we should look at this 10,000 years, or 20,000 years or 2,000 years, somebody will say why? Why not 2,001 years, or 2,005 years, or whatever. I am sure you put a lot of thought and effort into that, and I don't have an answer for it at this point in time. I really need to think about it a little bit more myself.

All in all, though, I want to both compliment -- I want to compliment you and your staff, both for the presentation today which, as everybody else has pointed out, you have really demonstrated major project since two years ago, and we are all, I think, impressed by that, and I think that it shows in the way that you can present this material today, and I think that it shows as well in the branch technical position.

So I would like to thank you for today.

If anybody has any final comments, if not, we are only going to finish three-quarters of an hour late.

Let me thank you, again, John, and thank your staff. We appreciate deeply the time and effort that went into this, and I hope that your briefing to the Commission on April 1st has no significance. I only mean that in the sense of the date it has no significance.

We are adjourned.

[Whereupon, at 5:55 p.m., the meeting was concluded.]

REPORTER'S CERTIFICATE

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

NAME OF PROCEEDING: ACNW Working Group on Staff Performance

DOCKET NUMBER:

PLACE OF PROCEEDING: Bethesda, MD

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

Barbara Whitlock

Official Reporter
Ann Riley & Associates, Ltd.

TEST CASE MODELING FOR PERFORMANCE ASSESSMENT OF LOW-LEVEL RADIOACTIVE WASTE DISPOSAL FACILITIES

Ralph Cady (RES/WMB), Tim McCartin (RES/WMB),
Chris McKenney (NMSS/LLWM), Robert Shewmaker(NMSS/LLWM),
Phil Reed (RES/WMB), Mark Thaggard (NMSS/LLWM)

for

Advisory Committee on Nuclear Waste
Working Group Meeting on LLW Performance Assessment
Bethesda, Maryland
March 22, 1994

Purposes and Goals of Test Case Modeling

- To develop staff familiarity with the process and staff capability in LLW PA.
- To provide insight important for the resolution of regulatory issues.
  - For example, the time-frame issue.
- To develop a better understanding of important processes in LLW PA.
- To examine consequences of different conceptual models in LLW PA.
- To test the feasibility of approaches proposed in the BTP.
  - For example, the use of formal sensitivity and uncertainty analyses.

Problem

Estimate the peak dose received by the maximally exposed member of the general public (not an intruder). Potential significant off-site transport mechanisms:

- ground water,
- surface water, and
- air.

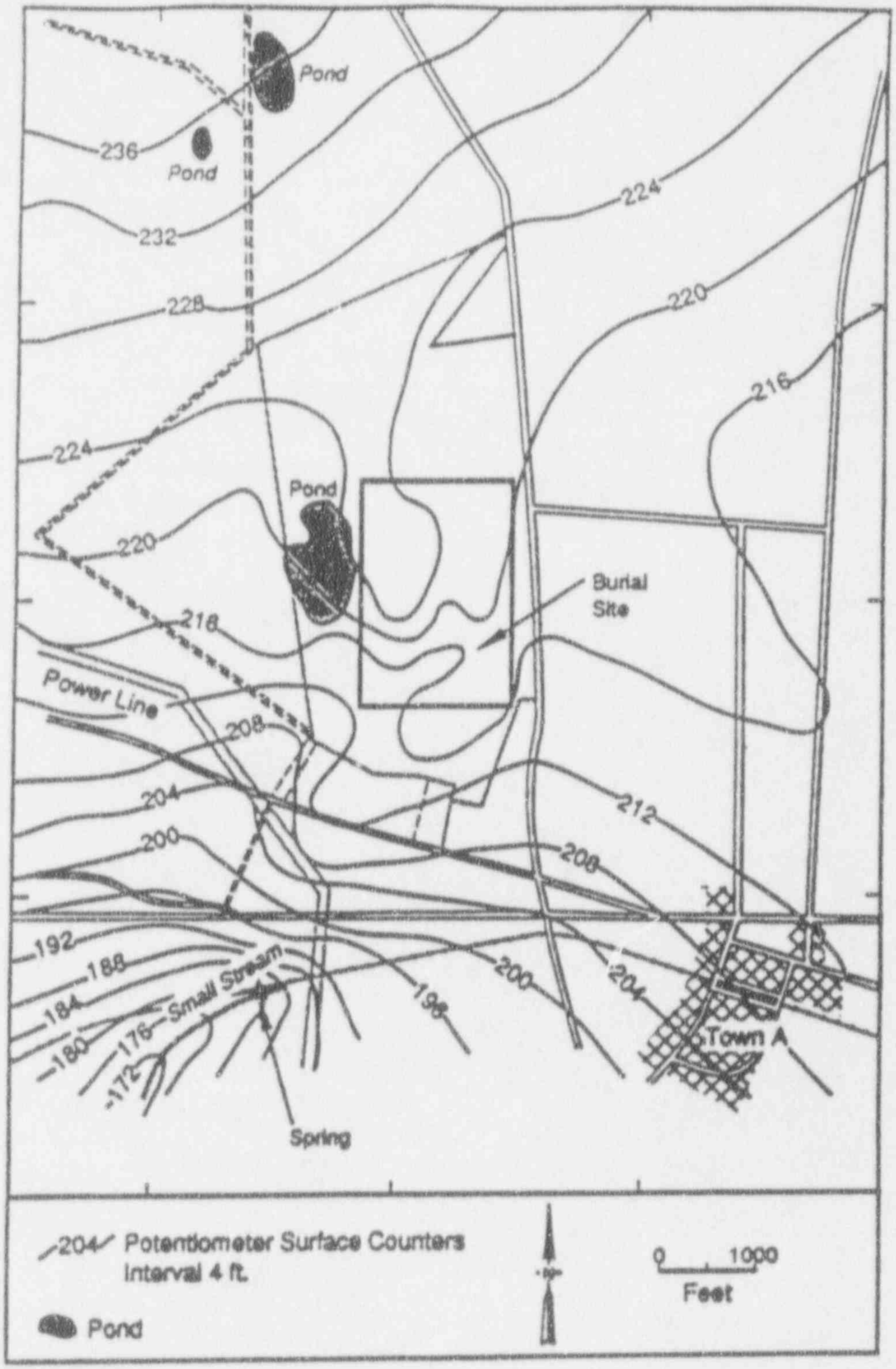


Figure 2.4.8 Potentiometric Surface of Zone 1 at the Disposal Facility

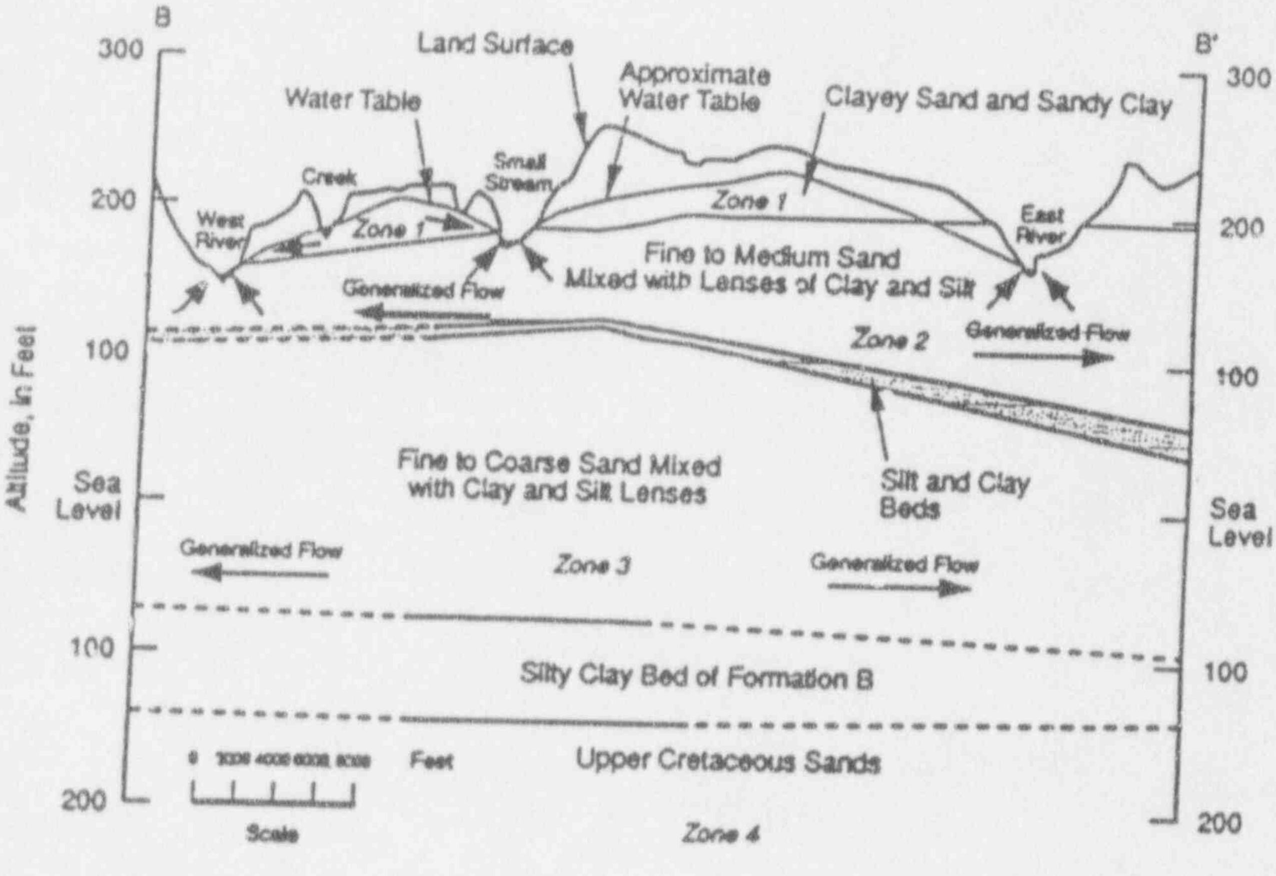


Figure 2.4.5 Hydrologic Section along B-B' near the Waste Disposal Facility.

3

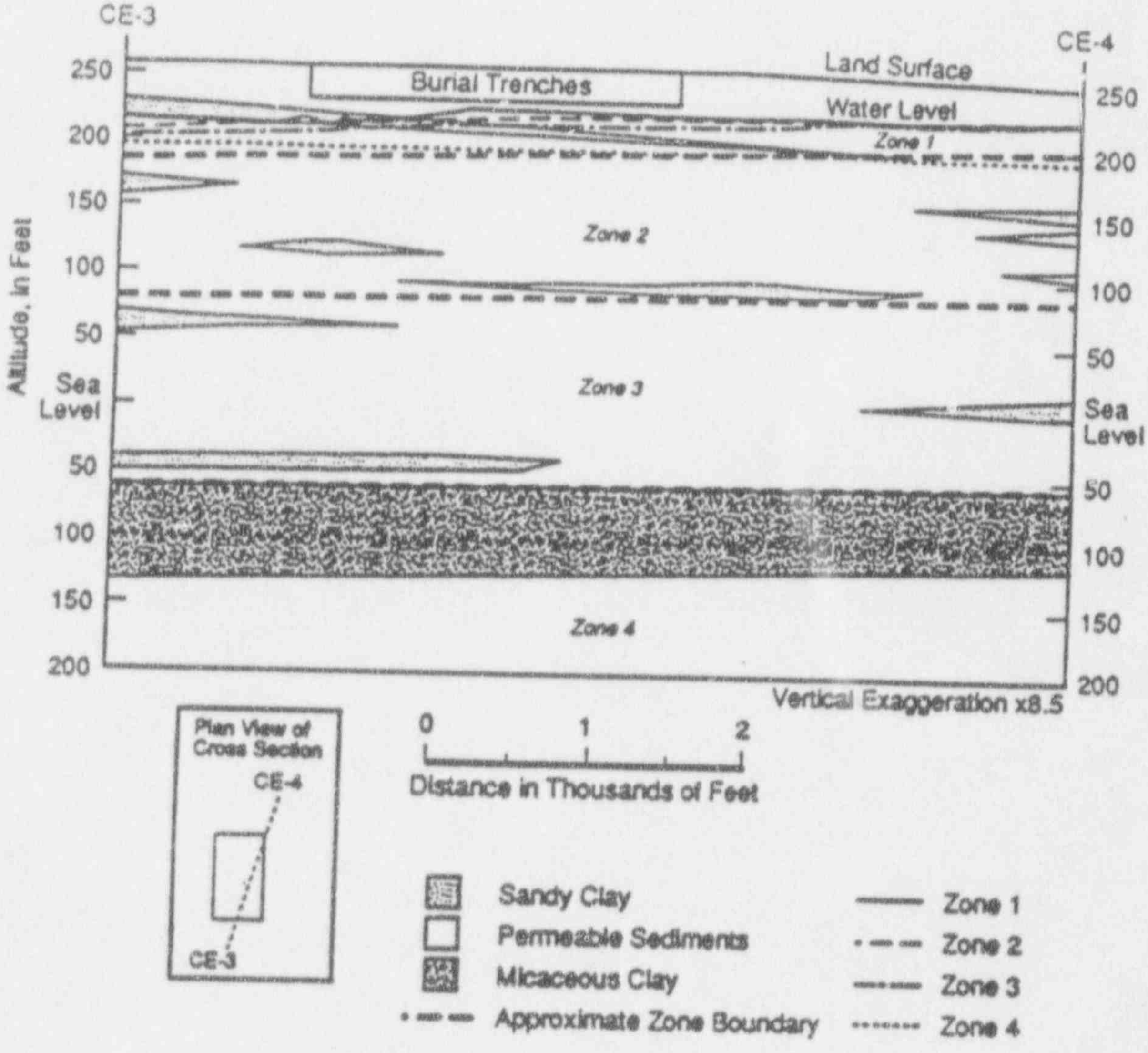
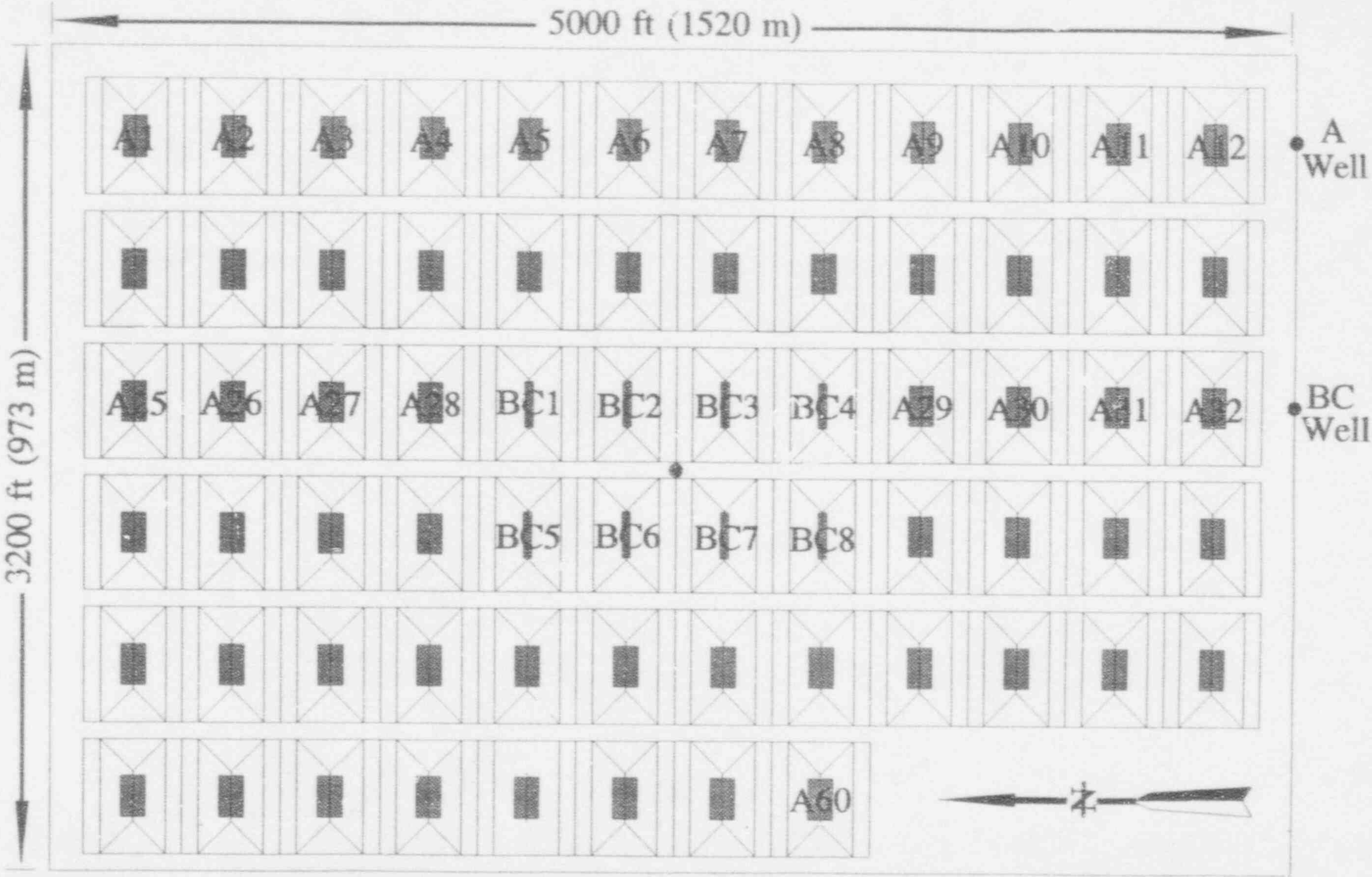


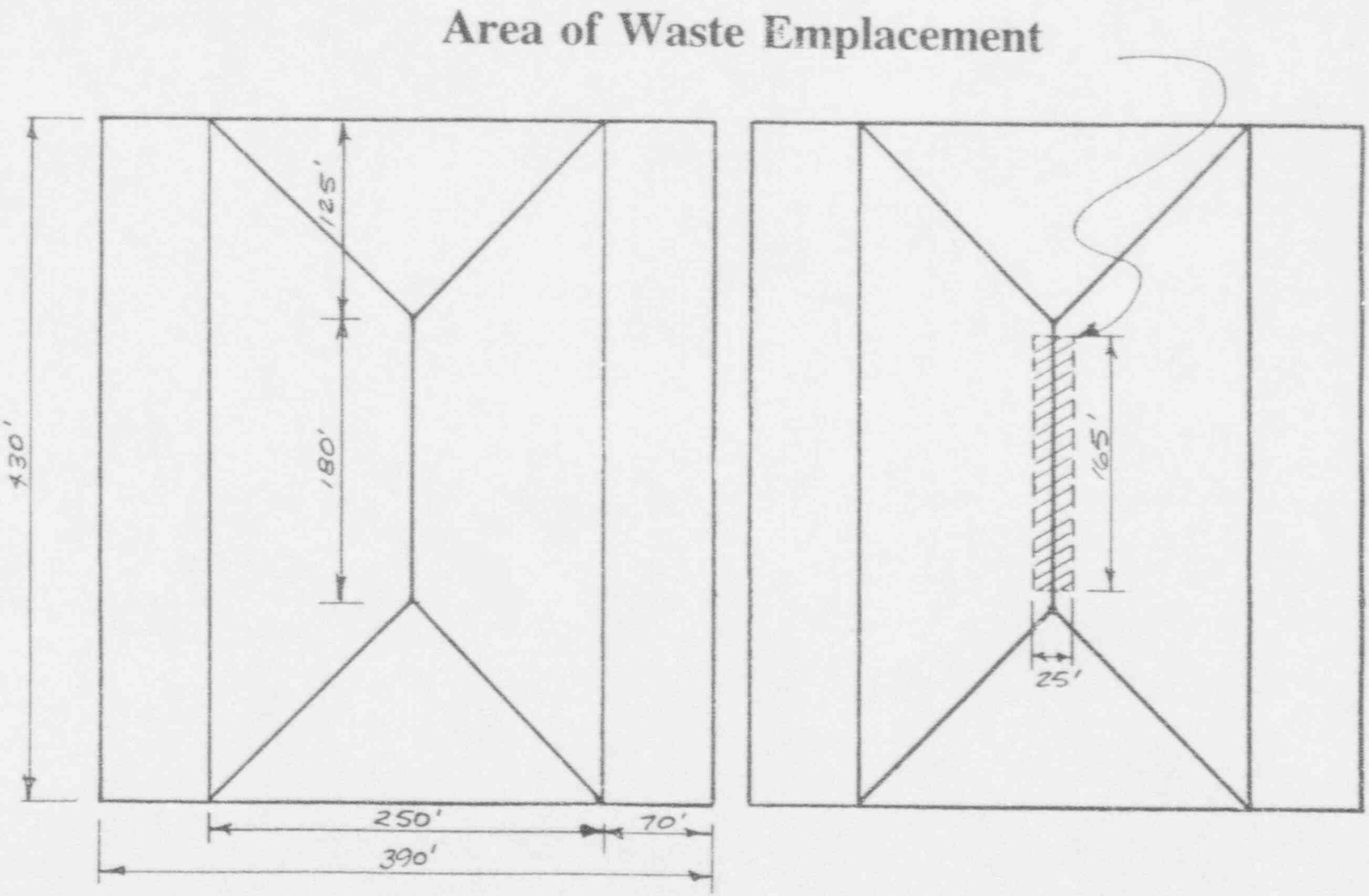
Figure 2.4.7 Cross Section Through the Disposal Facility Showing the Thickness of the Four Water-Bearing Zones and Potentiometric Surfaces

4

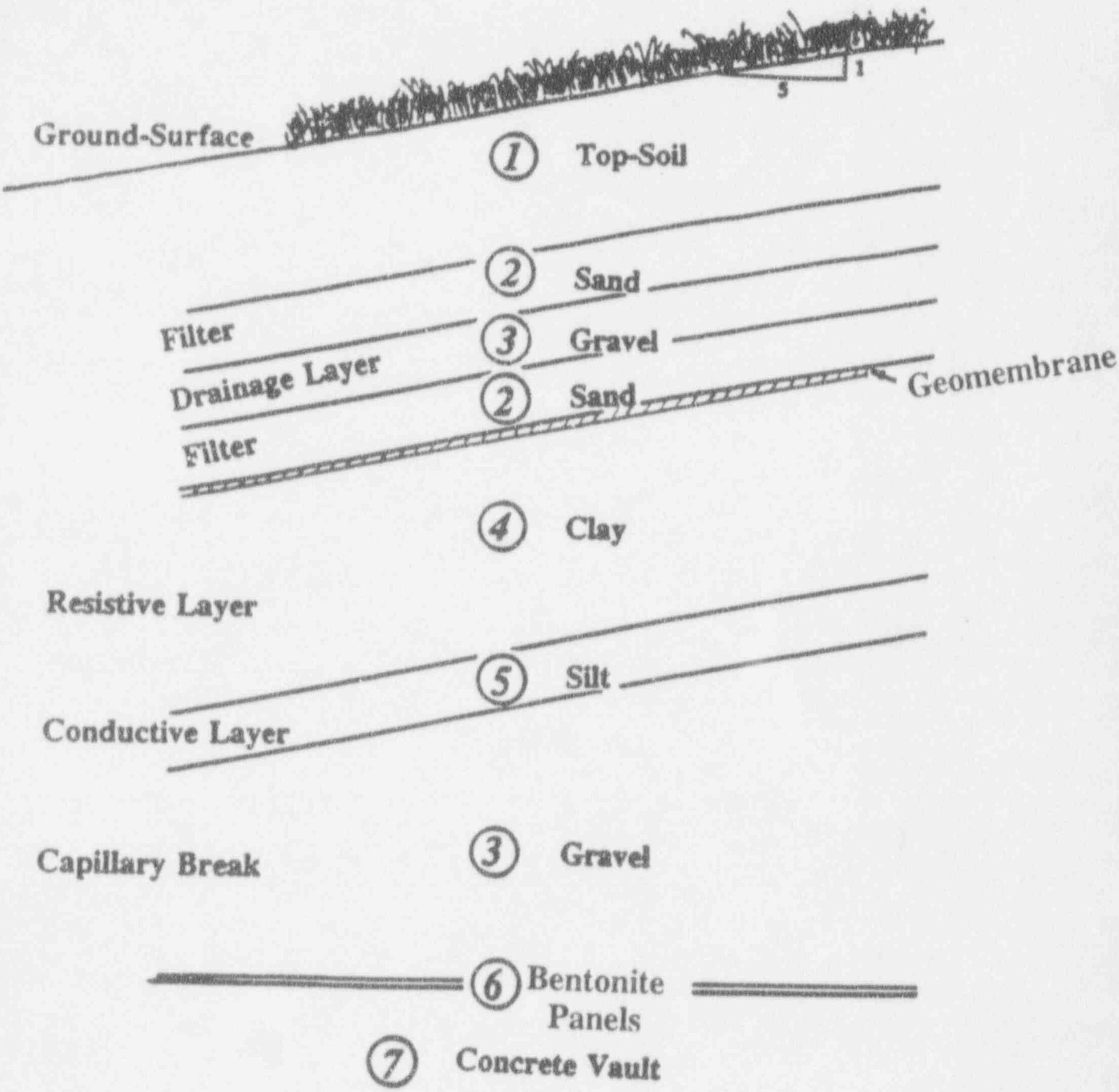


Class A vaults: 94 ft x 142 ft

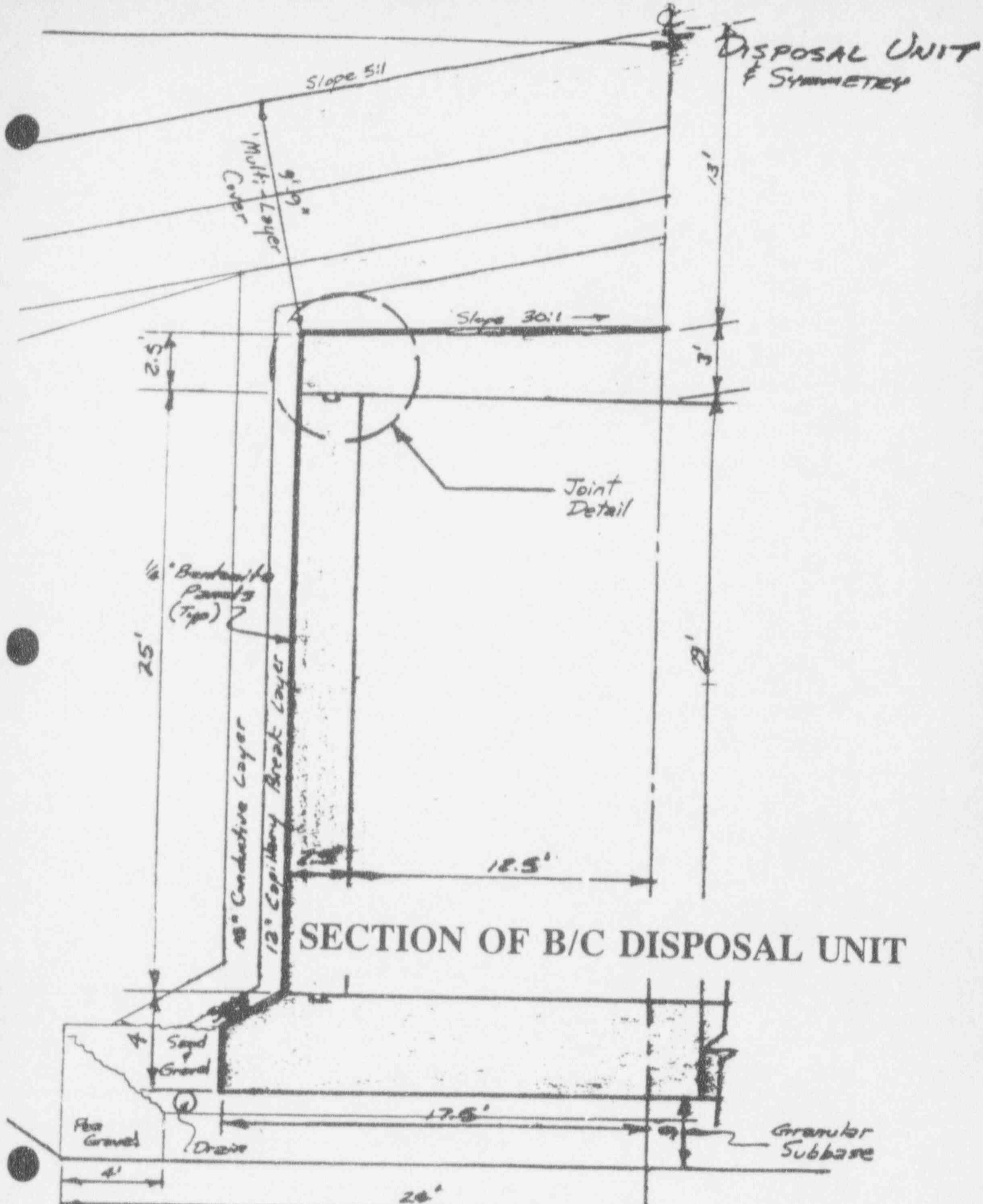
Class BC vaults: 25 ft x 165 ft



CLASS B/C DISPOSAL VAULTS



TEST CASE SOIL COVER SYSTEM



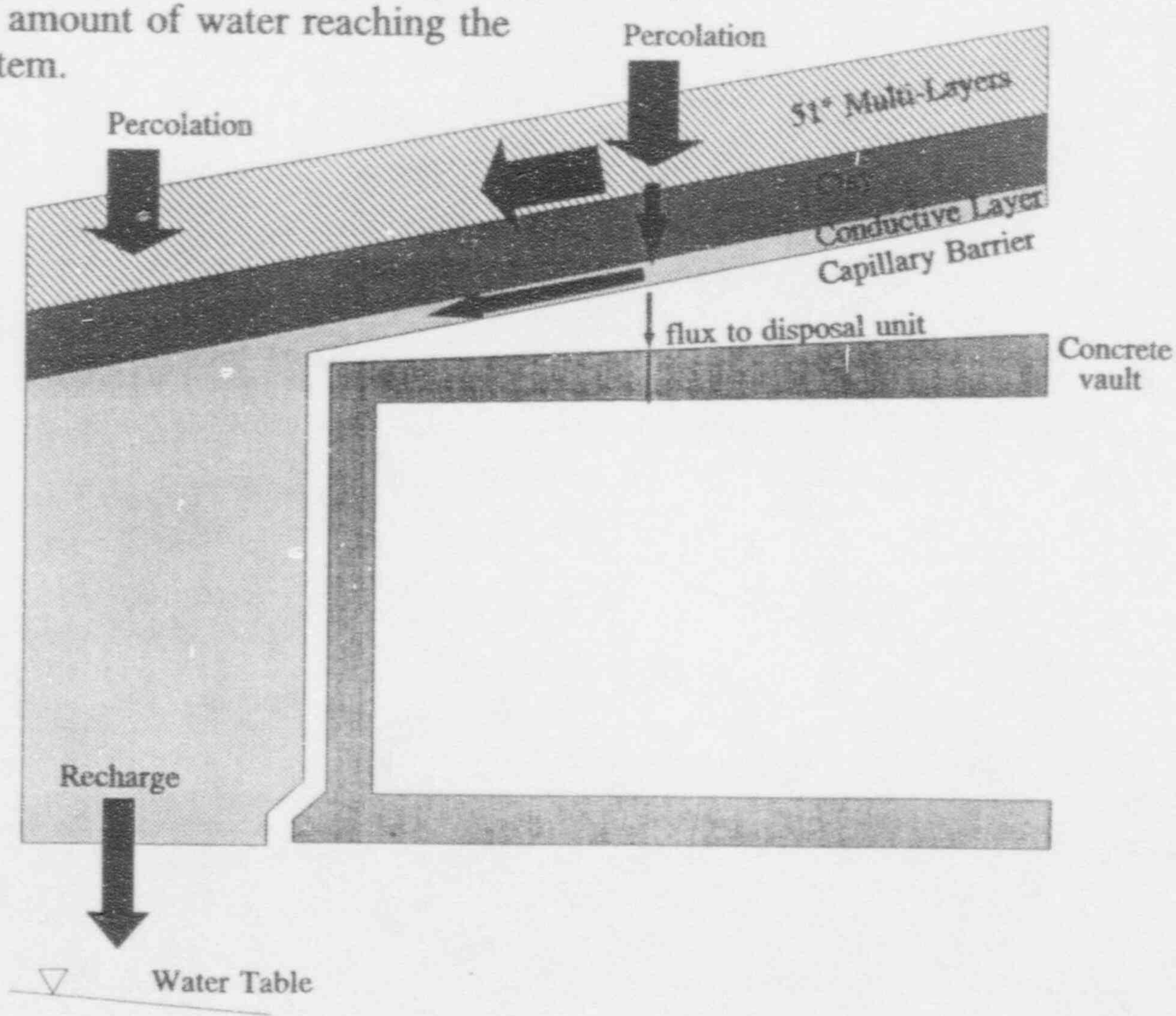
SECTION OF B/C DISPOSAL UNIT

Infiltration Conceptual Model

Objectives:

To determine the amount of water reaching a typical disposal unit.

To determine the amount of water reaching the ground-water system.



Infiltration Approach Implemented

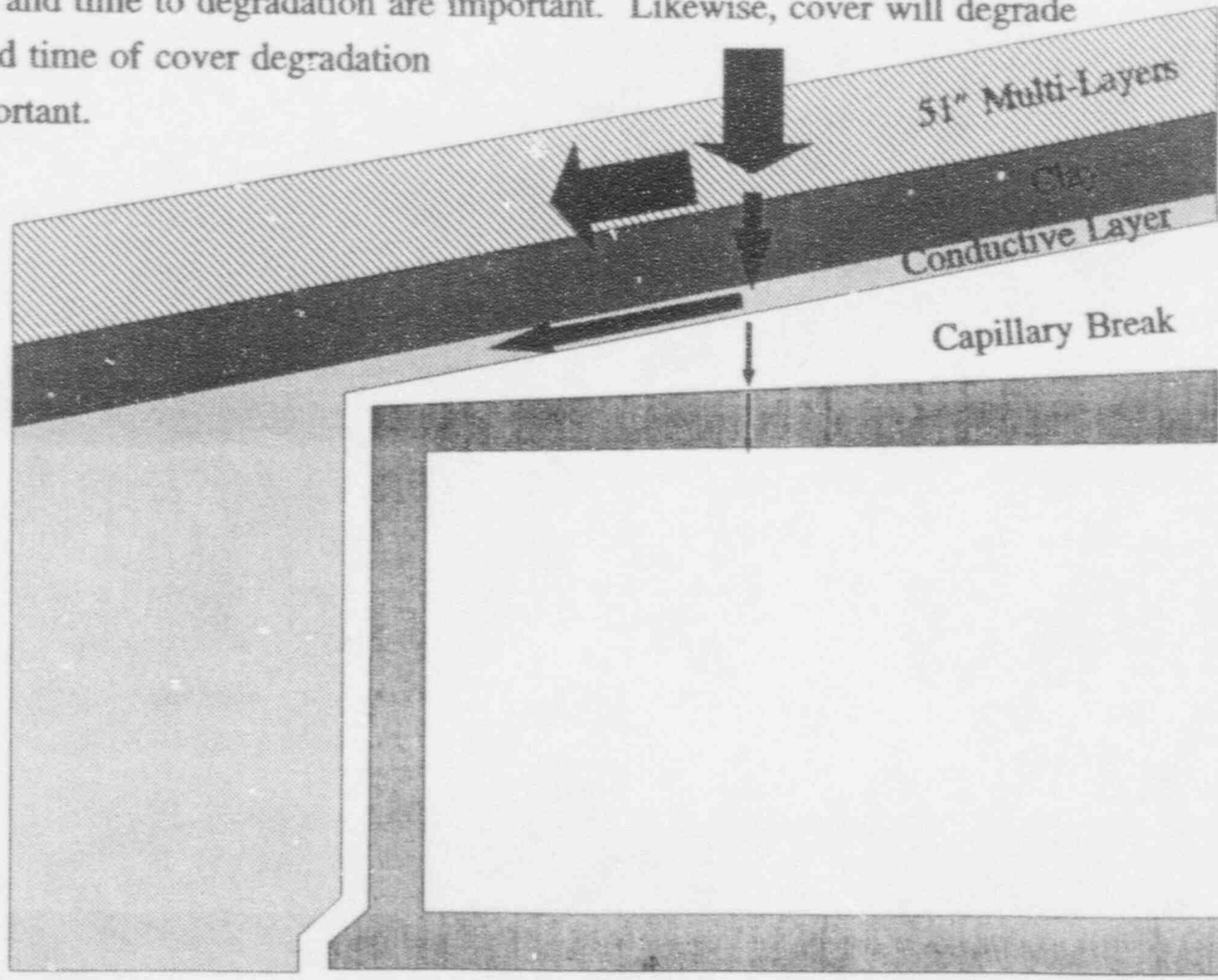
- Range of percolation rates determined from daily water balance analysis using 29 years of weather data.

- Flux into the disposal unit determined from quasi-two dimensional, steady-state unsaturated flow analysis of moisture movement through the cover.
  - Hydraulic parameters sampled and used as effective values.

- After degradation of the cover, it is assumed that the capillary barrier no longer functions.

Engineered-System Conceptual Model

Concrete permeability expected to increase with degradation, therefore degraded permeability and time to degradation are important. Likewise, cover will degrade so degree and time of cover degradation are also important.



Test Case Model of Flux Through a Concrete Vault

$$\begin{array}{c}\text{"As-built"}\\ \text{Vault Flux}\\ [L/T]\end{array} = \min\left(\begin{array}{c}\text{"As-built"}\\ \text{Concrete Hydraulic}\\ \text{Conductivity}\end{array}, \begin{array}{c}\text{Flux through}\\ \text{Engineered}\\ \text{Cover}\end{array}\right)$$

$$\begin{array}{c}\text{Degraded}\\ \text{Vault Flux}\\ [L/T]\end{array} = \min\left(\begin{array}{c}\text{Degraded}\\ \text{Concrete Hydraulic}\\ \text{Conductivity}\end{array}, \begin{array}{c}\text{Flux through}\\ \text{Engineered}\\ \text{Cover}\end{array}\right)$$

Source-Term Conceptualization

- Waste classes treated separately:
  - class A,
  - classes B & C.

- Three release mechanisms:
  - rinse or wash-off,
  - diffusion (cement solidified), and
  - dissolution (activated metals).

- Three container types (step function failure):
  - carbon steel drum (Class A),
  - carbon steel liner (activated metals, Class B & C), and
  - HIC (Class B & C).

- Solubility limits reduce releases:
  - based on ground-water chemistry, or
  - buffered by concrete.

Source-Term Implementation

- Combined features of BLT and NEFTRAN II

  - BLT (NUREG/CR 5387, BNL)

    1) rinse release
    2) diffusion release
    3) dissolution release

  - NEFTRAN II (NUREG/CR 5618, SNL)

    1) radionuclide chains
    2) transient conditions
    3) step function container failure
    4) solubility limits
    5) efficient for uncertainty analysis

SOURCE TERM
Additional Work

- Speciation and solubility data

- Improved release characteristics based on detailed geochemical modeling and experimental data (e.g., field lysimeter studies)

    - radionuclide specific (e.g., Carbon 14)

- Improved understanding of other chemical factors

    - decontamination waste

Conceptualization of Ground-Water Flow & Transport

- General flow in the aquifer is governed principally by regional hydraulic gradient and average "local" hydraulic conductivity.

- Flow field between the waste-disposal units and the well is affected by well and the percolation through the vault and engineered cover.

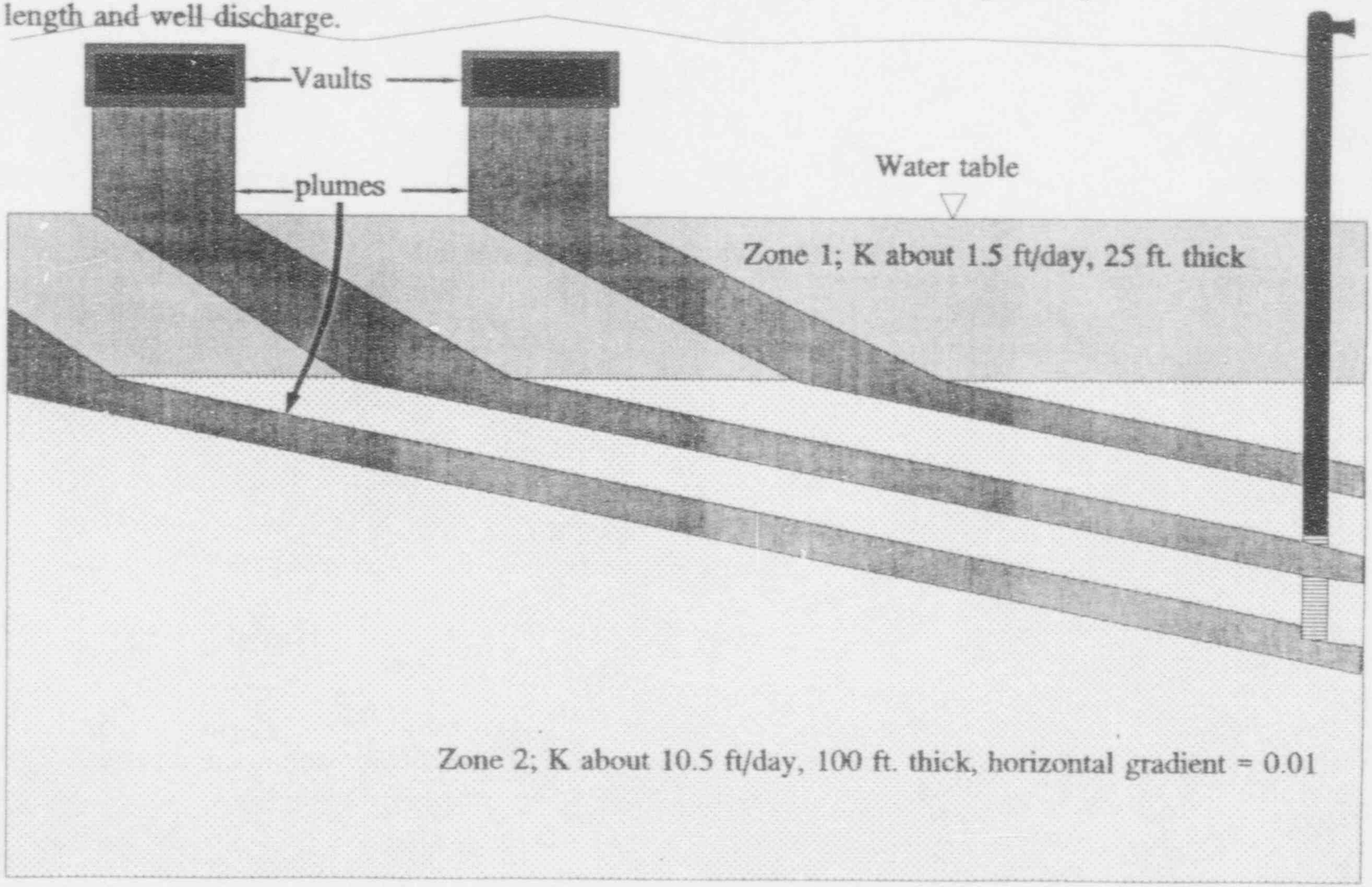
- Variations in the flow field due to local variations in hydraulic conductivity can be approximated by dispersivity.

- Flow paths from the vaults intercepted by the well define a series of streamtubes that can be simulated and mixed at the well with uncontaminated water not passing through the vaults. (No dispersion out of the streamtube.)
  - Given vault dimension relative to the proximity of well to the nearest vault, horizontal transverse dispersion is minimal (a low-capacity well intercepts only a segment of the plume from a vault).
  - Plumes are thin relative to the vertical distance between plumes and the typical length of a well screen. Neglecting vertical transverse dispersion into inter-plume water will be offset by "mixing" at the well as long as the plume is thin relative to the well-screen length.

- Radionuclide-dependent sorption approximated as linear-reversible sorption (K_D).

Ground-Water Conceptualization

Ground-water flow and transport to a well: plume geometry depends upon both infiltration into and between vaults as well as ground-water flow. Interception of plumes by well also depends upon well-screen length and well discharge.



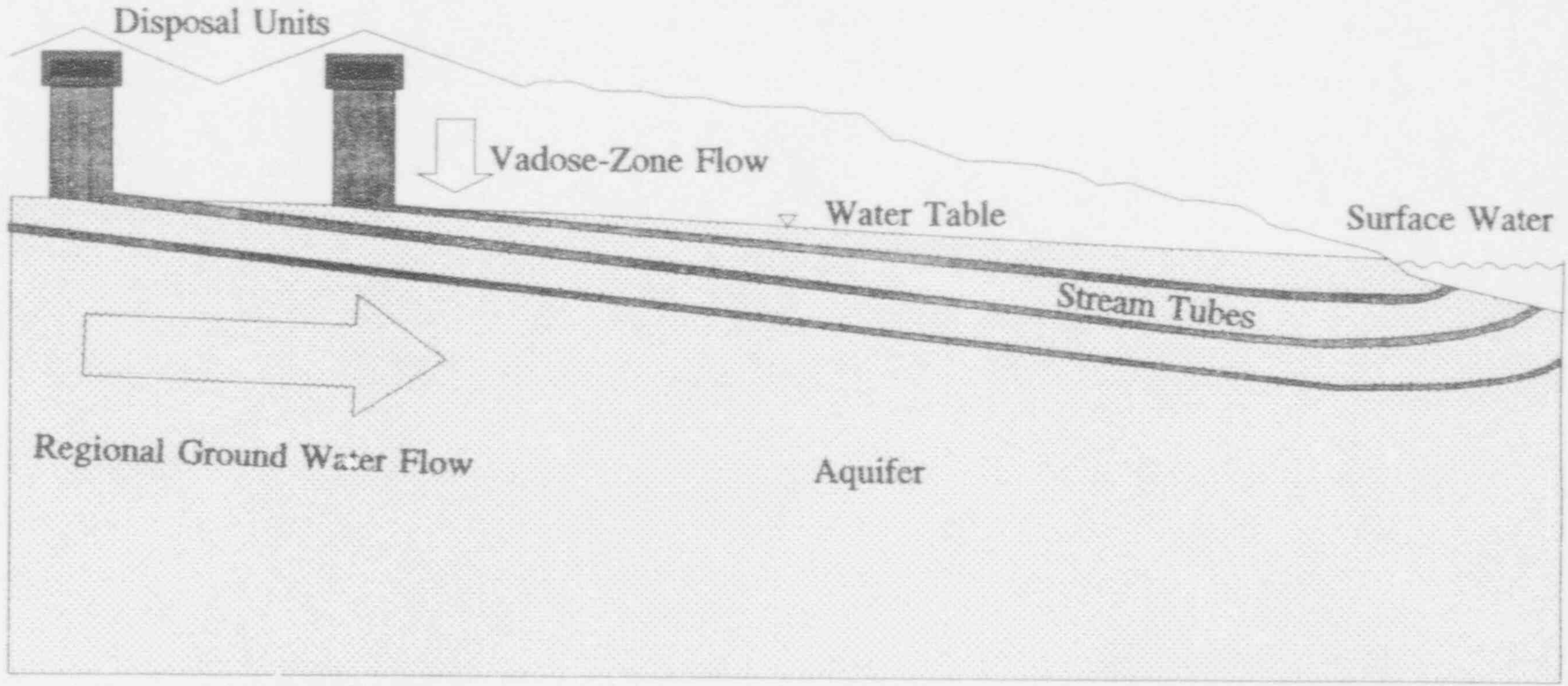
Conceptualization of Surface-Water Flow & Transport

- For purposes of this analysis, we are only considering the ground-water component of surface-water flow. This conservatively neglects any runoff of precipitation that would mix and dilute contaminated surface water.

- For contaminated water to discharge to a surface water-body, we assume that the volume of water that percolates or recharges the aquifer between the facility and the surface-water body will discharge upstream of any release of contaminated ground water. This neglects the loss of water that would be consumed by plants or an evaporative demand adjacent to the surface-water body.

- All water percolating to ground water within the facility (both contaminated by passing through the vaults and uncontaminated water that bypasses the vaults) will discharge to the surface-water body upstream of any reasonable potential exposure point. In addition, to attain a reasonable water discharge to support surface-water activities, an additional flux of uncontaminated water may have to be considered for mixing with the contaminated water.

Conceptualization of Ground-Water Discharge to Surface Water



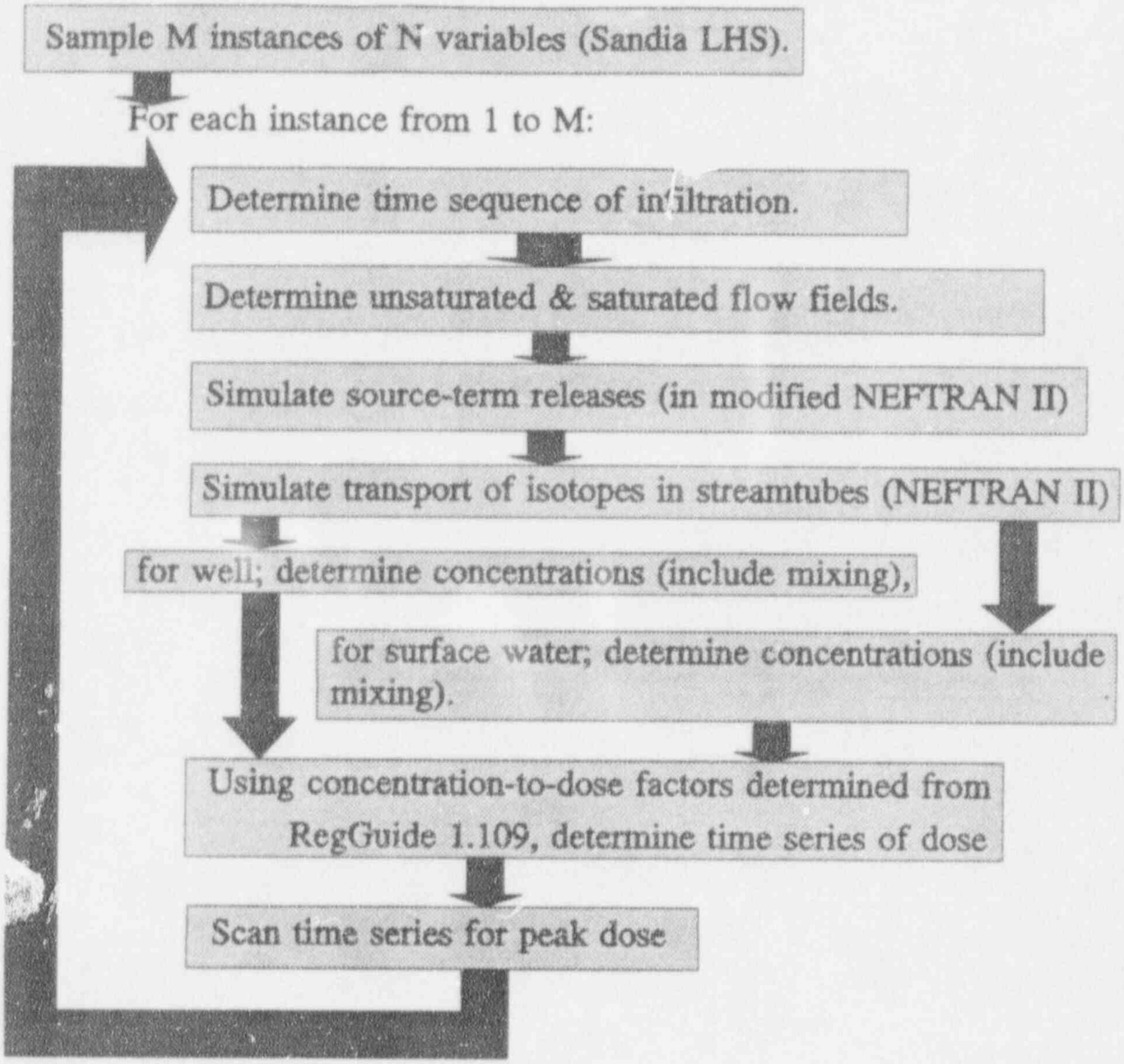
Conceptualization of Dose Sub-Modeling

- Adjacent to the facility is a rural self-sufficient household.
- Ground water drawn for all necessary uses:
  - irrigation,
  - drinking water, and
  - household use.
- Individual consumption rates are regionally-typical values.

Approach:

- Spreadsheet Model of Reg. Guide 1.109 to develop ingestion pathway dose conversion factors with:
  - modifications to Reg. Guide 1.109 to account for leaching of radionuclides out of the root zone,
  - regionally-specific data, and
  - transfer factors from NUREG/CR-5512.

Flow Diagram of System Code



Sensitivity Analysis

Determine significance of parameters/processes by evaluating the sensitivity of dose to variables using regression of M dose values to M values of each of the N variables (Sandia Stepwise).

Performance Assessment Modeling

Status of Test Case Phase I

- Input Data:
  - Developed input data base using real site data.
  - Hypothetical facility design;
    - Concrete vaults and multilayer cover,
    - Inventory based on Richland '89 data (NUREG-1418).

- Conceptual model(s) appropriate to site and design.

- Fully integrated systems code that couples sub-models.
  - Internal evaluation process to debug and document.
  - Code structured to allow parameter sensitivity and uncertainty analyses using an approach similar to that used in HLW.

- Staff has completed hundreds of model "realizations" and is evaluating:
  - Modeling approaches from the BTP,
  - Sensitivity of parameter values, and
  - Multiple conceptual models.

Contractor Support for Ancillary Analyses

Infiltration:

- PNL, **Application of an Infiltration Evaluation Methodology**, through 1995, issuance of NUREG/CR's 5523, 5996, & 6114 (Vol. 1)

Engineering:

- N.I.S.T, **Degradation Mechanisms for Concrete LLW Barriers**, through 1995, **Concrete Degradation Computer Model for LLW Performance Assessments**, through 1994.

Source Term:

- Battelle, Pacific Northwest Laboratory, **Geochemical Modeling for Performance Assessment of LLW Disposal Facility**, 1993-1995.

- Brookhaven National Laboratory, "**Prediction of Release from Class A and Class B/C Vaults in a Hypothetical LLW Disposal Site**, 1993.

Air Pathway:

- ORNL, **Air Pathway Assessment for LLW PA**, 1993-1994.

Ground Water:

- MIT, **Application of Stochastic Methodology for Modeling Ground-Water Flow and Transport**, End January 1994, preparation of NUREG/CR's 5965, & 6114 Vol.3

- Princeton University, **Vapor-Phase Flow and Transport Modeling**, End January 1994, preparation of NUREG/CR-6114 Vol. 2

Surface Water:

- ORNL, **Surface-Water Pathway Modeling for LLW PA**, 1993-1994

Dose:

- ORNL, **Dose Assessment for LLW PA**, 1993-1994.

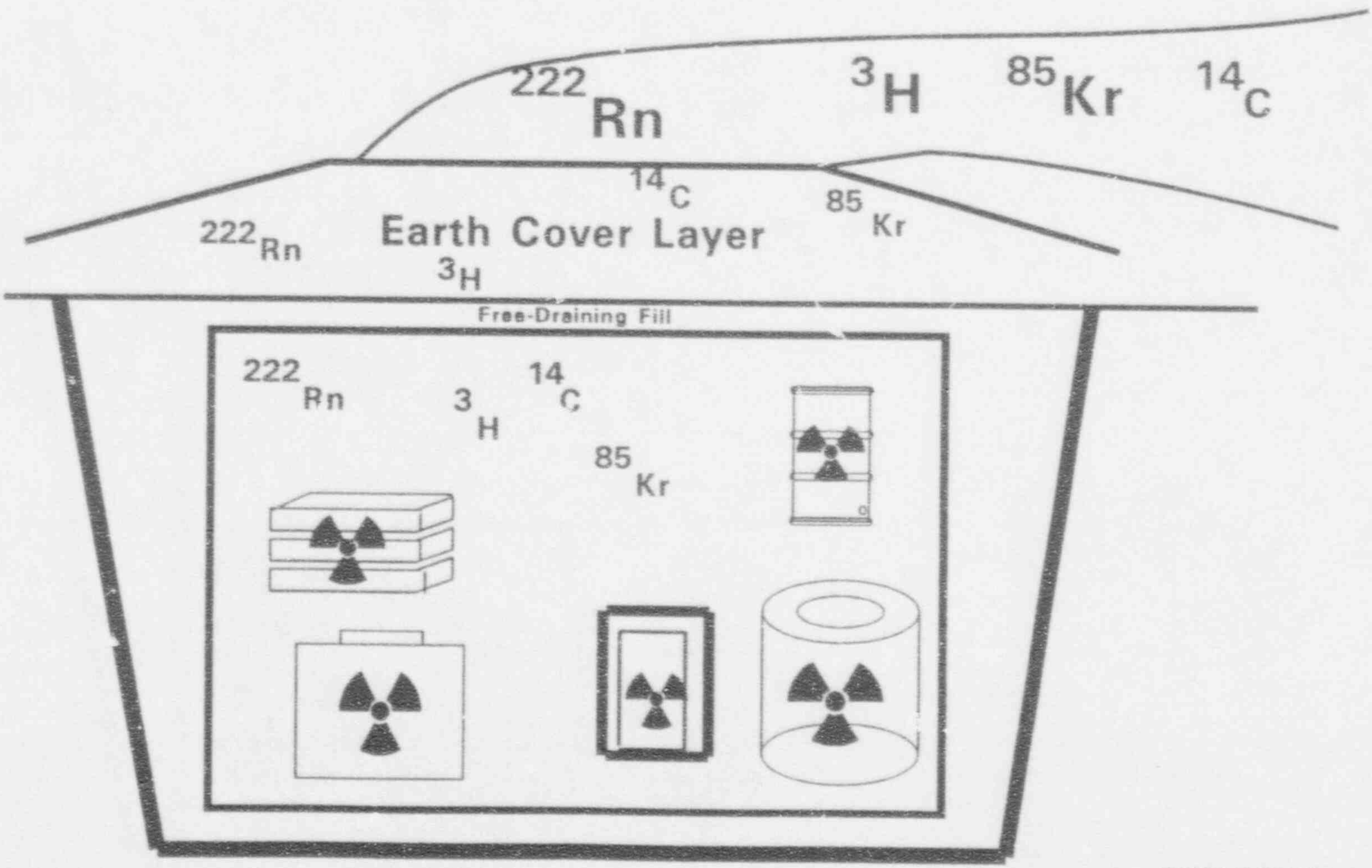
LLW GASEOUS SOURCE TERM RELEASES: ATMOSPHERIC TRANSPORT AND DOSE

UNITED STATES NUCLEAR REGULATORY COMMISSION

ADVISORY COMMITTEE ON NUCLEAR WASTE
LLW Performance Assessment Program Capabilities Meeting
March 22, 1994

Phil Reed, RES/DRA/WMB (301) 492-3979
Robert Hogg, NMSS/DLLWMD/LLWB (301) 504-2579
Chris McKenney, NMSS/DLLWMD/LLWB (301) 504-2812

AIR PATHWAY CONCEPTUAL MODEL



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COMPUTER CODE DESCRIPTIONS

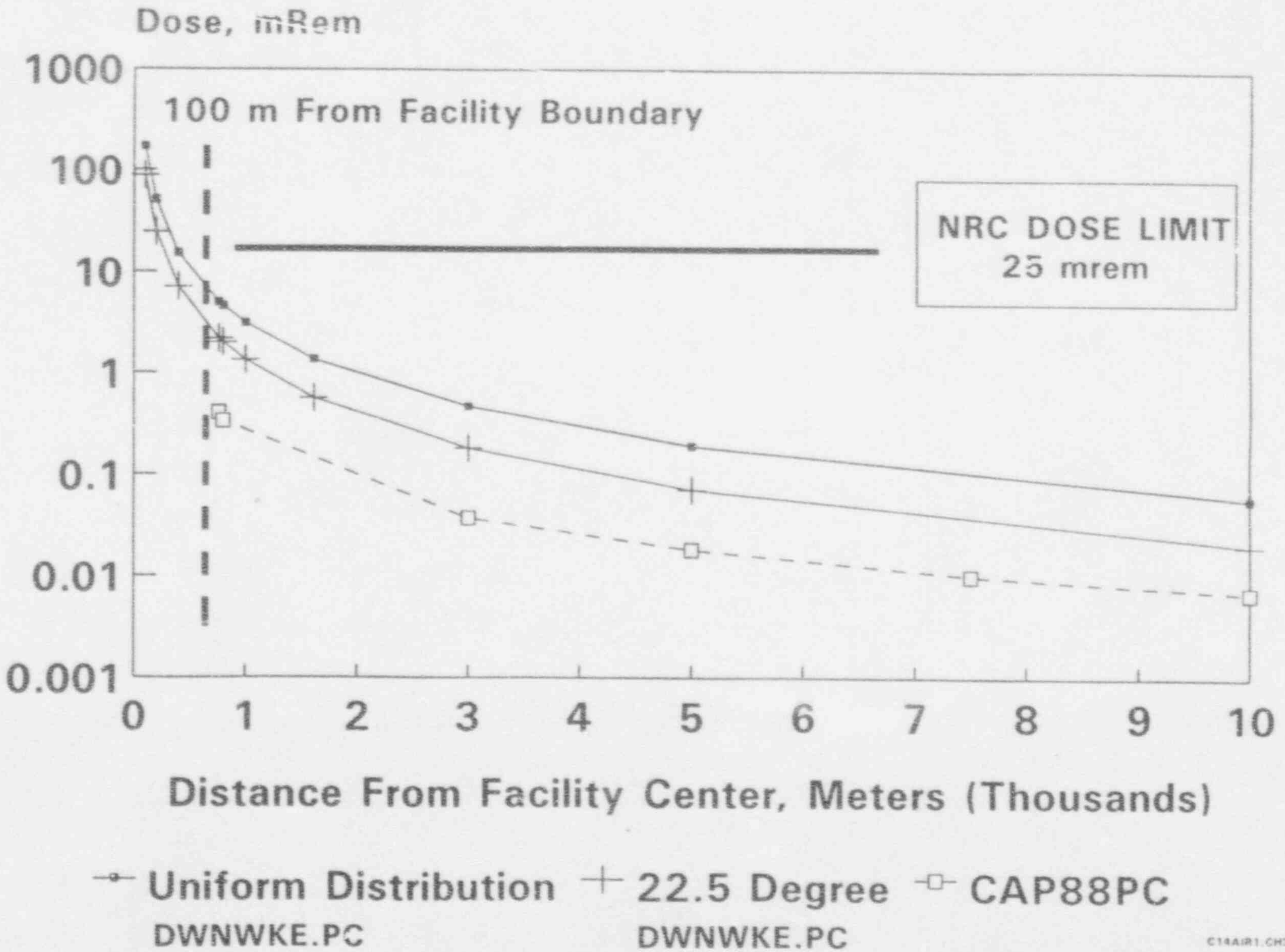
Atmospheric Transport and Dose

Model	Description
1. DWNWKE.PC	Transport, Dispersion;Downwind,Point RI
2. CAP88-PC	Area RI, MultiDr(16-Sec), HP, RG1.109, Met
3. PRESTO-II	HP fr LLW; ATM Tr, Downwind, Point RI
4. GENII	HP, 16-sector Wind Field

ACNWMODL.CH3 PRR 03/16/94

DOSE CALCULATIONS FROM LLW FACILITY

Carbon-14 Atmospheric Releases



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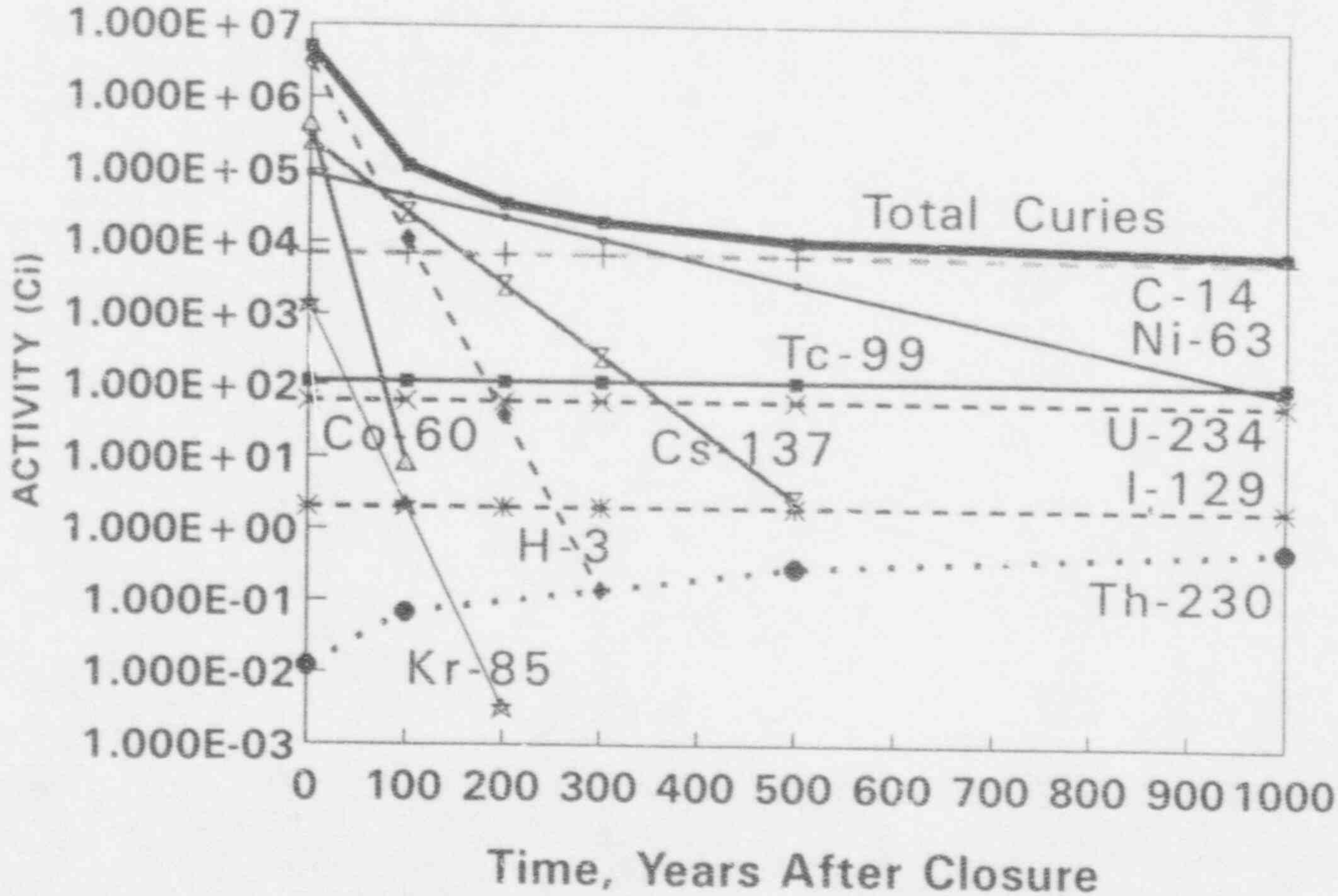
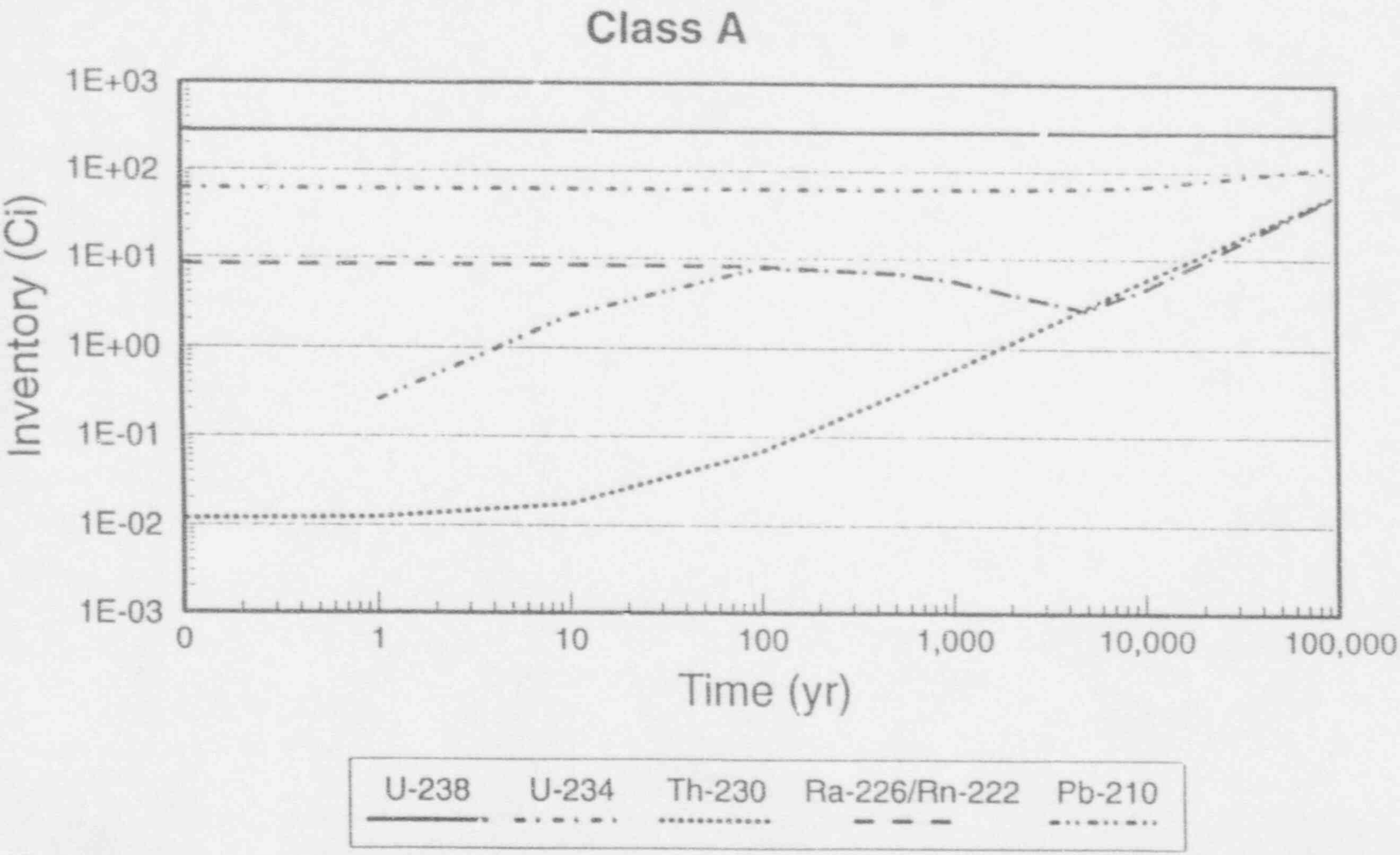
C14AIR1.CH3 PRR 03/16/94

LLW PERFORMANCE ASSESSMENT

Total Inventory Decay (Class A + B + C)



URANIUM SERIES (4n+2)



Note - Majority of short-lived daughters are not plotted to limit number of curves.

Note - Curves that start at times > 0 yr have initial inventory of 0 Ci.

AIR PATHWAY TRANSPORT

LLW Performance Assessment
Conclusions

- Screening Process Effective
- Simple Model Acceptable
- Single Sector Direction Adquate
- Point Source Models Appropriate
- Area Model Provide More Resolution
- Decay Acceptable for H-3 and Kr-85

ACNWCONI.CH3 PRR 03/18/94

T-1J-2

G.1.G

Texas Low-Level Radioactive Waste Disposal Authority

RECEIVED
ADVISORY COMMITTEE ON
REACTOR SAFEGUARDS, U.S.N.R.C.

MAR 16 1994

AM 7 8 9 10 11 12 1 2 3 4 5 6 PM

March 11, 1994

Advisory Committee on Nuclear Waste
Nuclear Regulatory Commission
7920 Norfolk Avenue
Mail Stop 315
Bethesda, MD 20814

Attention: Richard Major

Dear Sir:

Enclosed is the copy of the performance assessment for the proposed Texas low-level radioactive waste disposal facility which I promised you. If you have any questions, please let me know.

Sincerely,

Ruben A. Alvarado, P. E.
Chief Engineer

Enclosure

raa

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7701 North Lamar Blvd. Suite 300 • Austin, Texas 78752 • (512) 451-5292, Fax (512) 451-5296

Performance Assessment for Normal Releases of Radioactivity

by

Randall J. Charbeneau
Center for Research in Water Resources
University of Texas at Austin

Prepared for

Texas Low Level Radioactive
Waste Disposal Authority

December 18, 1993

Table of Contents

List of Tables

EXECUTIVE SUMMARY

This report presents the results of a radiological assessment of potential doses from normal releases of radioactivity from the proposed Texas Low-Level Radioactive Waste Disposal Facility. Only releases which might potentially occur at the end of the period of institutional control are considered. All potential pathways are evaluated, and simple and conservative models are used. Waste canisters are assumed to fail at 100 years after the closure of the facility, releasing Class A waste to exposure pathways. The Class B/C waste form is assumed to fail at 300 years after closure. Nuclide transport and dose calculations are considered for a period of 10,000 years after closure of the facility.

Infiltration through the waste disposal facility cover system is calculated using the HELP computer model, with the asphalt and geomembrane layers of the cover system being neglected. After failure of the waste containers and waste form, radionuclides are leached from the facility with the infiltrating water.

One series of pathways considers the leachate returning to the ground surface because of the upward water potential gradient, and includes the build-up of radioactivity in the soil, suspension of contaminated dust into the atmosphere, and plant uptake of radioactivity from the soil with subsequent ingestion of plants by grazing animals. Exposures are associated with direct radiation from the soil, inhalation and immersion in the suspended dust, and ingestion of animals grown onsite. A second series of pathways considers leachate from the disposal units being transported into the aquifer, and that groundwater is produced from a well located at the site boundary and utilized as drinking water for man and livestock as well as irrigation water for a garden. Exposures are due to ingestion of drinking water and one-half the annual consumption of meat and plants grown onsite.

Additional exposure pathways consider biological wastes, which upon decomposition, may generate gases containing H-3 and C-14 which can diffuse upward through the cover system. In addition, radon gas is generated through decay of radium, and this gas can also diffuse through the cover system. These gases may lead to exposures through inhalation and immersion.

A final pathway considers an inadvertent intruder who, at the end of the institutional control period, decides to have a house built on the facility and must first install a well to secure an adequate supply of water. In placing the well, the drilling company is assumed to drill through the Class B/C waste disposal trenches, bringing Class C ion exchange resin

(RWDMRES) mixed with drill cuttings and mud to the ground surface. The cuttings settle out in the "mud pit" and the drilling crew is exposed to direct gamma radiation from the waste contained in the mud pit.

Dose projections based on these simulations indicate compliance with the limits specified in 10 CFR Part 61 and TRCR 45.50. The effective dose equivalent must not exceed 25 mrem/yr. In addition, the dose to the thyroid must not exceed 75 mrem/yr and the dose to any other organ must not exceed 25 mrem/yr. The maximum dose rate of 2.1 mrem/yr is from the decomposition gases and radon at a time of 100 years after closure. However, the asphalt and geomembrane would act as a diffusion barrier, decreasing this estimate considerably. Dose rates from the remaining exposure pathways are less than 0.4 mrem/yr. All of these doses are well below the dose limits prescribed by current regulations.

1. Site Characterization

The proposed Texas site for disposal of low-level radioactive waste is located on northern Faskin Ranch in southern Hudspeth County, approximately 75 miles southeast of El Paso, Texas. The site area lies within the Chihuahuan Desert in the northwest Eagle Flat basin, which is a sediment-filled basin within the Basin and Range Physiographic Province. The sediment fill was laid down by alluvial fan, fluvial, and eolian processes, and it lies on fractured Cretaceous bedrock that is exposed on Faskin Ranch southeast of the proposed site. The thickness of the basin-fill sediments at the proposed site ranges from 160 ft to greater than 650 ft (Jackson and others, 1993).

Northwest Eagle Flat basin is an internally drained basin that drains through the ephemeral Blanca Draw into Grayton Lake playa. Most of northern Faskin Ranch is relatively flat with slopes that are less than 1 percent. Blanca Draw is generally dry except after high rainfall. The surface geomorphology of the area can be subdivided into ephemeral stream (Blanca Draw) and interstream settings. The ephemeral stream setting has no active channel with mobile sediment and is vegetated with tobosa grass and mesquite. The interstream setting has areas characterized by sandy and silty surficial sediments. Vegetation in the interstream setting consists of black grama grass and widely scattered mesquite and soaptree yucca. The proposed site is located in an interstream setting (Jackson and others, 1993).

The regional climate is subtropical arid. Long-term meteorologic data were obtained at Sierra Blanca, situated on the western edge of Faskin Ranch area. Mean annual precipitation is 12.6 in. Precipitation in the region is characterized by large interannual variations (5 in in 1964 to 21 in in 1974). Most of the precipitation falls as local, intense, short-duration convective storms during the summer, when temperature and potential evaporation are highest. Minor winter frontal storms are of longer duration (Scanlon and others, 1993).

Groundwater at Faskin Ranch is found at depths between 670 and 750 ft. The water is primarily Na-Cl to Na-SO_4-Cl in composition with total dissolved solids between 1500 to 4000 mg/L. Recharge occurs along the Streeruwitz Hills to the northeast. Groundwater moves southwest from the location of recharge, turns northwest as it moves beneath Faskin Ranch, and then merges with groundwater that flows along the southeasterly sloping regional hydraulic gradient. The discharge location may be along the Rio Grande. The uncorrected age of groundwater beneath the ranch, based on ^{14}C measurements, is approximately 30,000 years. There is no evidence of local recharge near Faskin Ranch (Darling and Hibbs, 1993).

Interpretation of pumping test data suggests that groundwater at Faskin Ranch is in a leaky confined aquifer. Evidence that the aquifer is pressurized is given by the fact that when the drilling of local monitoring wells reached the depth of the aquifer, the static water leve in the drill pipe increased significantly. At Faskin Ranch, the effective hydraulic conductivity is about 0.1 ft/d, the hydraulic gradient is about 0.002, and the effective porosity is estimated to be 0.05. This gives an estimate of the local groundwater seepage velocity of

$$V_a = \frac{0.1 \times 0.002}{0.05} = 0.004 \frac{\text{ft}}{\text{d}} \cong 0.5 \frac{\text{m}}{\text{yr}}$$

Mathematical modeling of the groundwater flow system provides estimates of the travel time between Faskin Ranch and the Rio Grande which vary between 20,000 and 40,000 years (Darling and Hibbs, 1993).

Within the unsaturated zone, the sediments beneath Blanca Draw are fine grained and ranged from clay to clay loam, while in interstream areas some profiles are predominantly clay whereas others are primarily clay loam and sandy loam. The spatial variability of water content is controlled primarily by variations in sediment grain size. Except for local fissured areas, water contents do not change with time. Within fissured areas, temporal changes in water contents are noted to depths of 5 ft. Typical water potentials at the proposed site are low in the upper 7 ft (-120 to -20 bar) except after rainfall. These potentials increase with depth to maximum values of -60 to -4 bars in different profiles. Overall, these low potentials indicate that the sediments are dry, and the upward water potential gradients indicate an upward driving force for liquid flow. Exceptions to this trend are found in fissured sediments and in sediments beneath the borrow pit. These locations had much higher water potentials in the upper 40 ft than the sediments 30 ft distant (Scanlon and others, 1993).

Chloride concentration profiles may be used to estimate recharge rates. Typical chloride profiles at the proposed site are bulge shaped with low concentrations near the surface which increase to maximum concentrations at depths between 2 and 20 ft, and gradually decrease with depth below the peak concentrations. Water fluxes (net infiltration rates) estimated from chloride data were highest at the surface and decreased to less than 1 mm/yr within the top meter. Within fissured areas, chloride was flushed from the profiles within the upper 20 to 30 ft, but concentrations increased at greater depths and in sediments laterally adjacent (Scanlon and others, 1993).

The typical profiles in the interstream settings have variable water contents, low water potentials, upward water potential gradients, and high maximum chloride concentrations. In these settings the water potential data indicate upward driving forces for liquid flow, and the chloride data indicate very low fluxes for thousands of years (Scanlon and others, 1993).

2. Overview of Performance Assessment Approach

In 1982 the U.S. Nuclear Regulatory Commission (NRC) released the licensing requirements for land disposal of radioactive waste as Part 61 of Title 10, Chapter 1, of the Code of Federal Regulations (10 CFR 61). The State of Texas counterpart of 10 CFR 61 is the Texas Regulations for Control of Radiation (TRCR Part 45.50). The Texas regulations carry all of the requirements of 10 CFR 61. In addition, they require that the disposal site shall not be located on a groundwater recharge zone nor where soil conditions would make clean-up impracticable.

10 CFR Part 61.41 establishes exposure limits to members of the general population from releases of radioactivity to the general environment from land disposal facilities. 10 CFR Part 61.13(a) requires that pathways analyzed in demonstrating protection of the general population must include air, soil, groundwater, surface water, plant uptake, and exhumation by burrowing animals. The 10 CFR Part 61.41 radiological limits are applicable during the operational and post-operational periods. The analyses used to demonstrate compliance with 10 CFR Part 61.41 after permanent facility closure is commonly called a performance assessment.

A performance assessment is essentially a modeling study which shows that the performance objectives are met. The central focus of the present study is placed on those objectives dealing with the radiological dose to individuals who might potentially be impacted from releases of radioactivity from the site. These doses may occur either from accidental releases of radioactivity during operation of the site or through what may be called normal releases of radioactivity after the site is closed. The performance objectives of Part 61.41 dealing with radiological doses refer specifically to post-closure exposures.

The basic framework of a performance assessment is centered around site characterization. Initially, a set of performance objectives must be established. A minimal set of objectives for a land disposal facility is presented in 10 CFR Part 61.41. After the performance objectives have been identified, the various reasonable potential exposure scenarios must be identified. Many of these scenarios may be dismissed with simple calculations or through arguments showing that their exposures and resulting doses are bounded by other scenarios which are considered. Once the exposure scenarios have been identified, conceptual mathematical models are developed. Application of simple models with conservative assumptions is preferable to the use of complex and detailed models if the simple models are able to show that the performance objectives are met. Screening calculations with the conceptual models identify those scenarios which require more detailed modeling efforts. These detailed models are intimately tied to site characteristics and facility design, and may require significant computational effort in their evaluation of performance assessment calculations. The results from either simple or detailed models of exposure scenarios are evaluated and compared with the performance objectives. This may lead to acceptance and reporting of the model results or to further assumptions and more detailed modeling efforts.

A model of an exposure pathway consists of two parts. First, the release from a source with known inventory must be modeled so that one can estimate the activity release rate for each nuclide (Ci/yr). The second part of an exposure pathway involves a model of migration of the nuclide through the various environmental media which make up the pathway. This model will lead to an estimate of the exposure concentration at a receptor point from the particular pathway.

Exposure scenarios may involve many pathways and environmental media. The released radioactivity may enter the air, soil, surface water, or groundwater environments and be transported from the source area. Biological pathways are also important in many scenarios. Exposures occur from direct radiation, inhalation of radioactive gases and nuclides on suspended dust, immersion within a radioactive cloud of gases and suspended dust, and ingestion of contaminated food. The dose to man is calculated from dose conversion factors which relate the dose (mrem/yr) to the exposure concentration (Ci/m^3).

Normal release scenarios were developed to estimate possible migration pathways for radiocontaminants from the Texas site. Potential exposure pathways are suggested in NUREG-1199 (1987), PLAP (RAE, 1988), as well as in NUREG/CR-5532 (1990). These scenarios are listed in Table 1, along with radiation types, transport mechanisms, and pathways relevant to each scenario. The discussion sections corresponding to the release scenarios are also presented. Every scenario given in NUREG-1199 and from other sources has been addressed either by eliminating it from consideration because of site specific conditions, or by calculating the resulting dose.

Table 1 Offsite Impacts on Individuals Resulting from Normal Conditions-after NUREG-1199 Table 6.1

	Scenario	Rad.	Transp. Mech.	Pathway	Reference
1)	Doses to individuals near disposal site from parked waste vehicle	γ	Direct rad.	1000 ft to site boundary results in negligible exposure.	Not appl.
2)	Doses to individuals near disposal site from site operations	γ	Direct rad.	1000 ft to site boundary results in negligible exposure.	Not appl.
3)	Airborne releases from contaminated surfaces e.g. buildings and grounds	α, β, γ	Air	Only containerized waste received, no operational releases permitted.	Not appl.
4)	Airborne releases from decomposing waste (e.g., methane, CO_2)	α, β, γ	Air	Decomposing gases and radon may diffuse through the cover system.	Sec. 12
5)	Airborne dispersion of contamination unearthed by plants and animals	α, β, γ	Air	No intrusion due to cover depth and disposal unit design.	Not appl.
6)	Airborne discharge from disposal cells (water coll. in sumps or trenches)	β	Air	No water contacts waste in disposal units.	Not appl.
7)	Airborne dispersion of contamination association with demolition	α, β, γ	Air	Only containerized waste received, no operational releases permitted.	Not appl.
8)	Waterborne releases from contam. surfaces e.g. buildings and grounds	α, β, γ	Surface water	Only containerized waste received, no operational releases permitted.	Not appl.
9)	Waterborne dispersion of contam. unearthed by plants and animals	α, β, γ	Surface water	No significant surface water flow. No intrusion due to cover depth and unit design.	Not appl.
10)	Waterborne discharges from disposal cells (e.g. from trench sumps)	α, β, γ	Surface water	No significant surface water flow. No intrusion due to cover depth and unit design.	Not appl.
11)	Waterborne dispersion of contamination association with demolition	α, β, γ	Surface water	No significant surface water flow. Only containerized waste received, no operation releases.	Not appl.
12)	Radionuclide leaching and migration	α, β, γ	Soil water and groundwater	a) Leachate migrates through vadose to groundwater. Exposure from well at boundary.	Sec. 8,11
			Soil water, biota, air	b) Leachate migrates through vadose to surface. Exposure to onsite humans.	Sec. 6,7, 10
13)	Release through biotic pathways	α, β, γ	Biota	No intrusion due to cover thickness and unit design.	Not appl.

As evidenced by Table 1, the majority of the NUREG-1199 exposure scenarios are not applicable to the site. Direct gamma radiation (scenarios 1 and 2) is not a problem because radioactive material is kept containerized and shielded until it is 1000 feet from the site boundary. Because only containerized waste is received and because the Texas Department of Health will not allow any operational spillage to remain exposed, there will be no release due to contaminated surfaces imparting radionuclides to air or surface water (scenarios 3, 7, and 8). A scenario with leachate from the disposal trenches migrating through the vadose zone and returning to the soil surface (scenario 12 b) is considered along with exposures due to direct radiation from the soil, ingestion of grazing animals, and inhalation and immersion in suspended dust. A rainfall event of sufficient size to erode and transport a significant amount of this material will result in spreading the sediment over a larger area and diluting the radionuclide concentration. The resulting doses are bounded by those from the original soil surface.

A number of scenarios have been discounted because they involve penetration of the disposal unit covers by plants and animals (scenarios 5, 9, and 13). No deep burrowing insects are present on the site study area (Wester et al., 1993). Deep burrowing animals such as badgers and gophers and deep-rooted plants will be excluded from the study area through the institutional control period as part of institutional control activities. This will be included in the Authority's closure procedures. At the end of institutional control, the site area would potentially gophers (the only deep-burrowing mammal found by Wester et al., 1993) and honey mesquite (the only deep-rooted plant found by Wester et al., 1993) which would grow on the actual disposal site. Salt cedar was found on the study area, but only in the ephemeral drainage channels. However, the subsurface asphalt layer in each trench cap is designed to and will preclude burrowing into the waste by animals after the end of institutional control. The asphalt layer will also preclude penetration by deep-rooted plants into the disposed waste.

Scenarios 6 and 10 are not applicable because the area receives approximately 13 inches of precipitation per year which limits the likelihood of water accumulating in the unit sumps and overflowing to the trenches. While water will collect in the disposal trenches following heavy rainfall events, this water will not come into contact with contaminated surfaces and no exposures are likely.

10 CFR Part 61.43 requires that the design, operation and closure of the land disposal facility must ensure protection of any individual inadvertently intruding into the disposal site and occupying the site or contacting the waste at any time after active institutional controls over the disposal site are removed. The pathways with leachate from the facility returning to the soil surface represent intruder scenarios. The Update of Part 61

1

IMAGE EVALUATION TEST TARGET (MT-3)

150mm

6"

1

IMAGE EVALUATION
TEST TARGET (MT-3)

1.0 2.5 2.8 2.2 3.2 3.6 2.0 4.0 1.8
1.1
1.25 1.4 1.6

150mm

6"

1

IMAGE EVALUATION TEST TARGET (MT-3)

1.0 1.1 1.25 1.4 1.6 1.8 2.0 2.2 2.5 2.8 3.2 3.6 4.0

150mm

6"

1

IMAGE EVALUATION TEST TARGET (MT-3)

150mm

6"

Impacts Analysis, or "IMPACTS" methodology, (NUREG/CR-4370, 1986) discusses several other intruder scenarios. In the intruder-construction scenario, it is assumed that at some time following the end of institutional controls an intruder inadvertently constructs a house on the disposal facility and that the intruder contacts the waste during site excavation. However, the design for the Texas facility has t_ waste buried at a depth in excess of 5 m, and no contact with the waste during excavation is likely. Similar statements follow for the intruder-discovery and intruder-agriculture scenarios. The former is similar to the intruder-construction scenario except the period of exposure to the waste is of shorter duration. In the intruder-agriculture scenario, it is assumed that an intruder lives in the building constructed as part of the intruder-construction scenario, and consumes food grown in soil contaminated by the waste excavated and distributed around the building during construction activities. In these scenarios, exposure to the waste is unlikely except by direct gamma radiation, and the shielding afforded by the soil cover is sufficient to allow only insignificant doses.

The only intruder scenario from IMPACTS which is plausible is the intruder-drilling scenario, and this is discussed in detail in section 13.

The remaining scenarios in Table 1 involve radionuclide leaching from the disposal units by infiltrating precipitation, and subsequent transport through the vadose zone to groundwater or to the soil surface, or airborne releases from decomposing waste and radon. In analyzing these potential pathways a conservative approach has been taken. For the most part, simple models have been utilized.

In dry soils with an upward water potential gradient, such as exists at the site, it is unlikely that precipitation will infiltrate the disposal unit cover system and come into contact with the waste. This means that leaching of the waste inventory is an unlikely source term. Nevertheless, a leaching source term has been considered with net infiltration estimated through water balance modeling. Infiltration through the waste disposal units is discussed in section 4, and leachate generation is discussed in section 5.

The scenario for radionuclides leached from the disposal units and returning to the soil surface because of the upward water potential gradient includes the build-up of radioactivity in the soil, suspension of contaminated dust into the atmosphere, and plant uptake of radioactivity from the soil with subsequent ingestion of plants by grazing animals. Exposures are associated with direct radiation from the soil, inhalation and immersion in the suspended dust, and ingestion of animals grown onsite. Transport to the ground surface and the atmosphere is discussed in sections 6 and 7, and dose calculations from surface exposures are discussed in section 10.

A groundwater scenario is very unlikely at Faskin Ranch because the soils are dry, the water potential gradient in the surface soils is upward, and the aquifer is confined and under pressure. However, groundwater is often considered to be an important exposure pathway at other locations, and a groundwater scenario is considered. For the groundwater scenario, it is assumed that leachate from the disposal units is somehow transported into the aquifer, and that groundwater is produced from a well located at the site boundary and utilized as drinking water for man and livestock as well as irrigation water for a garden. Exposures are due to ingestion of drinking water and one-half the annual consumption of meat and plants grown onsite. Transport to groundwater is discussed in section 8, and groundwater dose calculations are discussed in section 11.

The inventory for the facility contains biological wastes, which upon decomposition, may generate gases containing H-3 and C-14 which can diffuse upward through the cover system. In addition, radon gas is generated through decay of radium, and this gas can also diffuse through the cover system. The scenario with decomposition gases and radon is considered in section 12.

3. Expected Inventory for the Waste Disposal Facility

The Texas Low-Level Radioactive Waste Disposal Facility is expected to receive approximately 2,000,000 ft^3 of waste over its operational lifetime of 30 years. Approximately seventy percent of the total waste volume to be disposed of will be from pressurized water reactor plants operated in the state. The remaining thirty percent of the waste will come from industrial and institutional sources, and from decommissioning of the disposal site. Waste from decommissioning and decontamination of the disposal facility will be disposed of on site and can be accommodated within the total capacity for which the facility is designed. The disposal facility will receive waste generated within the State of Texas. In addition, the States of Maine and Vermont are actively negotiating with the State of Texas for disposal of waste from those states in the Texas facility.

Data for calculation of the radiological source term is developed and presented in Shuman and Baird (1993). Included are identification of the individual waste streams, information on the physical, chemical and radiological characteristics of the waste streams, average annual volumes, and individual nuclide concentrations for each waste class. Specifically, Table 3-7 from Shuman and Baird (1993) gives the volumes of each utility and non-utility waste stream, Table 3-8 gives the percent abundance of each waste class for each waste stream, and Tables 3-9 and 3-10 give the waste stream concentrations for each nuclide for utility and non-utility waste. For example, the projected activity of C-14 from utility ion exchange resins (RWDMRES) and cartridge filters (PROCFIL) which will fall in Class C is calculated from

$$\left(99{,}000 + 18{,}000\,\mathrm{ft}^3\right) \times (0.27) \times \left(0.085\,\frac{\mathrm{Ci}}{\mathrm{ft}^3}\right) = 2{,}700\,\mathrm{Ci}$$

The resulting nuclide inventory in terms of activity is shown in Table 2. This table shows the total Class A and ClassB/C waste streams by nuclide projected to be delivered to the facility during its 30 year operational period. The total activity to be delivered to the facility is 340,000 Ci. Due to radioactive decay over the operational period, the total inventory at the time of site closure is considerably less than the total activities delivered.

Table 2 Nuclide Inventory (Ci) Used for Radiological Assessment

Nuclide	Class A	Class B/C	Nuclide	Class A	Class B/C
H-3	7.7E+03	8.5E+04	I-125	2.2E+01	0.0E+00
Be-7	3.8E+02	0.0E+00	Sb-125	1.2E+02	4.2E+02
C-14	1.4E+02	2.7E+02	I-129	1.8E-03	2.7E-03
Na-22	9.3E-01	0.0E+00	I-131	2.9E+02	0.0E+00
P-32	7.1E+01	0.0E+00	Ba-133	3.6E-03	0.0E+00
S-35	1.4E+01	0.0E+00	Cs-134	1.1E+03	6.4E+02
Cl-36	[illegible].3E-01	0.0E+00	Cs-137	1.5E+03	1.1E+04
Ca-45	1.1E-01	0.0E+00	Ce-139	9.6E-09	0.0E+00
Sc-46	5.7E-01	0.0E+00	Ba/La-140	8.7E+01	0.0E+00
Cr-51	3.5E+02	5.5E+01	Ce-141	7.0E-01	0.0E+00
Mn-54	8.9E+02	1.2E+04	Ce-144	1.1E+02	8.4E+02
Fe-55	2.0E+03	9.4E+04	Pm-147	[illegible]E+02	0.0E+00
Co-56	7.7E-05	0.0E+00	Eu-152	3.2E-06	0.0E+00
Co-57	5.5E+01	4.1E+02	Gd-153	5.5E-03	0.0E+00
Co-58	6.7E+03	1.3E+04	Hf-175	1.9E-03	0.0E+00
Fe-59	4.4E+01	0.0E+00	W-178	8.9E-03	0.0E+00
Ni-59	4.2E+00	2.5E+01	Ta-182	1.9E-03	0.0E+00
Co-60	6.1E+03	7.4E+04	Re-187	1.9E-03	0.0E+00
Ni-63	2.0E+03	1.0E+04	Ir-192	2.4E+00	0.0E+00
Zn-65	3.5E-03	2.7E+02	Au-198	1.9E+00	0.0E+00
Ge-68	1.4E-05	0.0E+00	Hg-203	8.1E-09	0.0E+00
Se-75	2.0E-02	0.0E+00	Ra-226	8.7E+01	0.0E+00
Kr-85	1.2E+01	5.1E+01	Ra-228	1.7E+00	0.0E+00
Sr-85	3.4E-01	0.0E+00	Th-230	7.0E-02	0.0E+00
Rb-86	5.2E-01	0.0E+00	Th-232	8.6E-01	0.0E+00
Y-88	1.6E-06	0.0E+00	U-234	1.9E-02	0.0E+00
Sr-90	5.4E+00	6.0E+01	U-235	9.3E-04	0.0E+00
Nb-94	0.0E+00	2.5E-02	Pu-238	2.3E-01	4.7E+00
Nb-95	2.1E+02	1.7E+02	U-238	4.5E-01	0.0E+00
Zr-95	2.2E+02	1.4E+02	Pu-239/40	8.0E-03	6.3E-02
Tc-99	3.7E+00	4.8E-02	Am-241	2.3E+02	2.8E+00
Ru-103	4.7E-01	0.0E+00	Pu-241	1.2E+02	4.7E+02
Ru-106	0.0E+00	1.7E+00	Pu-242	0.0E+00	1.3E-02
Cd-109	3.8E-04	4.7E+00	Cm-242	0.0E+00	9.3E-04
In-111	4.6E-01	0.0E+00	Cm-243/44	6.4E-03	7.6E-03
Sn-113	1.2E-01	0.0E+00			
Sb-124	2.1E+00	0.0E+00	TOTAL	3.0E+04	3.1E+05

The nuclides will not be released into the environment until the concrete canisters for the Class A and Class B/C wastes fail, and until failure of the Class B/C waste forms. The concrete canisters have a design life of 500 years. Further, the waste forms for Class B/C waste are required to prevent leakage for a period of at least 300 years. In order to model the inventory at the time of failure and release to environmental pathways it is assumed that the concrete canisters fail completely 100 years after closure releasing Class A wastes, and that the required waste forms for the Class B/C waste fail after 300 years releasing these wastes. Before these times it is assumed that there is no routine release of radioactivity. Releases before 100 years would be detected through environmental monitoring during the institutional control period and remediated, while failure of the Class B/C waste forms before 300 years would be contrary to NRC requirements and highly unlikely in this arid environment.

During the first 30 year operational period, the inventory increases due to the yearly delivery of waste and decreases due to radioactive decay. The inventory for a given nuclide satisfies

$$\frac{dA}{dt} = \frac{I}{T_o} - \lambda_D A \qquad (1)$$

with the initial condition $A = 0$ at $t = 0$, and where

A	=	inventory activity of given nuclide at time t (Ci)
I	=	total inventory of nuclide delivered to the facility as specified in Table 2 (Ci)
λ_D	=	radioactive decay constant for nuclide (year^{-1})
T_o	=	operational time period = 30 years
t	=	time (years) since beginning of facility operation ($t < T_o$)

The inventory at the end of the operational time period is

$$A_o = \frac{I}{\lambda_D T_o} \left(1 - e^{-\lambda_D T_o}\right) \qquad (2)$$

After closure of the facility ($t > T_o$) the inventory decreases due to radioactive decay. The inventory at the time of failure of the concrete structures and waste form is given by

$$A_f = A_o e^{-\lambda_D (T_f - T_o)} \qquad (3)$$

where

T_f = time to failure from the beginning of operations (yrs)

The total inventory of the Class A and Class B/C disposal trenches, along with those for individual nuclides, are shown in Tables 3 and Table 4 for the end of the operational period (equation 2) and the time of failure of the retaining structures (equation 3). During the 30 year period of operations, a total inventory of 30,000 Ci of Class A waste is delivered to the facility while 9,600 Ci remains at the end of the operational time period and 2,900 Ci remains at the time of failure of the concrete canisters (100 years after closure of the facility). Similarly, for the Class B/C waste, 310,000 Ci are delivered during the period of operation while 93,000 Ci remain at the end of this period and 3,700 Ci remain at the time of failure of the Class B/C waste form (300 years after closure of the facility). Table 5 lists the 27 nuclides with inventory in excess of 10^{-10} Ci at the time of failure of the retaining structures for both the Class A or Class B/C waste streams. Only these nuclides are considered further in the performance assessment for [illegible] releases since the other nuclides are present in concentrations too small to be of significance.

There are a total of 72 nuclides listed in Table 2, though the ingrowth of radionuclides from those already in the table is not directly included. The ingrowth of radionuclides is considered as follows.

Y-90, Rh-106, and Te-125m are short-lived daughters of Sr-90, Ru-106, and Sb-125, respectively. Since Ru-106 is not present at the time of failure of the waste form and containment structures at significant levels (> 10^{-10} Ci), Rh-106 will not be present either. The activities of Y-90 and Te-125m are set equal to those of their parents, and they are transported through the environment with their parents.

Table 3. Total Radionuclide Inventory for Class A Disposal Units

Nuclide	Half-Life (yr)	Inventory (Ci) Closure (30 yr)	Inventory (Ci) Failure (130 yr)
H-3	1.24E+01	3.7E+03	1.4E+01
Be-7	1.46E-01	2.7E+00	1.9E-206
C-14	5.73E+03	1.4E+02	1.4E+02
Na-22	2.60E+00	1.2E-01	3.1E-13
P-32	3.92E-02	1.3E-01	0.0E+00
S-35	2.40E-01	1.6E-01	3.5E-127
Cl-36	3.01E+05	3.3E-01	3.3E-01
Ca-45	4.47E-01	2.3E-03	8.8E-71
Sc-46	2.30E-01	6.3E-03	5.4E-134
Cr-51	7.59E-02	1.3E+00	0.0E+00
Mn-54	8.56E-01	3.7E+01	2.5E-34
Fe-55	2.70E+00	2.6E+02	1.8E-09
Co-56	2.16E-01	8.0E-07	2.5E-146
Co-57	7.42E-01	2.0E+00	5.4E-41
Co-58	1.93E-01	6.2E+01	1.3E-154
Fe-59	1.22E-01	2.6E-01	4.6E-248
Ni-59	7.50E+04	4.2E+00	4.2E+00
Co-60	5.27E+00	1.5E+03	3.0E-03
Ni-63	9.60E+01	1.8E+03	8.5E+02
Zn-65	6.68E-01	1.1E-04	9.9E-50
Ge-68	7.89E-01	5.4E-07	3.8E-45
Se-75	3.28E-01	3.1E-04	6.0E-96
Kr-85	1.07E+01	5.2E+00	8.1E-03
Sr-85	1.78E-01	2.9E-03	1.0E-172
Rb-86	5.11E-02	1.3E-03	0.0E+00
Y-88	2.92E-01	2.2E-08	2.0E-111
Y-90*	7.31E-03	3.9E+00	3.6E-01
Sr-90	2.91E+01	3.9E+00	3.6E-01
Nb-94	2.03E+04	0.0E+00	0.0E+00
Nb-95	9.63E-02	9.9E-01	0.0E+00
Zr-95	1.75E-01	1.8E+00	3.4E-172
Tc-99	2.13E+05	3.7E+00	3.7E+00
Ru-103	1.08E-01	2.4E-03	4.5E-283
Ru-106	1.01E+00	0.0E+00	0.0E+00
Cd-109	1.27E+00	2.3E-05	4.9E-29
In-111	7.75E-03	1.7E-04	0.0E+00
Sn-113	3.15E-01	1.8E-03	6.4E-99
Sb-124	1.65E-01	1.7E-02	5.1E-185
I-125	1.65E-01	1.7E-01	3.4E-184
Te-125m*	1.59E-01	1.6E+01	2.2E-10
Sb-125	2.77E+00	1.6E+01	2.2E-10
I-129	1.57E+07	1.8E-03	1.8E-03
I-131	2.20E-02	3.1E-01	0.0E+00
Ba-133	1.07E+01	1.6E-03	2.5E-06
Cs-134	2.06E+00	1.1E+02	2.7E-13
Cs-137	3.00E+01	1.1E+03	1.1E+02
Ce-139	3.77E-01	1.7E-10	2.7E-90
Ba/La-140	3.49E-02	1.5E-01	0.0E+00
Ce-141	8.90E-02	3.0E-03	0.0E+00
Ce-144	7.79E-01	4.0E+00	9.0E-39
Pm-147	2.62E+00	2.2E+01	7.3E-11
Eu-152	1.33E+01	1.6E-06	8.8E-09
Gd-153	6.63E-01	1.7E-04	6.9E-50
Hf-175	1.92E-01	1.8E-05	1.9E-162
W-178	5.95E-02	2.5E-05	0.0E+00
Ta-182	3.15E-01	2.9E-05	8.3E-101
Re-187	5.00E+10	1.9E-03	1.9E-03
Ir-192	2.03E-01	2.3E-02	8.5E-151
Au-198	7.39E-03	6.9E-04	0.0E+00
Hg-203	1.28E-01	5.0E-11	8.2E-247
Ra-226	1.60E+03	8.7E+01	8.3E+01
Ra-228	5.75E+00	4.6E-01	2.7E-06
Th-230	7.70E+04	7.0E-02	7.0E-02
Th-232	1.41E+10	8.6E-01	8.6E-01
U-234*	2.45E+05	1.9E-02	1.9E-02
U-235	7.04E+08	9.3E-04	9.3E-04
Np-237*	2.14E+06	4.7E-02	4.7E-02
U-238	4.47E+09	4.5E-01	4.5E-01
Pu-239/40*	2.42E+04	8.0E-03	8.0E-03
Pu-242	3.76E+05	0.0E+00	0.0E+00
Total		8.9E+03	1.2E+03

Nuclides with transformed activities - see discussion in text

Table 4 Total Radionuclide Inventory for Class B/C Disposal Units

		Inventory (Ci)	
		Closure	Failure
Nuclide	Half-Life (yr)	(30 yr)	(330 yr)
H-3	1.24E+01	4.1E+04	2.0E-03
Be-7	1.46E-01	0.0E+00	0.0E+00
C-14	5.73E+03	2.7E+03	2.6E+03
Na-22	2.60E+00	0.0E+00	0.0E+00
P-32	3.92E-02	0.0E+00	0.0E+00
S-35	2.40E-01	0.0E+00	0.0E+00
Cl-36	3.01E+05	0.0E+00	0.0E+00
Ca-45	4.47E-01	0.0E+00	0.0E+00
Sc-46	2.30E-01	0.0E+00	0.0E+00
Cr-51	7.59E-02	2.0E-01	0.0E+00
Mn-54	8.56E-01	5.0E+02	1.6E-103
Fe-55	2.70E+00	1.2E+04	4.4E-30
Co-56	2.16E-01	0.0E+00	0.0E+00
Co-57	7.42E-01	1.5E+01	3.0E-121
Co-58	1.93E-01	1.2E+02	0.0E+00
Fe-59	1.22E-01	0.0E+00	0.0E+00
Ni-59	7.50E+04	2.5E+01	2.5E+01
Co-60	5.27E+00	1.8E+04	1.4E-13
Ni-63	9.60E+01	9.2E+03	1.1E+03
Zn-65	6.68E-01	8.5E+00	6.1E-135
Ge-68	7.89E-01	0.0E+00	0.0E+00
Se-75	3.28E-01	0.0E+00	0.0E+00
Kr-85	1.07E+01	2.3E+01	8.5E-08
Sr-85	1.78E-01	0.0E+00	0.0E+00
Rb-86	5.11E-02	0.0E+00	0.0E+00
Y-88	2.92E-01	0.0E+00	0.0E+00
Y-90*	7.31E-03	4.3E+01	3.4E-02
Sr-90	2.91E+01	4.3E+01	3.4E-02
Nb-94	2.03E+04	2.5E-02	2.5E-02
Nb-95	9.63E-02	8.1E-01	0.0E+00
Zr-95	1.75E-01	1.2E+00	0.0E+00
Tc-99	[illegible]13E+05	4.8E-02	4.8E-02
Ru-103	1.08E-01	0.0E+00	0.0E+00
Ru-106	1.01E+00	8.2E-02	2.5E-91
Cd-109	1.27E+00	2.9E-01	2.6E-72
In-111	7.75E-03	0.0E+00	0.0E+00

		Inventory (Ci)	
		Closure	Failure
Nuclide	Half-Life (yr)	(30 yr)	(330 yr)
Sn-113	3.15E-01	0.0E+00	0.0E+00
Sb-124	1.65E-01	0.0E+00	0.0E+00
I-125	1.65E-01	0.0E+00	0.0E+00
Te-125m*	1.59E-01	5.6E+01	1.4E-31
Sb-125	2.77E+00	5.6E+01	1.4E-31
I-129	1.57E+07	2.7E-03	2.7E-03
I-131	2.20E-02	0.0E+00	0.0E+00
Ba-133	1.07E+01	0.0E+00	0.0E+00
Cs-134	2.06E+00	6.4E+01	1.0E-42
Cs-137	3.00E+01	8.1E+03	7.9E+00
Ce-139	[illegible]7E-01	0.0E+00	0.0E+00
Ba/La-140	3.49E-02	0.0E+00	0.0E+00
Ce-141	8.90E-02	0.0E+00	0.0E+00
Ce-144	7.79E-01	3.1E+01	3.6E-115
Pm-147	2.62E+00	0.0E+00	0.0E+00
Eu-152	1.33E+01	0.0E+00	0.0E+00
Gd-153	6.63E-01	0.0E+00	0.0E+00
Hf-175	1.92E-01	0.0E+00	0.0E+00
W-178	5.95E-02	0.0E+00	0.0E+00
Ta-182	3.15E-01	0.0E+00	0.0E+00
Re-187	5.00E+10	0.0E+00	0.0E+00
Ir-192	2.03E-01	0.0E+00	0.0E+00
Au-198	7.39E-03	0.0E+00	0.0E+00
Hg-203	1.28E-01	0.0E+00	0.0E+00
Ra-226	1.60E+03	0.0E+00	0.0E+00
Ra-228	5.75E+00	0.0E+00	0.0E+00
Th-230	7.70E+04	0.0E+00	0.0E+00
Th-232	1.41E+10	0.0E+00	0.0E+00
U-234*	2.45E+05	1.7E-03	1.7E-03
U-235	7.04E+08	0.0E+00	0.0E+00
Np-237*	2.14E+06	3.7E-03	3.7E-03
U-238	4.47E+09	0.0E+00	0.0E+00
Pu-239/40*	2.43E+04	6.3E-02	6.3E-02
Pu-242	3.76E+05	1.3E-02	1.3E-02
Total		9.3E+04	3.7E+03

* Nuclides with transformed activities - see discussion in text

Table 5 Nuclides Considered in Exposure Assessment for Normal Release Pathways

H-3	Cs-137
C-14	Eu-152
Cl-36	Re-187
Fe-55	Ra-226
Ni-59	Ra-228
Co-60	Th-230
Ni-63	Th-232
Kr-85	U-234
Sr-90	U-235
Nb-94	Np-237
Tc-99	U-238
Sb-125	Pu-239
I-129	Pu-242
Ba-133	

The short-lived daughters of Pb-210, Ra-226, Th-228, Th-232, U-235, and U-238 are assumed to be in equilibrium with their parent nuclides and only the transport of the parent through the environmental pathway is modeled. However, when calculating the resulting doses, the dose conversion factors for the parent and the short-lived daughters are added together before multiplication by the parent exposure concentration. This in effect assumes that the daughters are transported with the parent nuclides. This approach is applied somewhat differently depending on the source of the dose conversion factors, in that some of the literature sources include the short-lived daughter factors in with the parent factors. Details are presented later.

Pu-241 and Am-241 are relatively short-lived nuclides (when compared with their slow movement through the subsurface environment) which decay to Np-237, which has a very long half-life. These nuclides are handled by transforming their initial inventory activities to that of Np-237 through the relations

$$A_{Np\text{-}237} = A_{Pu\text{-}241} \frac{T_{1/2}(Pu\text{-}241)}{T_{1/2}(Np\text{-}237)} = 6.29E\text{-}06 \ A_{Pu\text{-}241} \quad (4)$$

$$A_{Np\text{-}237} = A_{Am\text{-}241} \frac{T_{1/2}(Am\text{-}241)}{T_{1/2}(Np\text{-}237)} = 2.19E\text{-}04 \ A_{Am\text{-}241} \quad (5)$$

where

A_j = Activity of the j^{th} Nuclide (Ci)

$T_{1/2}(j)$ = Half-Life of the j^{th} Nuclide (yr)

The activity of Np-237 is set equal to the transformed activities of Pu-241 and Am-241 before transport and dose analysis. Tables 3 and 4 correspond to this corrected activity.

The nuclide Cm-242 decays to Pu-238 and then to the longer-lived U-234. The initial activity of Cm-242 is transformed to U-234 through

$$A_{U\text{-}234} = A_{Cm-242} \frac{T_{1/2}(Cm-242)}{T_{1/2}(U-234)} = 1.82E-06 \ A_{Cm-242} \quad (6)$$

Similarly, the initial activity of Pu-238 is transformed to U-234 through

$$A_{U\text{-}234} = A_{Pu-238} \frac{T_{1/2}(Pu-238)}{T_{1/2}(U-234)} = 3.58E-04 \ A_{Pu-238} \quad (7)$$

The nuclides Cm-243 and Cm-244 decay to Pu-239 and Pu-240. The initial activities of Cm-243/244 are transformed to Pu-239/240 through

$$A_{Pu\text{-}239/240} = A_{Cm-243/244} \frac{T_{1/2}(Cm-243)}{T_{1/2}(Pu-240)} = 4.36E-03 \ A_{Cm-243/244} \quad (8)$$

This is conservative because the half-life of Cm-243 is longer than that of Cm-244, while that of Pu-240 is shorter than that of Pu-239. For calculation of environmental transport of Pu-239/240, the longer half-life of Pu-239 is used. All of these transformations are reflected in Tables 3 and 4.

4. Infiltration Through the Waste Disposal Units

The site characterization studies have shown that the amount of infiltration outside of the waste disposal unit cover system is not significant, with estimates ranging from 0 to 0.3 inches per year. The infiltration through the waste disposal unit cover system is of interest because it determines the amount of water which may come into contact with the waste and transport the waste from the disposal units as leachate. Because of the upward gradient which exists at the site, leachate released from the units may return to the ground surface with the water being lost to evapotranspiration. Although there does not appear to be a viable pathway through the unsaturated zone to groundwater, the contaminated leachate which is calculated to potentially leave the facility is also considered as a source for the groundwater pathway.

The HELP (2.05) computer model (Schroeder et al., 1988) was used to estimate the quantity of water percolating through the cover system of the waste disposal. The solar radiation conditions for El Paso were used along with the mean monthly temperature and rainfall for Sierra Blanca as shown in Table 6. The cover systems for the Class A and Class B/C units are the same and are composed of 1) an upper soil cover layer which will be used to support a poor grass cover for soil stabilization, 2) a geosynthetic clay liner (GCL), 3) an eight-inch thick layer of asphalt which will act as an intruder biointrusion barrier, 4) a layer of fill, 5) the temporary cover layer, and 6) the filter/bedding layer. The total thickness of the cover system is 16.5 feet (5.0 m). The parameters for the HELP model simulations the cover system are presented in Table 7. For performance assessment, the analysis of the cover system neglects the GCL and asphalt layer , and thus provides a conservative estimate of infiltration.

Table 6 Sierra Blanca, Texas (1963-1988)

Month	Mean Temperature	Mean Precipitation
January	42.65	0.40
February	48.05	0.37
March	52.80	0.34
April	60.65	0.27
May	79.60	0.46
June	76.60	1.21
July	78.15	2.07
August	75.90	2.41
September	70.61	2.61
October	61.28	1.27
November	50.27	0.48
December	43.60	0.57
ANNUAL		12.46

Table 7 Parameters Used to Characterize the Class A and Class B/C Covers*

Parameter	Value
Top Drainage Layer (Soil Cover)	
Thickness--in. (cm)	60 (152)
Permeability--cm/s	0.001
Porosity	0.457
Vegative Cover	Poor Grass
Evaporative Zone Depth--in. (cm)	46.8 (119)
Slope	0
Secondary Drainage Layer (Fill)	
Thickness--in. (cm)	80.85 (205)
Permeability--cm/s	1×10^{-5}
Porosity	0.398
Slope	0
Secondary Drainage Layer (Temporary Cover)	
Thickness--in. (cm)	24 (61)
Permeability--cm/s	1.0×10^{-5}
Porosity	0.398
Slope	0
Secondary Drainage Layer (Filter/Bedding)	
Thickness--in. (cm)	24 (61)
Permeability--cm/s	1.0×10^{-2}
Porosity	0.417
Slope (percent)	0

* GCL and asphalt layers are neglected

Analyses of the cover systems using the HELP computer code for poor grass surface conditions show a percolation value of 0.0570 in/yr (0.0014[illegible] m^3/m^2/yr) for the Class A and Class B/C covers. This value compares well with the 0.06 in/yr estimate from bomb chloride and reflects the average percolation rate from the base of the cover system over a 50-year period. At the beginning of the simulation, the layers have water contents near field capacity. This is conservative in that the cover system will be placed with the material at optimum water content. During the first couple of years, the cover system dries out and the ending soil water content is less than field capacity and probably more closely reflects actual field conditions to be expected. This suggests that the percolation rate noted above is conservative. Because the barrier layers are neglected, there is no ponding depth within the cover system.

The design calls for 15 Class A disposal units with a top width and length of 211 and 673 feet, respectively. This gives a total Class A disposal unit surface area of 2,130,000 ft^2 (198,000 m^2). With an average percolation rate of 0.001448 m^3/m^2/yr, the discharge through the Class A disposal units is 287 m^3/yr (10,200 ft^3/yr). Similarly, the design calls for 5 Class B/C disposal units with a top width and length of 140 and 719 feet, respectively. This gives a total Class B/C disposal unit surface area of 503,000 ft^2 (47,000 m^2) and an average discharge of 68 m^3 (2,400 ft^3) through the units. The combined discharge from the disposal units averages 355 m^3/yr (12,500 ft^3/yr). These values are shown in Table 8 along with the average monthly percolation rates calculated with the HELP model.

Table 8 Monthly Values for Percolation Through Covers

Month	Percolation – inches (cm)
January	0.0049 (0.0124)
February	0.0044 (0.0112)
March	0.0049 (0.0124)
April	0.0047 (0.0119)
May	0.0048 (0.0122)
June	0.0047 (0.0119)
July	0.0048 (0.0122)
August	0.0048 (0.0122)
September	0.0047 (0.0119)
October	0.0048 (0.0122)
November	0.0047 (0.0119)
December	0.0048 (0.0122)
TOTAL	0.0570 (0.1448)

AVERAGE YEARLY WATER DISCHARGE THROUGH DISPOSAL UNITS

Class A	Class B/C
287 m^3	68 m^3

Total = 355 m^3

5. Radionuclide Release and Leachate Generation

The release rate of radionuclides from the facility has been modeled for a period of time extending from closure of the waste facility to approximately 10,000 years beyond the estimated failure time of the concrete canisters and waste form. The 10,000-year analysis period was chosen based on the use of a 10,000-year analysis period by the U.S. Environmental Protection Agency for its "Generally Applicable Environmental Standard" for radiological assessments (proposed rule, 40-CFR, Part 193). As noted in above, it is assumed that the concrete canisters fail at 100 years after closure releasing Class A wastes to environmental pathways, and that the waste forms of the Class B/C wastes fail at 300 years after closure. The calculated doses for longer times are also reported for critical nuclides.

The release rate of radionuclides from the waste disposal units is an important parameter for characterizing the transport through many of the potential transport pathways. It is assumed that releases from the concrete canisters are negligible until their time of failure, and upon failure, that this failure of the canisters is complete. Thus, no credit is taken for the concrete canisters after 100 years. However, it is assumed that the waste forms will continue to stop the release of Class B/C wastes until 300 years after closure, and that after this time the waste forms will continue to partially impede the release of radioactivity from Class B/C wastes. This approach is conservative in that the time to failure used in the analyses is significantly less than the design lifetime and expected lifetime for the retainers in this arid environment.

After failure of the concrete structures, some of the water that percolates through the cover comes into contact with the waste, and the waste is leached from the facility. The leach rate constant depends on the amount of water which percolates through the disposal units, the fraction of the waste which is contacted by the percolating water, and the nuclide storage capacity of the material within the disposal units. Radionuclide leaching is modeled using mass balance principles:

$$\frac{dA}{dt} + \dot{m}_{facility} = -\lambda_D A \qquad (9)$$

where A is the activity (Ci) contained within the disposal trenches, $\dot{m}_{facility}$ is the leachate flux from the trenches (Ci/yr), and the term on the right-hand-side is the loss due to radioactive decay (Ci/yr). The total activity within the waste disposal units is given by

$$A = (\theta_{waste} + \rho_{waste} K_d) c_w A_s L_{waste} \quad (10)$$

where

- θ_{waste} = volumetric water content of waste (cm^3 water/cm^3 waste)
- ρ_{waste} = bulk density of waste (gm/cm^3)
- K_d = equilibrium distribution coefficient (cm^3/gm)
- c_w = nuclide concentration in water (Ci/m^3)
- A_s = surface area of the disposal units (m^2)
- L_{waste} = waste thickness (m)

The leachate flux from the waste disposal units is given by

$$\dot{m}_{facility} = q\, A_s\, c_w\, f_L = \frac{q\, f_L}{(\theta_{waste} + \rho_{waste} K_d)\, L_{waste}} A = \lambda_L\, A \quad (11)$$

where

- q = percolation of water through the disposal trenches (m/yr)
- f_L = factor which accounts for the fraction of the waste which is contacted by water percolating through the liner system and from which leachate generation occurs
- λ_L = leach rate constant (yr^{-1})

The fraction f_L is included to account for the very nonuniform seepage through the disposal trenches which is expected under these small water discharge conditions. If water moves uniformly and continuously through saturated waste disposal units and the waste is completely accessible, then $f_L = 1$. However, because the amount of water discharge is very small, and the waste disposal units are expected to have a higher effective permeability than the overlying fill and temporary cover, the region of water flow from through the disposal units is much less than the total area. Within the IMPACTS methodology (NUREG/CR-4370, 1986) this is accounted for with the contact time parameter, t_c (pg. 4.52). For a site in the southwest they suggest values of ranging from 0.0072 to 0.000036 for t_c (or f_L). For the performance assessment calculations made here it is assumed that f_L = 0.001 for the Class A waste disposal trenches, and f_L = 0.0001 for the Class B/C disposal trenches. This latter reduction in f_L reflects the waste form accessibility index for Class B/C wastes, also included within the IMPACTS methodology.

Equation (11) shows that leachate generation appears as a first-order process and is characterized by a leach rate constant, λ_L, given by

$$\lambda_L = \frac{q\, f_L}{(\theta_{waste} + \rho_{waste}\, K_d)\, L_{waste}} \qquad (12)$$

The leach rate constant is the ratio of the radionuclide release rate (Ci/yr) to the current inventory (Ci). The leach rate is the approximate fraction of the current inventory that is released each year.

The release of radionuclides to environmental pathways occurs after failure of the retaining structures and the inventory decreases both because of leaching and radioactive decay. The activities at the time of failure of the concrete canisters for Class A wastes were presented in Table 3 while those for Class B/C wastes at the time of failure of the waste forms were presented in Table 4. During the period of time with environmental releases of radioactivity the inventory is given by equation (9) which may be written

$$\frac{dA}{dt} = -(\lambda_D + \lambda_L)\, A \qquad (13)$$

with $A = A_f$ at $t = T_f$. This gives the inventory during the period of leaching as

$$A = A_f\, e^{-(\lambda_D+\lambda_L)(t-T_f)} \qquad (14)$$

for $t \geq T_f$. A failure time of 130 years (100 years past closure) is assumed for the Class A waste and 330 years (300 years after closure) for the Class B/C waste.

The parameters used in the assessment calculations are shown in Table 9, and in Table 10 for significant nuclides listed in Table 5. Distribution coefficients for radionuclides are available in Looney et al. (1987), EPA (1988), Baes et al. (1984), and other sources. Generally, the values from Looney et al. (1987) for assessing subsurface transport at the Savannah River Plant were used. These values are lower because the Savannah River Plant report selected conservative values from a literature survey for application at the humid environment at Savannah River. This results in a more conservative assessment.

Table 9 Leach Rate Parameters

Parameter	Class A	Class B/C
q (m/yr)	0.00145	0.00145
A_s (m^2)	245,000	245,000
f_L	0.001	0.0001
θ_{waste}	0.10	0.10
ρ_{waste} (gm/cc)	1.2	1.8
L_{waste} (m)	5.5	2.75

Equation (11) shows that the leachate release rate from the disposal units (Ci/yr) is equal to the product of the nuclide leach rate constant and the nuclide inventory (Ci). The maximum disposal unit radionuclide release rate for significant nuclides listed in Table 5 is found by multiplying their activities at the time of failure from Tables 3 and 4 by their leach rate constants from Table 10.

Table 10 Parameters for Significant Nuclides Listed in Table 5

Nuclide	Half-Life (yr)	Radioactive Decay Coef. (yr-1)	Distribution Coef. Kd (L/kg)	Retardation Factor (-)	Leach Rate Class A (yr-1)	Leach Rate Class B/C (yr-1)
H-3	1.24E+01	5.61E-02	0.001	1.02E+00	2.60E-06	5.17E-07
C-14	5.73E+03	1.21E-04	0.01	1.20E+00	2.35E-06	4.46E-07
Cl-36	3.01E+05	2.30E-06	0.001	1.02E+00	2.60E-06	5.17E-07
Fe-55	2.70E+00	2.57E-01	5	1.01E+02	4.32E-08	5.79E-09
Ni-59	7.50E+04	9.24E-06	100	2.00E+03	2.19E-09	2.92E-10
Co-60	5.27E+00	1.32E-01	10	2.01E+02	2.18E-08	2.91E-09
Ni-63	9.60E+01	7.22E-03	100	2.00E+03	2.19E-09	2.92E-10
Kr-85	1.07E+01	6.47E-02	0	1.00E+00	2.63E-06	5.27E-07
Sr-90	2.91E+01	2.38E-02	8	1.61E+02	2.71E-08	3.63E-09
Nb-94	2.03E+04	3.41E-05	300	6.00E+03	7.31E-10	9.75E-11
Tc-99	2.13E+05	3.25E-06	0.001	1.02E+00	2.60E-06	5.17E-07
Sb-125	2.77E+00	2.50E-01	4000	8.00E+04	5.48E-11	7.31E-12
I-129	1.57E+07	4.41E-08	0.2	5.00E+00	7.74E-07	1.14E-07
Ba-133	1.07E+01	6.45E-02	100	2.00E+03	2.19E-09	2.92E-10
Cs-137	3.00E+01	2.31E-02	500	1.00E+04	4.39E-10	5.85E-11
Eu-152	1.33E+01	5.20E-02	1000	2.00E+04	2.19E-10	2.93E-11
Re-187	5.00E+10	1.39E-11	7.5	1.51E+02	2.89E-08	3.87E-09
Ra-226	1.60E+03	4.33E-04	220	4.40E+03	9.97E-10	1.33E-10
Ra-228	5.75E+00	1.21E-01	220	4.40E+03	9.97E-10	1.33E-10
Th-230	7.70E+04	9.00E-06	100	2.00E+03	2.19E-09	2.92E-10
Th-232	1.41E+10	4.93E-11	100	2.00E+03	2.19E-09	2.92E-10
U-234	2.45E+05	2.83E-06	40	8.01E+02	5.47E-09	7.30E-10
U-235	7.04E+08	9.85E-10	40	8.01E+02	5.47E-09	7.30E-10
Np-237	2.14E+06	3.24E-07	10	2.01E+02	2.18E-08	2.91E-09
U-238	4.47E+09	1.55E-10	40	8.01E+02	5.47E-09	7.30E-10
Pu-239/40	2.42E+04	2.86E-05	100	2.00E+03	2.19E-09	2.92E-10
Pu-242	3.76E+05	1.84E-06	100	2.00E+03	2.19E-09	2.92E-10

6. Transport to the Soil Surface

There is no physical evidence that any leachate will actually be generated from the disposal units. Nevertheless, for the performance assessment calculations it is assumed that the 50-year average percolation from the base of the cover system as predicted by the HELP model provides an adequate estimate of the net infiltration rate. The apparent potential gradient in the upper 40 to 50 feet of the unsaturated zone is upward, and the fate of the leachate released from the disposal trenches may be to migrate upward to the soil surface. Groundwater does not appear to be a viable pathway, both because the aquifer is confined and because the age of its waters are old. For the following calculations it is assumed that three-quarters of the disposal unit leachate returns to the ground surface, and that one-quarter infiltrates to the aquifer.

If leachate does return to the soil surface, the water will pass into the atmosphere either through evaporation or transpiration, while the nuclides (except for H-3 and C-14) will accumulate on the surface soil. Removal of activity occurs through decay and suspension of the soil particles. Exposures occur through direct radiation from the soil and the suspended soil particles, inhalation of H-3 and C-14 and suspended particles, and from ingestion along biotic pathways involving plant and animal uptake.

Leachate enters the unsaturated zone from the base of the disposal trenches at a depth of approximately 35 ft (10.7 m). With the large capillary suctions that exist within the unsaturated zone, the entering leachate will be pulled laterally as well as vertically, displacing the existing soil water as it migrates. To estimate the mean travel time to the ground surface, it is assumed that the leachate arrives at the soil surface within an area having the same magnitude, A_s, as the surface area of the disposal units. This area is about 245,000 m^2. Three-quarters of the disposal unit leachate is assumed to move upward through this area, while the remaining one-quarter of the leachate is assumed to move downward. With an average volumetric water content of 0.10 taken from the site characterization data for the upper 10 m of the soil profile, the total water volume which must be displaced is 10.7 x 245,000 x 0.10 = 260,000 m^3. The total volumetric water discharge from the disposal units is 355 m^3, and the amount assumed to return to the ground surface is 265 m^3 (see Table 8). If it is assumed that the volumetric water content remains at 0.10 (which is conservative in that a higher water content would result in a longer travel time), then the mean travel time for the leachate water is T_{water} = 260,000/265 = 980 years. This is the mean travel time for the water. Because of nuclide partitioning between the soil and water, nuclides will have a longer travel time depending on their partition coefficients and retardation factors. The mean nuclide travel time is

$$T_{nuclide} = T_{water} \times R_{nuclide} \tag{15}$$

where the nuclide retardation factor is calculated from

$$R_{nuclide} = 1 + \frac{\rho_b K_d}{\theta} \tag{16}$$

where

ρ_b = soil bulk density (gm/cc)
θ = soil water content (dimensionless)

During the time of travel from the waste disposal units to the ground surface, the nuclide activity decreases because of radioactive decay. The maximum flux to the ground surface, $\dot{m}_{smax}$, is equal to the maximum flux released from the units at the time of failure, $\dot{m}_{fmax}$, decreased by the factor accounting for exponential decay during the transport time:

$$\dot{m}_{smax} = f_{surface} \; \dot{m}_{fmax} \; e^{-\lambda_D T_{nuclide}} \tag{17}$$

where

$\dot{m}_{smax}$ = maximum nuclide flux to the ground surface (Ci/yr)
$f_{surface}$ = fraction of disposal unit leachate which returns to the ground surface
$\dot{m}_{fmax}$ = maximum nuclide flux from the disposal units at the time of failure (Ci/yr) = $\lambda_D A_f$ (equation 9)

The maximum nuclide concentration in the soil near the soil surface, C_G (Ci/m^3), is calculated from

$$C_G = \frac{\dot{m}_{smax} \; (\theta + \rho_b K_d)}{f_{surface} \, Q_w} \tag{18}$$

This equation follows from the definition of the retardation factor.

7. Transport to the Atmosphere

Once the nuclide reaches the ground surface, the surface concentration starts to build up. The surface concentration increases because of the leachate migration to the surface, while at the same time it decreases because of decay and nuclide loss due to suspension of soil material retaining the nuclide. Both loss terms are proportional to the surface concentration. The corresponding mass balance equation for the ground surface is

$$A_s \frac{dC_A}{dT_s} = \dot{m}_{surface} - (\lambda_D + S) A_s C_A \quad (19)$$

where

C_A = surface concentration (Ci/m^2)

T_s = time increment since nuclide first arrives at ground surface = $t - T_f - T_{nuclide}$ (yr)

A_s = surface area (m^2)

$\dot{m}_{surface}$ = radionuclide flux to the ground surface as a function of time (Ci/yr)

S = suspension rate constant (yr^{-1})

The leach rate to the soil surface is given by

$$\dot{m}_{surface}(T_s) = \dot{m}_{smax}\, e^{-(\lambda_L + \lambda_D) T_s} \quad (20)$$

With $C_A = 0$ at $T_s = 0$, the surface concentration is given by

$$C_A = \frac{\dot{m}_{smax}}{A_s(S - \lambda_L)} \left[e^{-\lambda_L T_s} - e^{-S T_s}\right] e^{-\lambda_D T_s} \;(\text{Ci/m}^2) \quad (21)$$

The maximum surface concentration occurs at the time when the leachate rate is balanced by the loss rate due to suspension and decay. This time is calculated from

$$T_{equilibrium} = \frac{1}{S - \lambda_L} \ln\left(\frac{S + \lambda_D}{\lambda_L + \lambda_D}\right) \quad (22)$$

The suspension rate constant, S, is assumed to have a value of 10^{-7} sec^{-1} = 3.154 yr^{-1}, which corresponds to a half-life of 0.22 years. This is quite short compared with the travel times for most nuclides, which implies that the equilibrium condition which balances leachate arrival and nuclide losses is reached shortly after arrival of the leachate at the ground surface. The value of S was reported by Peterson (NUREG/CR-3332, 1983) as typical for an arid environment. Its magnitude primarily influences the equilibrium times, $T_{equilibrium}$, and since these are so much smaller that the nuclide travel times, $T_{nuclide}$, the value of S does not affect the calculated surface and air phase concentrations appreciably. Variation over two orders of magnitude results in little change in the calculated dose.

The nuclide enters the atmosphere along with suspended soil and dust particles. The release rate to the atmosphere, $\dot{m}_{air}$, is found from

$$\dot{m}_{air} = S\, A_s\, C_A \qquad \text{(Ci/yr)} \qquad (23)$$

This nuclide flux mixes with the air which passes over the area A_s. The air discharge over the area is

$$Q_{air} = W\ H\ V_{wind} \qquad (m^3/yr) \qquad (24)$$

where

W	=	transverse width of the leachate release area (m)
H	=	mixing height of air passing over the release area (m)
V_{wind}	=	mean wind speed (m/yr)

For these calculations, a width of $W = \sqrt{A_s} = 500$ m is assumed, along with a mixing height of H = 2 m. The value of W is conservatively chosen as the square-root of the area A_s. Since the area of the disposal trenches is embedded within the actual leachate discharge area, the true width would be considerably larger and the air dilution discharge would be greater, resulting in a lower air concentration. Likewise, the thickness of the mixing boundary layer which develops as the wind moves over the area of the facility would be greater than the chosen value of 2 meters. The mean 2 m height wind speed for the proposed facility location is 6.07 mph = 8.56×10^7 m/yr (Jurica and Culhane, 1993). Thus the air discharge over the leachate release area is 8.56×10^{10} m^3/yr. The resulting air concentration is found from

$$C_{air} = \frac{\dot{m}_{air}}{Q_{air}} \qquad (Ci/m^3) \qquad (25)$$

and the maximum air concentration is found by evaluating the flux into the atmosphere at the time when the surface concentration is maximum:

$$T_s = T_{equilibrium} \qquad (26)$$

The parameters used in the pathway of leachate returning to the ground surface and atmospheric pathway are shown in Table 11. Table 12 provides the calculated soil surface nuclide flux, the soil concentration, and the air concentration for each of the significant nuclides listed in Table 5.

Table 11 Parameters for Ground Surface and Atmospheric Model

ρ_b	=	2.0 L/kg
θ	=	0.10
$f_{surface}$	=	0.75
S	=	3.15 yr^{-1}
W	=	500 m
H	=	2 m
V_{wind}	=	6.07 mph

Table 12 Radionuclide Flux to Soil Surface and Exposure Concentrations

Nuclide	Time After Closure (yr)	Soil Surface Flux (Ci/yr)	Soil Conc. (Ci/m^3)	Surface Conc. (Ci/m^2)	Air Conc. (Ci/m^3)
H-3	1.3E+03	8.5E-30	2.4E-33	1.0E-35	9.2E-41
C-14	1.5E+03	9.6E-04	3.2E-07	1.2E-09	1.1E-14
Cl-36	1.3E+03	6.5E-07	1.9E-10	8.4E-13	7.7E-18
Fe-55	1.0E+05	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ni-59	2.0E+06	1.5E-16	8.5E-17	2.0E-22	1.8E-27
Co-60	2.0E+05	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ni-63	2.0E+06	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Kr-85	1.3E+03	3.4E-36	9.7E-40	4.0E-42	3.7E-47
Sr-90	1.6E+05	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Nb-94	5.9E+06	3.8E-100	6.4E-100	4.9E-106	4.5E-111
Tc-99	1.3E+03	7.3E-06	2.1E-09	9.4E-12	8.6E-17
Sb-125	7.9E+07	0.0E+00	0.0E+00	0.0E+00	0.0E+00
I-129	5.2E+03	1.3E-09	1.8E-12	1.6E-15	1.5E-20
Ba-133	2.0E+06	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cs-137	9.9E+06	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Eu-152	2.0E+07	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Re-187	1.5E+05	4.2E-11	1.8E-12	5.4E-17	4.9E-22
Ra-226	4.3E+06	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ra-228	4.3E+06	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Th-230	2.0E+06	2.2E-18	1.3E-18	2.9E-24	2.6E-29
Th-232	2.0E+06	1.4E-09	8.0E-10	1.8E-15	1.7E-20
U-234*	7.9E+05	8.5E-12	1.9E-12	1.1E-17	1.0E-22
U-235	7.9E+05	3.8E-12	8.7E-13	5.0E-18	4.5E-23
Np-237*	2.0E+05	7.3E-10	4.1E-11	9.4E-16	8.6E-21
U-238	7.9E+05	1.8E-09	4.2E-10	2.4E-15	2.2E-20
Pu-239/40*	2.0E+06	8.0E-36	4.5E-36	1.0E-41	9.5E-47
Pu-242	2.0E+06	7.7E-14	4.4E-14	1.0E-19	9.1E-25

8. Transport to Groundwater

As noted above, leachate from the facility disposal units enters an environment with an upward energy gradient, and the volume of leachate may not be sufficient to reverse this gradient. In addition, groundwater at Faskin Ranch site appears to be in a confined, pressurized aquifer, so that recharge from surface infiltration would not be possible. Nevertheless, the groundwater pathway has been modeled to address a common concern about low-level radioactive waste disposal facilities – contamination of the groundwater. In developing a groundwater scenario it has been assumed that one-quarter of the leachate from the waste disposal units becomes aquifer recharge.

The travel time to the aquifer for recharge water is based on a simple advection model. At the Faskin Ranch site the unsaturated zone may be separated into a layer of unsaturated alluvium and a layer of unsaturated fractured rock. The travel time to the aquifer is calculated from

$$T_{aquifer} = \frac{L_1\theta_1 + L_2\theta_2}{f_{aquifer}\, q} \qquad (27)$$

where

L_1	=	thickness of the unsaturated alluvium (m)
θ_1	=	water content of the alluvium
L_2	=	thickness of the unsaturated fractured bedrock (m)
θ_2	=	water content of the unsaturated bedrock
$f_{aquifer}$	=	fraction of disposal unit percolation which travels downward to the aquifer
q	=	percolation through the disposal units (m/yr)

The nuclide travel time to the aquifer is calculated from

$$T_{naq} = T_{aquifer} + \frac{(L_1 + L_2)\,\rho_b\, K_d}{f_{aquifer}\, q} \qquad (28)$$

The radionuclide influx to the aquifer is related to that from the facility disposal units through

$$\dot{m}_{aquifer} = f_{aquifer}\ \dot{m}_{fmax}\ e^{-\lambda_D T_{naq}} \qquad (29)$$

where $\dot{m}_{fmax}$ is evaluated at the time of failure of the waste retaining structures.

In order to estimate the aquifer concentration beneath the facility, a mixing model similar to that used for the air concentration is applied. The aquifer concentration is given by

$$C_{aquifer} = \frac{\dot{m}_{aquifer}}{b\ W\ n\ V_a} \tag{30}$$

where

b	=	thickness of aquifer the mixing zone beneath the facility (m)
W	=	width of the mixing zone beneath the facility (m)
n	=	aquifer porosity
V_a	=	aquifer seepage velocity (m/yr)

$C_{aquifer}$ represents the maximum nuclide concentration which would occur in the aquifer at the downgradient edge of the source region beneath the facility.

To estimate the concentration at a well at the site boundary, a conservative model is chosen which assumes that $C_{aquifer}$ remains constant at its maximum calculated value and that steady-state conditions are achieved. In addition, the transverse mixing is neglected. The well concentration for this problem has been given by Bear (1979, pg. 270) as

$$C_{well} = C_{aquifer} \exp\left[\frac{L}{2a_L}\left(1 - \sqrt{1 + \frac{4\lambda_D a_L R_a}{V_a}}\right)\right] \tag{31}$$

where

L	=	distance to the site boundary (m)
a_L	=	longitudinal dispersivity (m)
R_a	=	nuclide retardation factor within the aquifer $= 1 + \frac{\rho_b K_d}{n}$

The parameters used for the groundwater model are shown in Table 13 and are taken from the site characterization studies and the assumed size of the mixing zone. The resulting aquifer influx, aquifer concentration, and well concentrations are shown in Table 14.

Table 13 Parameters for Groundwater Model

θ_1	=	0.10
L_1	=	100 m
θ_2	=	0.025
L_2	=	110 m
$f_{aquifer}$	=	0.25
b	=	30 m
W	=	500 m
n	=	0.04
V_a	=	0.50 m/yr
L_{aq}	=	30 m
a_L	=	3 m

Table 14 Concentrations from Groundwater Model

Nuclide	Time After Closure (yr)	Aquifer Influx (Ci/yr)	Aquifer Conc. (Ci/m^3)	Well Conc. (Ci/m^3)
H-3	3.6E+04	0.0E+00	0.0E+00	0.0E+00
C-14	4.7E+04	1.3E-06	4.3E-09	4.3E-09
Cl-36	3.6E+04	2.0E-07	6.7E-10	6.7E-10
Fe-55	5.8E+06	0.0E+00	0.0E+00	0.0E+00
Ni-59	1.2E+08	0.0E+00	0.0E+00	0.0E+00
Co-60	1.2E+07	0.0E+00	0.0E+00	0.0E+00
Ni-63	1.2E+08	0.0E+00	0.0E+00	0.0E+00
Kr-85	3.5E+04	0.0E+00	0.0E+00	0.0E+00
Sr-90	9.3E+06	0.0E+00	0.0E+00	0.0E+00
Nb-94	3.5E+08	0.0E+00	0.0E+00	0.0E+00
Tc-99	3.6E+04	2.2E-06	7.3E-09	7.3E-09
Sb-125	4.6E+09	0.0E+00	0.0E+00	0.0E+00
I-129	2.7E+05	4.2E-10	1.4E-12	1.4E-12
Ba-133	1.2E+08	0.0E+00	0.0E+00	0.0E+00
Cs-137	5.8E+08	0.0E+00	0.0E+00	0.0E+00
Eu-152	1.2E+09	0.0E+00	0.0E+00	0.0E+00
Re-187	8.7E+06	1.4E-11	4.7E-14	4.7E-14
Ra-226	2.6E+08	0.0E+00	0.0E+00	0.0E+00
Ra-228	2.6E+08	0.0E+00	0.0E+00	0.0E+00
Th-230	1.2E+08	0.0E+00	0.0E+00	0.0E+00
Th-232	1.2E+08	4.7E-10	1.6E-12	1.6E-12
U-234*	4.6E+07	1.8E-68	5.9E-71	4.2E-71
U-235	4.6E+07	1.2E-12	4.1E-15	4.1E-15
Np-237*	1.2E+07	6.0E-12	2.0E-14	2.0E-14
U-238	4.6E+07	6.1E-10	2.1E-12	2.1E-12
Pu-239/40*	1.2E+08	0.0E+00	0.0E+00	0.0E+00
Pu-242	1.2E+08	1.4E-105	4.7E-108	2.8E-108

9. Environmental Concentrations from Transport Pathways

Tables 12 and 14 provide the nuclide exposure concentrations from disposal unit leachate returning to the ground surface, and leachate moving downward to contaminate the groundwater aquifer. For calculation of exposure doses, only those nuclides which have exposure concentrations in excess of 10^{-10} Ci/m^3 are considered. In addition, because of its perceived environmental impact, I-129 is also considered even though its exposure concentrations fall below this cut-off level. All other nuclides are expected to provide neglible contributions to the calculated exposure dose.

A look at Table 12 shows that C-14, Cl-36, Tc-99, Th-232, and U-238 have a calculated exposure concentration in excess of 10^{-10} Ci/m^3 in contaminated soil. Table 14 shows that only C-14, Cl-36, and Tc-99 exceed this level at the groundwater well. Table 15 lists the nuclides which are considered for dose assessment.

Table 15 Nuclides Calculated to be Present in Exposure Concentrations at Levels Significant for Dose Calculation

C-14	I-129
Cl-36	Th-232
Tc-99	U-238

10. Dose Calculations from Surface Exposures

Release and transport of radionuclides from the waste disposal units to potential human access locations at the soil surface were modeled using simple analytical models. Three exposures ar~ considered for dose calculations from this pathway. First, an individual residing onsite will receive direct radiation exposure, and doses are calculated using both surface and soil concentrations. The second pathway results from uptake of the nuclides from the soil by plants and ingestion of plants by livestock. It is assumed that these livestock provide one-half the yearly meat intake for the exposed individual. The third exposure pathway results from inhalation and immersion in the cloud of nuclides arising from suspension of the contaminated surface soil. Biological uptake and transfer rates for radionuclides in the food chain play an important role in determining the doses to individuals. The assumptions in each pathway anal,, s regarding human uptake and the routes by which human exposure is postulated to occur are based on the method used by NRC in Regulatory Guide 1.109 (1977), with many of the pathway dose conversion factors calculated using the IMPACTS methodology and factors.

Table 16 shows the primary dose conversion factors (DCFs) for the significant nuclides used in analyses of the various pathways. The DCFs for inhalation and ingestion are taken from EPA Federal Guidance Report No. 11 (1988), while those for immersion and areal and volume direct gamma radiation are taken from the Update of Part 61 Impacts Analysis Methodology (NUREG/CR-4370, 1986). As noted above, short-lived daughters are included by summing the DCFs for daughter nuclides and modeling the transport of the long-lived parent. Table 17 shows the nuclides involved in these modified DCFs, and the resulting summed DCFs are those presented in Table 16.

Table 16 Primary Dose Conversion Factors for Signifcant Nuclides Listed in Table 15

	Inhalation (EPA) mrem/pCi		Ingestion (EPA) mrem/pCi		Immersion (Impacts) mrem-m^3/pCi-yr		Areal Gamma (Impacts) mrem-m^2/pCi-yr		Volume Gamma (Impacts)
Nuclide	Thyroid	Effective	Thyroid	Effective	Thyroid	Effective	Thyroid	Effective	mrem-m^3/pCi-yr
C-14	2.09E-06	2.35E-08	2.09E-06	2.09E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cl-36	1.86E-06	2.19E-05	2.96E-06	3.03E-06	1.52E-12	1.47E-11	1.68E-13	1.62E-12	0.00E+00
Tc-99	4.48E-06	8.3[illegible]E-06	5.99E-06	1.46E-06	3.07E-09	2.34E-09	7.26E-11	5.52E-11	1.39E-14
I-129	5.77E-03	1.74E-04	9.18E-03	2.76E-04	4.15E-05	3.81E-05	2.17E-06	2.03E-06	1.61E-08
Th-232*	8.46E-03	1.99E+00	6.76E-04	4.98E-03	2.83E-02	2.40E-02	4.62E-04	3.90E-04	1.29E-05
U-238*	8.26E-05	1.18E-01	8.52E-06	2.70E-04	1.14E-02	9.65E-03	2.19E-04	1.85E-04	6.55E-08

Table 17 Corrections to Dose Conversion Factors for Short-Lived Daughters

Inhalation and Ingestion (EPA and NRC*)

Th-232: Th-232, Ra-228, Ac-228, Th-228, Ra-224, Rn-220*, Po-216*, Pb-212, Bi-212, Po-212*, Tl-208*

U-238: U-238, Th-234, Pa-234

Immersion and Direct Gamma (NRC)

Th-232: Th-232, Ra-228, Th-228

* DCFs taken from NUREG/CR-0150-V3

Table 18 shows the food consumption rates and transfer factors used in the food chain analysis. The consumption rate values are based on those in Regulatory Guide 1.109 while the transfer factors are those taken from the IMPACTS analysis of Part 61. The soil-to-plant transfer factors (f_1) and feed/water-to-meat transfer factors (f_4) from IMPACTS are listed in Table 19.

Table 18 Biological Pathway Consumption Rates and Transfer Factors

Soil-to-plant transfer factors (f_1)	IMPACTS*
Consumption of plants by man (f_2)	190 kg/yr
Consumption of plants by animals (f_3)	50 kg/day
Feed/water-to-meat transfer factors (f_4)	IMPACTS*, day/kg
Consumption of animals by man (f_5)	95 kg/yr
Air inhalation rate by man (f_6)	8,000 m^3/yr
Consumption of water by man (f_7)	370 L/yr
Consumption of water by beef cows (f_8)	50 L/d
Soil deposition by irrigation (W_1)	0.0148 m^3/kg
Foliar deposition by irrigation (W_2)	0.0140 m
Crop yield per unit area (CY)	1 kg/m^2

IMPACTS* - transfer factors are nuclide dependent and are taken from NUREG/CR-4370

Table 19   Transfer Factors from Impacts Methodology*

Element	f_1 (dimensionless)	f_4 (day/kg)
C	5.5	0.031
Cl	5.0	0.080
Tc	[illegible]	0.0087
I	0.0045	0.0070
Th	0.0042	0.00040
U	0.0025	0.00034

f_1 = soil-to-plant transfer factors

f_2 = feed/water-to-meat transfer factors

* Transfer factors are taken from NUREG/CR-4370

Direct Gamma Dose from Contaminated Soil

The radionuclide concentrations due to disposal facility leachate returning to the soil surface are calculated as shown above, and concentration values for the significant nuclides are reported in Table 12. The direct radiation dose can be calculated either from a volume source based on the volumetric radionuclide concentration (Ci/m^3), or from a surface source based on the surface concentration (Ci/m^2). For either formulation the dose is calculated from

$$H = C \times DCF_{radiation} \times 10^{12} \qquad (32)$$

where

H	=	dose in mrem/yr
C	=	exposure concentration in (Ci/m^3) or (Ci/m^2)
DCF	=	dose conversion factor in ($mrem\text{-}m^3/pCi\text{-}yr$) or ($mrem\text{-}m^2/pCi\text{-}yr$)

Calculations for both soil and surface concentration representations were made using the direct radiation (gamma) dose conversion factors from Table 16. The results are presented in Table 20. C-14 does not emit gamma radiation, so it is not included in the table. As shown in Table 20, all calculated direct radiation doses are small. Within the 10,000 year time period the largest dose comes from I-129, with a maximum dose of 2.9E-08 mrem/yr at 5,000 years after closure. This dose comes from a volumetric concentration representation. The maximum dose under this representation is 1.0E-02 mrem/yr, due to Th-232 at 2,000,000 years.

Table 20 Direct Radiation Dose from Contaminated Soil

Nuclide	Time After Closure (yrs)	Soil Volume Concentration (Ci/m^3)	Volume Gamma DCF $mrem\text{-}m^3/pCi\text{-}yr$	Volume Gamma Dose mrem/yr	Soil Areal Concentration (Ci/m^2)	Areal Gamma DCF $mrem\text{-}m^2/pCi\text{-}yr$	Dose Effective mrem/yr
Cl-36	1.31E+03	1.87E-10	1.47E-10	2.75E-08	8.42E-13	1.62E-12	1.36E-12
Tc-99	1.31E+03	2.10E-09	1.39E-14	1.53E-11	9.44E-12	5.52E-11	2.73E-10
I-129	5.23E+03	1.79E-12	1.61E-08	2.88E-08	1.65E-15	2.03E-06	3.34E-09
Th-232*	1.97E+06	7.98E-10	1.29E-05	1.03E-02	1.83E-15	3.90E-04	7.15E-07
U-238*	7.90E+05	4.17E-10	6.55E-08	[illegible]	2.39E-15	1.85E-04	4.43E-07

Ingestion Dose from Contaminated Soil

Onsite exposures can also occur from ingestion of animals which graze on plants grown on the site and which become contaminated by uptake of nuclides from the soil. The pathway dose conversion factors are taken from the IMPACTS methodology and include soil-to-plant transfer factors, consumption of plants by animals, feed-to-animal transfer factors, and consumption of animals by man, where one-half of the annual meat consumption is assumed to come from onsite animals. The pathway soil-to-man transfer factors for this scenario are calculated from

$$ST = f_1 \times f_3 \times f_4 \times \frac{f_5}{2} \qquad (kg/yr) \tag{33}$$

with the factors defined in Table 18. The doses are based on the volumetric soil concentrations shown in Table 12, the soil-to-man transfer factors, and the dose conversion factors for ingestion

$$H = C_G \times \frac{ST}{\rho_b} \times DCF_{ingestion} \times 10^{12} \tag{34}$$

where

H	=	dose in mrem/yr
C_G	=	soil concentration (Ci/m^3)
ST	=	soil-to-man transfer factor (kg/yr)
ρ_b	=	bulk density of soil (1,600 kg/m^3)
DCF	=	ingestion dose conversion factor (mrem/pCi)

The resulting doses are shown in Table 21. The maximum effective dose is 0.11 mrem/yr, and is due primarily to C-14 at a time of 1,500 years after closure of the facility. The contribution of nuclides listed in the table is negligible.

Table 21 Ingestion Dose from Contaminated Soil

Nuclide	Total Concentration (Ci/m^3)	Time After Closure (yrs)	Soil-to-Man Transfer Factor kg/yr	Ingestion DCF mrem/pCi Thyroid	Ingestion DCF mrem/pCi Effective	Thyroid Dose (mrem/yr)	Effective Dose (mrem/yr)
C-14	3.2E-07	1.5E+03	2.9E+02	2.1E-06	2.1E-06	1.2E-01	1.2E-01
Cl-36	[illegible].9E-10	1.3E+03	6.8E+02	3.0E-06	3.0E-06	2.4E-04	2.4E-04
Tc-99	2.1E-09	1.3E+03	1.6E+01	6.0E-06	1.5E-06	1.3E-04	3.1E-05
I-129	1.8E-12	5.2E+03	5.4E-02	9.2E-03	2.8E-04	5.5E-07	1.7E-08
Th-232*	8.0E-10	2.0E+06	1.4E-03	6.8E-04	5.0E-03	4.8E-07	3.6E-06
U-238*	4.2E-10	7.9E+05	1.5E-03	8.5E-06	2.7E-04	3.2E-09	1.0E-07

Inhalation and Immersion Dose from Contaminated Soil

An additional onsite exposure from disposal facility leachate is due to suspension of contaminated soil at the site. The exposure is due to both inhalation and immersion within the cloud of suspended soil. The pathway dose conversion factors are based on the primary dose conversion factors for inhalation and immersion from Table 16, along with an inhalation rate of 8,000 m^3/yr. The significant nuclide air concentrations are presented in Table 12. The dose is calculated from

$$H = C_A \times (f_6 \times DCF_{inhalation} + DCF_{immersion}) \times 10^{12} \quad (35)$$

where

H	=	dose in mrem/yr
C_A	=	air concentration (Ci/m)
f_6	=	air inhalation rate by man (8,000 m^3/yr)
DCF	=	dose conversion factors in (mrem/pCi) and (mrem-m^3/pCi-yr)

The resulting air concentrations, pathway dose conversion factors, and thyroid and effective doses in mrem/yr are shown in Table 22. The maximum dose within the 10,000 year time frame is 9.1E-06 mrem/yr and is due to C-14, Cl-36, and Tc-99. The cumulative air dose, regardless of time of occurrence, is 1.9E-04 mrem/yr Thyroid and 2.9E-04 Effective whole body dose. The effective dose is primarily due to Th-232 and U-238 after a period of 2,000,000 years.

Table 22 Inhalation and Immersion Dose from Contaminated Soil

Nuclide	Air Concentration (Ci/m^3)	Time After Closure (yrs)	Thyroid DCF (mrem-m^3/pCi-yr)	Effective DCF	Thyroid Dose (mrem/yr)	Effective Dose (mrem/yr)
C-14	1.1E-14	1.5E+03	1.7E-02	1.9E-04	1.9E-04	2.1E-06
Cl-36	7.7E-18	1.3E+03	1.5E-02	1.8E-01	1.1E-07	1.3E-06
Tc-99	8.6E-17	1.3E+03	3.6E-02	6.7E-02	3.1E-06	5.7E-06
I-129	1.5E-20	5.2E+03	4.6E+01	1.4E+00	6.9E-07	2.1E-08
Th-232*	1.7E-20	2.0E+06	6.8E+01	1.6E+04	1.1E-06	2.7E-04
U-238*	2.2E-20	7.9E+05	6.7E-01	9.5E+02	1.5E-08	2.1E-05

11. Dose Calculations from Groundwater Exposures

The groundwater pathway to a site-boundary well at a distance of 100 ft (30 m) is described above, and the resulting well concentrations are shown in Table 14. The groundwater exposure scenario assumes that water from the well is used for human and livestock ingestion and for irrigation of a garden. One-half of the water for the garden comes from the well, with the remaining water supplied by rainfall. The garden is assumed to produce one-half of the annual plant consumption. Further, it is assumed that one-half of the ingested meat is produced on site with well-water, and that a" of the human drinking water comes from the well. The water-to-meat, water-to-plant, and plant-to-man transfer factors are taken from IMPACTS and are based on ICRP Publication 30 methodology. The fundamental dose conversion factors for ingestion are listed in Table 16. The total water-to-meat-to-man transfer factor is calculated from

$$WMMTF = f_7 \times f_8 \times f_4 \times \frac{f_5}{2} \quad (L/yr) \qquad (36)$$

This factor includes the annual consumption of water and the transfer from water to animals to man. Plants from the garden become contaminated from foliar and soil deposition by irrigation. The plant-to-man transfer factor for consumption of plants from the garden is

$$PMTF = \frac{f_2}{2} \quad (kg/yr) \qquad (37)$$

with the transfer factors from Tables 18 and 19. The soil-to-plant-to-man transfer factor includes plant uptake from the soil and consumption of plants by man. It is calculated from

$$SPMTF = f_1 \times \frac{f_2}{2} \quad (kg/yr) \qquad (38)$$

garden, W_1 and W_2, with corresponding factors for a location in the southwest calculated from the IMPACTS methodology (NUREG/CR-4370, 1986, Table D-18). The total groundwater pathway transfer factor is given by

$$GPTF = f_{irrigation}\left(W_1 \times SPMTF + \frac{W_2}{CY} \times PMTF \right) + \frac{WMMTF}{1000} \quad (m^3/yr) \qquad (39)$$

where $f_{irrigation}$ is the fraction of the garden irrigation water from the groundwater well with an assumed value of 0.5, and CY is the crop yield per unit area. With these transfer factors the groundwater dose is calculated from

$$H = C_{well} \times GPTF \times DCF_{ingestion} \times 10^{12} \qquad (40)$$

where

H	=	dose in mrem/yr
C_{well}	=	well-water concentration from aquifer (Ci/m^3)
GPTF	=	total scenario transfer factor (m^3/yr)
DCF	=	ingestion dose conversion factors (mrem/pCi)

Within 50,000 years the groundwater dose is due to C-14, Cl-36, and Tc-99, and the magnitude of the combined dose is 0.061 mrem/yr. Table 23 shows the total scenario transfer factors along with the thyroid and effective whole body dose equivalent, both in mrem/yr.

Table 23 Ingestion Dose from Groundwater Pathway

Nuclide	Maximum Well Concentration (Ci/m^3)	Time After Closure (yrs)	Groundwater Transfer Factor kg/yr	Ingestion DCF mrem/pCi		Thyroid Dose (mrem/yr)	Effective Dose (mrem/yr)
				Thyroid	Effective		
C-14	4.3E-09	4.7E+04	5.0E+00	2.1E-06	2.1E-06	4.4E-02	4.4E-02
Cl-36	6.7E-10	3.6E+04	4.7E+00	3.0E-06	3.0E-06	9.4E-03	9.7E-03
Tc-99	7.3E-09	3.7E+04	1.8E+00	6.0E-06	1.5E-06	8.0E-02	1.9E-02
I-129	1.4E-12	2.7E+05	1.1E+00	9.2E-03	2.8E-04	1.4E-02	4.1E-04
Th-232*	1.6E-12	1.2E+08	1.0E+00	6.8E-04	5.0E-03	1.1E-03	8.2E-03
U-238*	2.1E-12	4.6E+07	1.0E+00	8.5E-06	2.7E-04	1.8E-05	5.8E-04

12. Decomposition Gases and Radon

The inventory for the facility contains biological wastes (BIOWAST) generated primarily through research programs at universities and at medical schools. The waste consists of animal carcasses, tissues, animal bedding, and excreta, as well as vegetation and culture media. Upon decomposition, these wastes may generate gases containing H-3 and C-14 which can diffuse upward through the cover system. In addition, radon gas is generated through decay of radium, and this gas can also diffuse through the cover system.

The total inventory of BIOWAST is expected to contain 33 Ci of H-3 and 11.9 Ci of C-14. In addition, a total of 87 Ci of Ra-226 is contained in the Class A inventory. It is assumed that the gases generated from these wastes are released at the time of failure of the concrete canisters, 100 years after closure. The activity of these nuclides at this time may be calculated from equations (2) and (3), and are found to be

H-3	6.92E-02 Ci
C-14	1.17E+01 Ci
Ra-226	8.29E+01 Ci

The volume of air in the 15 Class A disposal trenches is calculated from the average of the top and bottom surface areas of each trench along with a waste thickness of 18 ft and an assumed volumetric air content of 0.2. This gives

$$V_{air} = 15 \times \frac{571 \times 113 + 673 \times 211}{2} \times 18 \times 0.2 = 5.58E{+}06 \text{ ft}^3 = 1.58E{+}05 \text{ m}^3$$

We assume that decomposition of the biological wastes results in 1/10 the activity being present in the gas phase at any one time. Further, we assume that Rn-222 is in equilibrium with Ra-226. At the end of the institutional control period the resulting air concentrations are then given by

H-3	4.38E-08 Ci/m^3	
C-14	7.41E-06 Ci/m^3	(41)
Rn-222	5.25E-04 Ci/m^3	

These gases may diffuse upward through the cover system, with diffusion resistance provided by the four layer of soil within the cover (the GCL and asphalt layers are neglected).

Diffusion through the cover system is much slower than diffusion through an equivalent length of air because the radionuclides must diffuse only through the air-filled volume of the pore space, and because the diffus on occurs along a very tortuous path. A number of authors have suggested methods for calculating effective diffusion coefficients in soil. The model presented by Millington (1959) is the most accepted, and it is assumed here. For a single soil layer, the Millington's relationship between the effective diffusion coefficient in soil, D_s, and and molecular diffusion coefficient in air, D_m, is

$$D_s = \frac{\theta_{air}^{10/3}}{n^2} D_m$$

where θ_{air} is the volumetric air content. For a layered cover with diffusion across the layers, the effective diffusion coefficient is calculated from

$$\overline{D}_s = \frac{\sum_i L_i}{\sum_i \frac{L_i}{\frac{\theta_{air,i}^{10/3}}{n_i^2}}} D_m$$

The characteristics of the cover system are presented below, with air contents from the HELP model:

Layer	Thickness (inches)	Porsosity	Air Content
1	60	0.46	0.38
2	80	0.40	0.17
3	24	0.40	0.17
4	24	0.42	0.37

Using these characteristics, the effective and molecular diffusion coefficients are related through

$$\overline{D}_s = 2.87(10^{-2})\, D_m \tag{42}$$

The average air content for the cover system is a simple arithmatic average of the air contents of the individual layers:

$$\overline{\theta}_{air} = \frac{\sum_i \theta_{air,i}\, L_i}{\sum_i L_i}$$

which gives

$$\overline{\theta}_{air} = 0.263 \tag{43}$$

Equations (42) and (43) describe the transport characteristics of the layered cover system.

To calculate the flux of decaying radioactive gas escaping from the facility it is assumed that the concentrations given in equation (41) remain constant, and that a steady-state flow condition has been established. In addition, the partitioning of the gases back into the aqueous phase and their sorption upon the soil matrix is neglected. Under these conditions the steady-state distribution of the gas concentration is given by

$$\overline{D}_s \frac{d^2C}{dx^2} - \overline{\theta}_{air}\lambda_D C = 0$$

If we assume all of the resistance to diffusion occurs across the cover system with no resistance from an atmospheric boundary layer, then the concentration at the base of the layer ($x = 0$) is C_o, which is the same as the concentration within the waste fill, while the concentration at the top of the layers ($x = L$) may be taken as $C = 0$. For these conditions the steady-state concentration is given by

$$C = C_o \frac{e^{\alpha(L-x)} - e^{-\alpha(L-x)}}{e^{\alpha L} - e^{-\alpha L}}$$

while the flux through the top of the clay layer is given by

$$J_{air} = -\overline{D}_s \left.\frac{dC}{dx}\right|_{x=L} = \frac{2\,\overline{D}_s\,\alpha\, C_o}{e^{\alpha L} - e^{-\alpha L}} \tag{42}$$

where $\alpha^2 = \frac{\bar{\theta}_{air} \lambda_D}{\bar{D}_s}$. The air concentrations are estimated using the same mixing model as resuspension of contaminated soil which was presented in equation (25). The surface area of the Class A trenches is A_{sa} = 198,000 m^2, the effective width of the mixing zone is calculated from W = $\sqrt{198000}$ = 450 m, and the corresponding air discharge through the mixing zone is, from equation (24), Q_{air} = 450 x 2 x 8.56(10^7) = 7.7(10^{10}) m^3/yr. The mass transfer to the atmosphere is given by $\dot{m}_{air} = J_{air} A_{sa}$. The half-life of Rn-222 is 3.8235 d. Molecular diffusion coefficients may be found from Lyman et al. 1982. For the three radioactive gases one finds

Nuclide	D_m (m^2/yr)	λ_D (yr^{-1})	α (m)
H-3 (as H_2O)	808	5.59E-02	2.52E-02
C-14 (as CO_2)	517	1.21E-04	1.46E-03
Rn-222	374	6.62E+01	1.27E+00

The cover system has a thickness of 188 inches = 4.78 m. Using these results, the mass transfer to the atmosphere and air concentrations are

Nuclide	$\dot{m}_{air}$ (Ci/yr)	C_{air} (Ci/m^3)
H-3	4.20E-02	5.45E-13
C-14	4.55E+00	5.91E-11
Rn-222	6.54E+00	8.49E-11

For H-3 the inhalation PDCF is taken from EPA while the immersion PDCF is taken from IMPACTS. For Rn-222, the PDCF's are taken from IMPACTS (NUREG/CR-4370, 1986). The resulting pathway DCF's are

Nuclide	Thyroid mrem-m^3/pCi-yr	Effective mrem-m^3/pCi-yr
H-3	5.12E-04	5.12E-04
Rn-222	2.65E-02	2.43E-02

The resulting doses may be calculated from equation (35) which includes both the inhalation and immersion pathways. The resulting doses are shown in Table 24.

Table 24 Calculated Doses from Decomposition Gases and Radon

Nuclide	Dose (mrem/yr)	
	Thyroid	Effective
H-3	2.8E-04	2.8E-04
C-14	1.0E+00	1.1E-02
Rn-222	2.3E+00	2.1E+00

These dose estimates are probably too high. The flux of C-14 (Ci/yr) through the cover would deplete the entire C-14 biological waste inventory within three years. A box mixing model is used for estimating the exposure concentrations in air, with a mixing height of 2 m. Such a height is consistent with calculation of on-site concentrations from facilities which are much smaller that the entire Class A cover system (198,000 m^2). The disposal units are embedded within a much larger area, so the calculated width of the mixing zone is also underestimated. Finally, all of the radionuclides gases will diffuse laterally as well as vertically through the cover system, giving a still larger mixing area. The effect of these conditions means that the dose estimates are large by at least an order of magnitude.

13. Intruder-Drilling Scenario

Most of the intruder scenarios are eliminated because of facility design considerations. However, the intruder-drilling scenario, as described in the Part 61 IMPACTS Methodology (NUREG/CR-4370, 1986), was considered. According to this scenario, at the end of the institutional control period an inadvertent intruder decides to have a house built on the facility and he must first install a well to secure an adequate supply of water to meet his living needs. In placing the well, the drilling company is assumed to drill through the Class B/C waste disposal trenches, bringing Class C ion exchange resin (RWDMRES) mixed with drill cuttings and mud to the ground surface. The cuttings settle out in the "mud pit" and the drilling crew is exposed to direct gamma radiation from the waste contained in the mud pit. Inhalation impacts are discounted because of the liquid nature of the contaminated mud. In the analysis of this scenario, only Cs-137 is considered. Cs-137 is actually a beta emitter, but its daughter, Ba-137m with a half-life of 2.55 minutes, is a gamma emitter. All other gamma emitters would have decayed to negligible activities by the end of the institutional control period.

The following assumptions are made. An 12-inch diameter hole is drilled through the 81-inch (inside height) waste canisters containing the ion exchange resins (RWDMRES) with an initial Cs-137 concentration of 0.039 Ci/ft^3. The canister was placed in the disposal facility at the time of closure, so its activity decreases during the 100-year control period. According to equations (3), by the end of institutional control, the Cs-137 would have decayed to a concentration of 0.0039 Ci/ft^3. This gives a total activity of 0.021 Ci mixed with the drill cuttings. After dilution with the cuttings from the 1,000-foot deep well with an average diameter of 8-inches (9.9 m^3 of cuttings), the concentration is

$$C_{pit} = 0.0021 \text{ Ci/m}^3$$

The cuttings are retained in a mud pit of dimensions 13 ft by 14 ft by 4 ft. This pit has a volume of about 21 m^3, of which 16 m^3 is filled with drilling fluid (i.e., the pit if filled with drilling fluid up to about 1 ft below the top of the pit). The cuttings will settle in the lower one-quarter of the pit and be shielded by 2 ft of drilling fluid. The drilling crew is assumed to spend 24 hours exposed to the cuttings. After use, the mud pit is filled with soil.

In calculating the dose, one has to account for the finite size of the mud pit containing the radionuclides, and for the shielding caused by the drilling fluid. The IMPACTS methodology calculated the areal exposure correction factor from

$$CF = \frac{A_{pit}}{A_{circle}} CF_{circle}$$

where A_{pit} is the area of the mud pit (A_{pit} = 13' x 14' = 182 ft^2), A_{circle} is the area of radius equal to the smallest maximum distance from the individual to an element of the exposure source ($A_{circle} = \pi \times 13^2 = 531\ ft^2$), and CF_{circle} is the correction factor for a point located a distance z above the center of the circular area of radius r containing radiating material. This factor is given (with correction) in Section 3.1 of NUREG/CR-3585 (1984) as

$$CF_{circle} = \frac{E_1(\mu_a z) - E_1(\mu_a \sqrt{z^2+r^2})}{E_1(\mu_a z)}$$

where

$E_1()$ = exponential integral (Abramowitz and Stegun, 1964)

μ_a = linear attenuation coefficient of air (which is taken as 0.01 m^{-1})

With z = 1 m and r = 4 m we have CF_{circle} = 0.343 and

$$CF = \frac{182}{531} \times 0.343 \quad 0.118$$

The shielding factor is radionuclide specific and is calculated using (NUREG/CR-4370, 1986)

$$SF = e^{-\mu_w L}\ B(\mu_w L)$$

where

μ_w = linear attenuation coefficient of water (m^{-1})

L = thickness of the shielding layer (m)

B( ) = polynomial buildup factor $\left(B(y) = 1 + 0.95\ y + 0.35\ y^2\right)$

For Cs-137 with $\mu_w = 8.62\ m^{-1}$ and L = 0.61 m, one has μ_m L = 5.26 and

$$SF = e^{-5.26} \times \left(1 + 0.95 \times 5.26 + 0.35 \times 5.26^2\right) = 0.0815$$

With these factors the dose is calculated from

$$H = C_{pit} \times CF \times SF \times f_D \times DCF_{radiation} \times 10^{12} \qquad (43)$$

where

H	=	dose in mrem/yr
C_{pit}	=	nuclide concentration in the mud pit (Ci/m^3) calculated from initial inventory concentration
λ_D	=	nuclide decay coefficient (yr^{-1})
T_{exp}	=	time of exposure after closure of the facility (yr)
CF	=	areal exposure correction factor
SF	=	shielding factor
f_D	=	exposure duration fraction
DCF	=	volume gamma radiation dose conversion factor (mrem-m^3/pCi-yr)

For Cs-137 the volume gamma dose conversion factor is 3.39E-06, and with an exposure duration fraction of f_D = 24/8760 = 2.74E-03 and λ_D = 0.023 yr^{-1}, the resulting dose is

$$H = 0.0021 \times 0.118 \times 0.0815 \times 2.74E\text{-}03 \times 3.39E\text{-}06 \times 1E{+}12 = 0.19 \text{ mrem/yr}$$

This is the dose associated with Cs-137. The dose from other nuclides contained within the drill cuttings is expected to be negligible compared to this value.

14. Assessment of Impacts and Regulatory Compliance

Radionuclide release and transport under various conditions have been modeled and resulting doses to humans have been calculated. Infiltration through the disposal trenches and leachate generation are discussed in Sections 4 and 5. The transport of radionuclides to the soil surface and resulting surface exposure pathways are discussed in Sections 6 and 7, while the doses from surface exposures are presented in Section 10. Section 8 and 11 present the groundwater pathways and resulting doses. Decomposition gases and radon are considered in Section 12 while the intruder-drilling scenario is discussed in Section 13. Table 25 summarizes the results of the calculations. Peak radionuclide doses and times are given for each pathway and receptor location analyzed.

Dose projections based on these simulations indicate compliance with the limits specified in 10 CFR Part 61 and TRCR 45.50. The effective dose equivalent must not exceed 25 mrem/yr. In addition, the dose to the thyroid must not exceed 75 mrem/yr and the dose to any other organ must not exceed 25 mrem/yr. The maximum dose rate of 2.1 mrem/yr is from the decomposition gases and radon at a time of 100 years after closure. However, the asphalt and geomembrane would act as a diffusion barrier, decreasing this estimate considerably. Dose rates from the remaining exposure pathways are less than 0.4 mrem/yr. All of these doses are well below the dose limits prescribed by current regulations.

Table 25 Summary of Maximum Doses by Pathway

Pathway	Receptor Location	Peak Dose[a] (mrem/yr)	Time[b] (yr)
Direct Gamma from Contaminated Soil	Onsite	5.6E-08	5,000
Ingestion from Contaminated Soil	Onsite	1.1E-01	1,500
Inhalation/Immersion from Contaminated Soil	Onsite	9.1E-06	5,000
Groundwater to Well	Site Boundary (100 ft)	6.1E-02	50,000
Decomposition Gases and Radon	Onsite	2.1E+00	100
Intruder Drilling	Onsite	1.9E-01	100

[a] 50-year committed effective dose equivalent

[b] years after site closure

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BRANCH TECHNICAL POSITION ON LOW-LEVEL WASTE PERFORMANCE ASSESSMENT

TECHNICAL ISSUES AND APPROACHES

Presentation to
The Advisory Committee on Nuclear Waste
March 22, 1994

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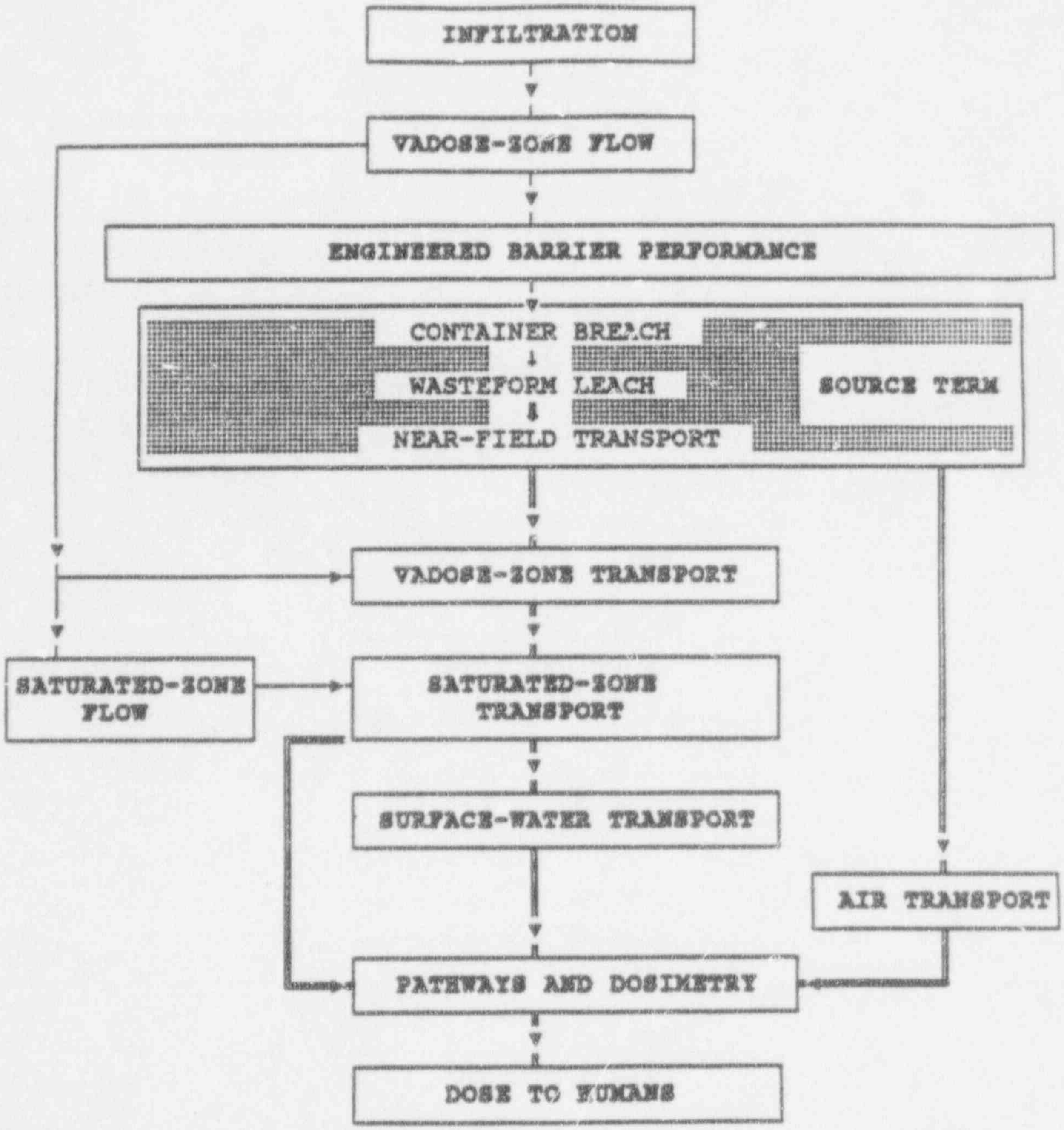


Figure 1. Modular conceptual model of processes in low-level waste performance assessment (modified from Kozak, et al., 1990b).

[Note: Single lines correspond to water flow pathways, double lines correspond to radionuclide transport pathways, and the stippled region corresponds to the disposal cell(s)].

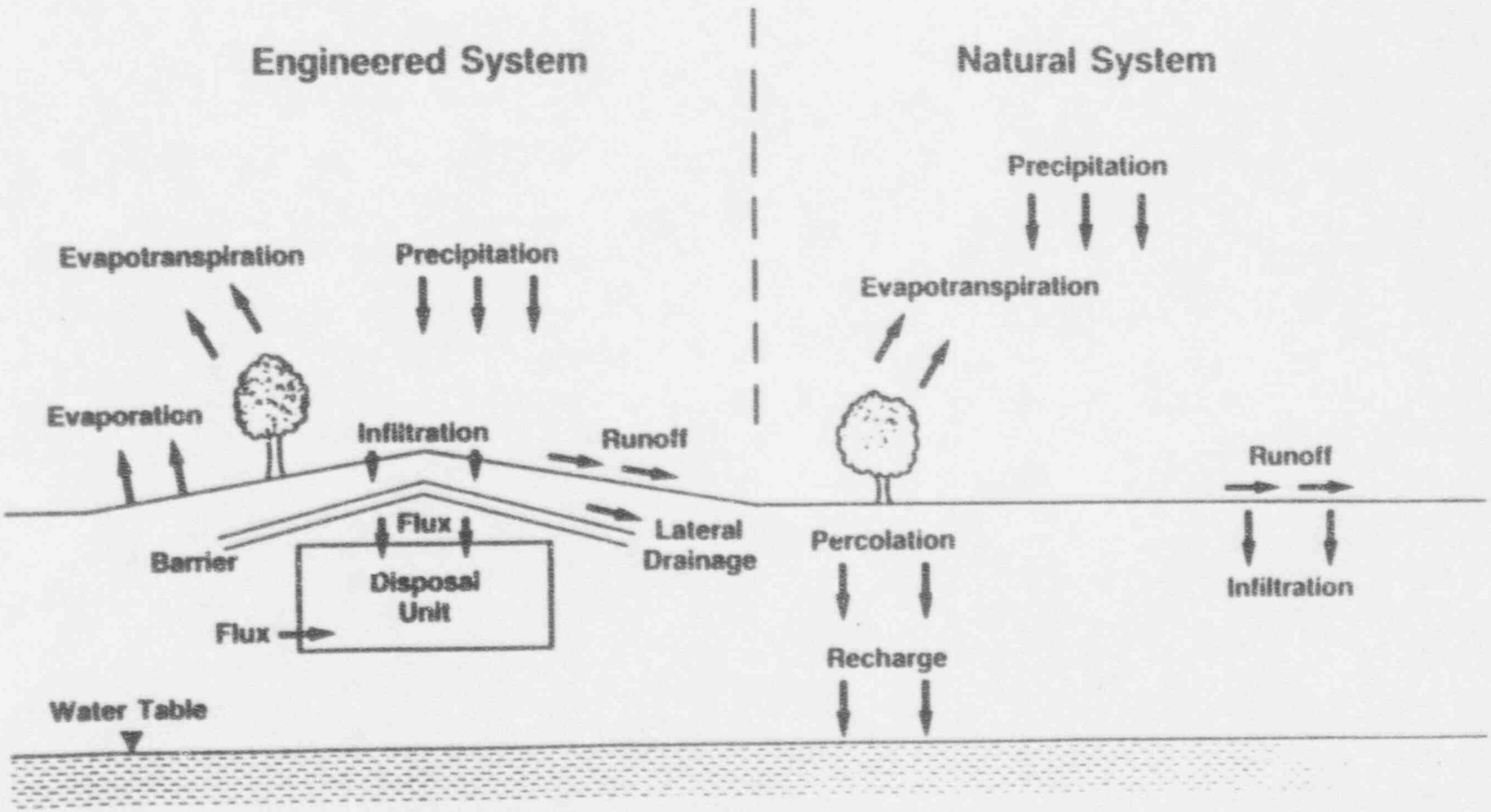


Figure 7. Schematic of processes in infiltration analysis.

INFILTRATION ANALYSIS

PURPOSE - DETERMINE AMOUNT OF WATER ENTERING DISPOSAL UNITS

<u>ISSUES</u>

- TRANSIENT BEHAVIOR OF CERTAIN PROCESSES
- CHANGES IN SITE CONDITIONS OVER TIME
- CHANGES IN PERFORMANCE OF ENGINEERED SYSTEM OVER TIME
- SPATIAL VARIABILITY

INFILTRATION ANALYSIS

MODELING APPROACHES

- ANALYSIS DIVIDED INTO TWO PARTS

  1. ANALYSIS OF STEADY-STATE PERCOLATION CONSIDERING TIME-VARYING PROCESSES

  2. ANALYSIS OF WATER ROUTING THROUGH COVER TO DETERMINE STEADY-STATE FLUX OF WATER INTO DISPOSAL UNITS

- SAMPLE RANGE OF PERCOLATION RATES TO USE AS UPPER BOUNDARY FOR WATER ROUTING ANALYSIS

- SAMPLE RANGE OF HYDRAULIC PARAMETERS TO USE AS EFFECTIVE PARAMETERS

- RE-ANALYZE AT DIFFERENT TIMES TO ACCOUNT FOR DEGRADATION OF FACILITY

ENGINEERED BARRIERS

PURPOSE - ESTABLISH MODEL REPRESENTATIONS OF PHYSICAL CHARACTERISTICS OF DESIGN FEATURES THROUGH TIME

<u>ISSUES</u>

- PERMEABILITY
  - NO RELEVANT LONG-TERM DATA
  - NOT INDEPENDENT OF OTHER MATERIALS
  - LIMITED MODELS FOR PREDICTION
  - MICRO vs MACRO & LAB vs FIELD BEHAVIOR

- DURABILITY
  - ALL MATERIAL DOES NOT DEGRADE AT SAME RATE
  - LITTLE RELEVANT LONG-TERM DATA
  - PREDICTIVE MODELS BASED ON SINGLE DEGRADATION MECHANISM
  - ACTUAL DEGRADATION MAY RESULT FROM SYNERGISTIC IMPACTS

ENGINEERED BARRIERS

APPROACHES

- MUST CONSIDER:

  - MATERIALS

  - DATA AVAILABLE ON MATERIAL PERFORMANCE USING THEORETICAL MODELS, TEST DATA, AND FIELD PERFORMANCE DATA

  - INTEGRATION OF MATERIALS INTO ENGINEERED BARRIERS

  - INTERACTIONS AMONG MATERIALS

  - INTERACTIONS AMONG ENGINEERED BARRIER SYSTEMS

  - CONSTRUCTION METHODS

  - OPERATIONAL REQUIREMENTS

  - QA/QC SYSTEMS

- EXERCISE ENGINEERING JUDGEMENT TO DEFINE:

  - NUMERICAL VALUES OF RELEVANT PARAMETERS FOR PA WITH RESECT TO TIME

  - DISTRIBUTION OF REASONABLY EXPECTED VALUES

- BE PREPARED TO SUBJECT PROCESS TO AN EXPERT PEER REVIEW

SOURCE TERM

ISSUES

- VARIABILITY AMONG WASTE CLASSES, WASTE TYPES, AND WASTE FORMS WITH RESPECT TO:

  - DISTRIBUTIONS OF RADIONUCLIDES
  - ACTIVITIES
  - RELEASE MECHANISMS AND RATES
  - CHEMICAL ENVIRONMENT

- VARIABLE CHEMICAL ENVIRONMENT OF DISPOSAL UNITS AFFECTS:

  - SOLUBILITY
  - DIFFUSION
  - SORPTION
  - CORROSION

- VARIABILITY OF CONTAINER LIFETIMES BETWEEN CARBON STEEL DRUMS, LINERS, AND HIGH INTEGRITY CONTAINERS (HICS)

SOURCE TERM

APPROACH

- DESCRIPTION OF RADIONUCLIDES BY:

  - WASTE CLASS (A, B, and C)
  - WASTE TYPE (ION-EXCHANGE RESINS,DRY SOLIDS, ETC.)
  - WASTE FORM (CEMENT SOLIDIFIED, ACTIVIATED METALS, ETC.)
  - WASTE CONTAINERS (CARBON STEEL DRUMS, LINERS, AND HIGH INTEGRITY CONTAINERS)

- RINSE RELEASE AS INITIAL RELEASE MECHANISM THAT CAN BE SUPPLEMENTED BY SPECIFIC INFORMATION SUCH AS:

  - DISSOLUTION RELEASE (ACTIVATED METALS)
  - DIFFUSION RELEASE (CEMENT SOLIDIFIED)
  - Kd RELEASE (ION-EXCHANGE RESINS)

SOURCE TERM

APPROACH (CONT.)

- CONSIDER INDIVIDUAL DISPOSAL UNITS (PERCENTAGE OF PARTICULAR RELEASE MECHANISMS AND WASTE CONTAINERS AS A GROUP)
  - NO ATTEMPT TO SIMULATE INDIVIDUAL CONTAINERS

- GEOCHEMICAL MODELING AND EMPIRICAL DATA USED TO:
  - EVALUATE SOLUBILITY LIMITS
  - EVALUATE SORPTION IN DISPOSAL UNIT
  - EVALUATE CHEMICAL ENVIRONMENT WITHIN DISPOSAL UNIT

GROUND-WATER FLOW AND TRANSPORT

ISSUES

- CONCEPTUALIZATION AND REPRESENTATION OF HYDROGEOLOGIC SYSTEM
- RELEVANT PROCESSES AND FEATURES TO INCLUDE IN ANALYSIS (HYDROLOGIC & GEOCHEMICAL)
- SPATIAL VARIABILITY
- ASSUMPTIONS ABOUT RECEPTOR LOCATION AND GW USE
- RELATIONSHIP OF GW SYSTEM TO SURFACE WATER (FOR SURFACE WATER PATHWAY ANALYSIS)

GROUND-WATER FLOW AND TRANSPORT

MODELING APPROACHES

- MODELS SHOULD BE AS SIMPLE AS POSSIBLE WHILE RETAINING FEATURES AND PROCESSES RELIED UPON TO DEMONSTRATE PERFORMANCE
- WELL LOCATIONS SHOULD BE ON DISPOSAL SITE BOUNDARY
- WELL DESIGN AND CONSTRUCTION CHARACTERISTICS REPRESENTATIVE OF SITE LOCATION
- WELL SHOULD BE ANALYZED AS PUMPING WELL SUPPLYING WATER SUFFICIENT TO MEET NEEDS OF HYPOTHETICAL USER
- RADIONUCLIDE CONCENTRATIONS IN PUMPED WATER SHOULD REPRESENT AVERAGE OVER A YEAR

SURFACE WATER

ISSUES

- NUMBER OF POTENTIALLY SIGNIFICANT ISSUES IDENTIFIED FOR PERFORMANCE OF ABOVE-GROUND VAULTS THAT ARE NOT ADDRESSED IN BTP
  - OVERLAND FLOW AND TRANSPORT
  - SORPTION ONTO SEDIMENTS
  - SEDIMENT TRANSPORT AND DEPOSITION IN RIVERS AND STREAMS
- ANALYSIS FOR BELOW-GROUND VAULT TIED TO GROUND WATER PATHWAY

SURFACE WATER

APPROACHES

- FOR BELOW-GROUND VAULTS AND EARTH-MOUNDED CONCRETE BUNKERS, MOST IMPORTANT TRANSPORT MECHANISM TO SURFACE WATER IS THROUGH GROUND-WATER TRANSPORT
- CONCENTRATION OF RADIONUCLIDES IN GROUND WATER MIXED WITH SURFACE WATER AT NEAREST POINT OF GW DISCHARGE TO SURFACE WATER
- NO CURRENTLY RECOMMENDED APPROACH FOR ASSESSING SURFACE-WATER CONTAMINATION FROM AGV

ATMOSPHERIC TRANSPORT

ISSUES

- THE IMPORTANCE OF GASEOUS RADIONUCLIDES RELEASED FROM LLW FACILITY IS UNCERTAIN

- FRACTION OF RADIONUCLIDES IN LLW CONVERTED TO GASES IS UNCERTAIN

- SCREENING ANALYSIS LIKELY TO BE ADEQUATE FOR COMPLIANCE DEMONSTRATION

ATMOSPHERIC TRANSPORT

APPROACH

- TIERED APPROACH; SIMPLE TO DETAILED
  - INITIAL SCREENING: TOTAL INVENTORY RELEASE (BOUNDING CALCULATION)
  - DETAILED ANALYSIS: WASTE STREAM AND WASTE FORM RELEASES; GAS FLOW THROUGH COVERS AND SOIL

DOSE MODELING

<u>TECHNICAL ISSUES</u>

- PATHWAY ANALYSIS
  - IDENTIFICATION OF SIGNIFICANT PATHWAYS
  - USE OF APPROPRIATE MODEL PARAMETERS

- DOSIMETRY
  - USE OF APPROPRIATE DOSIMETRIC MODELS

DOSE MODELING

APPROACHES

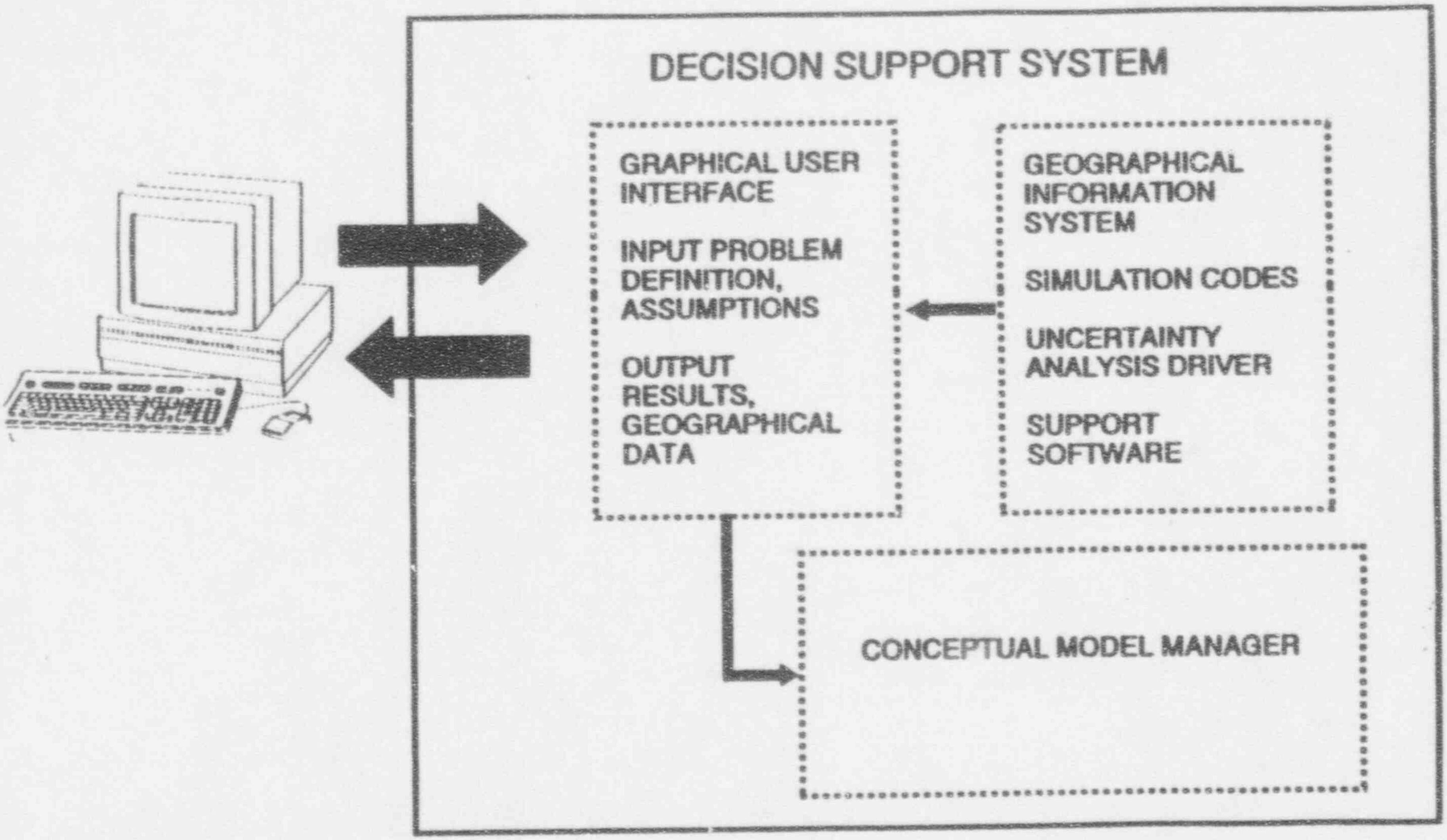
- PATHWAY ANALYSIS
  - PATHWAY IDENTIFICATION BASED ON SITE
  - REG. GUIDE 1.109 MODELS, NUREG/CR-5512 TRANSFER FACTORS, AND SITE SPECIFIC USAGE FACTORS

- DOSIMETRY
  - USE DOSE FACTORS DEVELOPED FROM ICRP 30 MODEL

PAM STATUS

DECISION SUPPORT SYSTEM (DSS)

- INTEGRATES MULTIPLE MODELS, AN UNCERTAINTY ANALYSIS PACKAGE AND GEOSTATISTICAL PACKAGE INTO SINGLE COMPUTATIONAL PLATFORM
- USER INTERACTS WITH SYSTEM THROUGH GRAPHICAL INTERFACE THAT ALLOWS DIRECT ACCESS TO SITE DATA STORED IN GEOGRAPHICAL INFORMATION SYSTEM
- USER CAN OBTAIN MAPS FROM GEOGRAPHICAL INFORMATION SYSTEM TO DEVELOP CONCEPTUAL MODELS; DSS IDENTIFIES APPROPRIATE MODELS FOR THE ANALYSIS BASED ON CONCEPTUAL MODEL ASSUMPTIONS OF USER
- DEVELOPED AT SANDIA NATIONAL LABORATORY AND FUNDED BY EPA, DOE, AND NRC
- OPTIMIZES THE PLACEMENT OF MONITOR WELLS ASSOCIATED WITH CLEAN-UP ACTIVITIES OF EXISTING SITES; SYSTEM BEING ADAPTED TO LLW PERFORMANCE ASSESSMENT


DECISION SUPPORT SYSTEM
GRAPHICAL USER INTERFACE
INPUT PROBLEM DEFINITION, ASSUMPTIONS
OUTPUT RESULTS, GEOGRAPHICAL DATA
GEOGRAPHICAL INFORMATION SYSTEM
SIMULATION CODES
UNCERTAINTY ANALYSIS DRIVER
SUPPORT SOFTWARE
CONCEPTUAL MODEL MANAGER

7-5,6,7,8

BRANCH TECHNICAL POSITION FOR PERFORMANCE ASSESSMENT OF LOW-LEVEL RADIOACTIVE WASTE DISPOSAL FACILITIES

Andrew C. Campbell
(301) 504-2500
Division of Low-Level Waste Management & Decommissioning
Office of Nuclear Material Safety & Safeguards

for

Advisory Committee on Nuclear Waste
Working Group Meeting on LLW Performance Assessment
Bethesda, Maryland
March 22, 1994

LLW PA TECHNICAL POSITION

Objectives

- Define LLW PA in context of 10 CFR Part 61 requirements
- Provide background on the performance assessment methodology (PAM), applicability, and technical issues
- Describe an iterative and comprehensive process for performance assessment modeling
- Address important technical policy issues in interpreting and implementing 10 CFR Part 61 technical requirements
- Provide guidance on acceptable approaches for resolving technical issues in modeling LLW facility performance

BACKGROUND and GUIDANCE NEEDS
LLW PERFORMANCE ASSESSMENT

- BACKGROUND
  - Shallow land burial (SLB) previously used for commercial LLW disposal - currently banned in many States
  - Other near surface disposal technologies (upper 30m)
    - Below Grade Vault (BGV)
    - Earth Mounded Concrete Bunker (EMCB)
    - Above Ground Vault (AGV) {no earthen cover}
  - States/Compacts developing Engineered disposal systems
    - SLB w/engineered cover at 2 arid sites
    - Concrete vaults (mostly BGV & EMCBs)
    - Multi-layer covers

- 10 CFR Part 61
  - Performance objectives apply to all types of near surface LLW disposal
  - Technical requirements apply only to disposal below surface, do not apply to AGVs

LLW PERFORMANCE ASSESSMENT

10 CFR 61.41

PROTECTION OF THE GENREAL POPULATION FROM RELEASES OF RADIOACTIVITY

"Concentrations of radioactive material which may be released to the general environment in ground water, surface water, air, soil, plants or animals must not result in an annual dose exceeding an equivalent of 25 millirems to the whole body, 75 millirems to the thyroid, and 25 millirems to any other organ of any member of the public. Reasonable effort should be made to maintain releases of radioactivity in effluents to the general environment as low as is reasonably achievable."

DEFINITION of LLW PERFORMANCE ASSESSMENT

- PERFORMANCE ASSESSMENT DEFINED AS THE TECHNICAL ANALYSES USED TO DEMONSTRATE COMPLIANCE WITH 10 CFR 61.41 PERFORMANCE OBJECTIVES, AS REQUIRED IN 10 CFR 61.13(a):

  (1) "Pathways analyzed in demonstrating protection of the general population from releases of radioactivity must include air, soil, ground water, surface water, plant uptake and exhumation by burrowing animals";

  (2) "The analyses must clearly identify and differentiate between the roles performed by the natural disposal site characteristics and design features in isolating and segregating the wastes"; and

  (3) "The analysis must clearly demonstrate that there is reasonable assurance that the exposure to humans from the release of radioactivity will not exceed the limits set forth in § 61.41."

- PA concerned with analyses of long-term performance (post-closure)
- Operations and stability addressed seperately in license application
- Intruder analyses generally not covered within PA

EXISTING LLW PA GUIDANCE DOCUMENTS

Provide Only General Guidance on PA

- Standard Format and Content Guide (NUREG-1199)
- Standard Review Plan (NUREG-1200)
  - Chapter 2: Site Characterization
  - Chapter 6: Safety Assessment
- Environmental Standard Review Plan (NUREG-1300)

TECHNICAL POSITION

Need for LLW PA Guidance

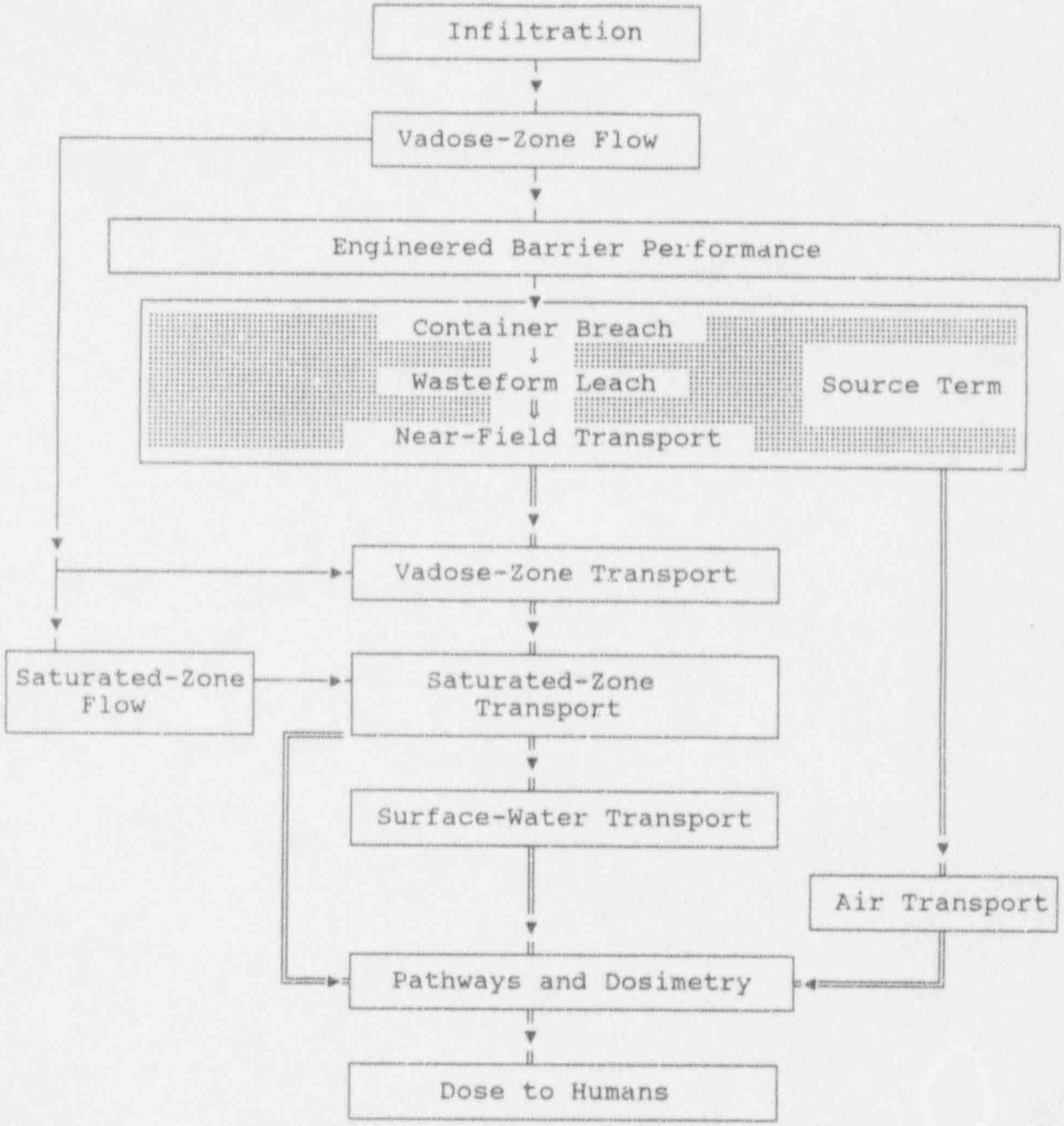
- An overall understanding of the PA process
- Relationship between site characterization & PA data collection
- The use of generic data in PA
- Resolution of policy issues
- Modeling infiltration, concrete degradation, source term, and transport of radionuclides in the environment
- Uncertainty and sensitivity analyses
- Verification and validation of computer models

PERFORMANCE ASSESSMENT METHODOLOGY

Sub-System Areas

- Infiltration
- Engineered Barriers Performance
- Source Term
- Transport
  - Groundwater
  - Surface Water
  - Air
- Pathway Analysis
- Dose

PERFORMANCE ASSESSMENT METHODOLOGY



Modular Conceptual Model of Processes in Low-Level Waste Performance Assessment (modified from Kozak and others, 1990).

APPROACH for DEVELOPING BRANCH TECHNICAL POSITION

- Structured after PAM

- Identification of Technical Issues
  - Test Case Modeling Program
  - NRC Research Program
  - States' Experience
  - DOE PATT
  - DOE/LLW Management Program
  - IAEA & INTRAVAL

- Develop BTP in Parallel with Test Case Modeling
  - Incorporate Staff Modeling Experience
  - Evaluate Regulatory Positions

- Work carried out by:
  PERFORMANCE ASSESSMENT WORKING GROUP (PAWG)
    - Staff from NMSS and RES Offices
    - Organized by Sub-Modeling Areas

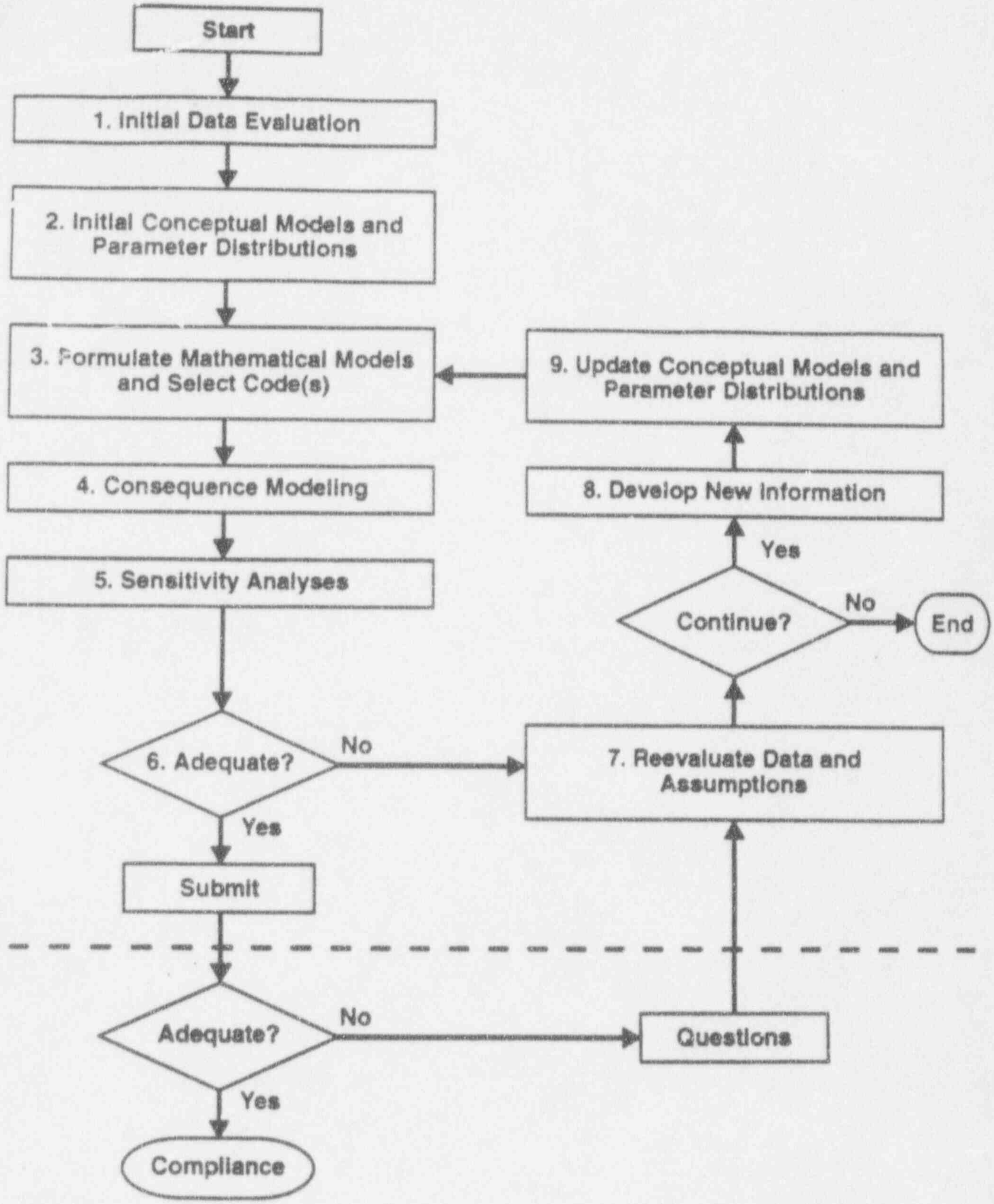
LLW PERFORMANCE ASSESSMENT PROCESS
Attributes and Goal

Attributes:

- Iterative process
- Comprehensive and quantitative to extent practicable
- Integrate site characterization and design with PA modeling activities
- Provide a process for regulatory decision making
- Procedure for documenting process
- Formal treatment of uncertainty and sensitivity as an intrinsic part of the process

Goal:

- Reach Defensible Regulatory Decisions


Start
1. Initial Data Evaluation
2. Initial Conceptual Models and Parameter Distributions
3. Formulate Mathematical Models and Select Code(s)
4. Consequence Modeling
5. Sensitivity Analyses
6. Adequate?
No
Yes
Submit
Adequate?
No
Yes
Compliance
Questions
7. Reevaluate Data and Assumptions
Continue?
No
End
Yes
8. Develop New Information
9. Update Conceptual Models and Parameter Distributions

TECHNICAL POLICY ISSUES
in LLW Performance Assessment

- Role of the Site and Consideration of Site Conditions, Processes, and Events
- Role of Engineered Barriers
- Time Frame for Performance Assessment Analyses
- Treatment of Uncertainty in Regulatory Decisions
- Role of Performance Assessment During Operational and Closure Periods

TECHNICAL POLICY ISSUES

Role of Site - Conditions, Processes, & Events

- **Site suitability requirements [§ 61.50]**
  - site stability
  - waste isolation
  - long-term performance
- **"Site characteristics should be considered in terms of the indefinite future and evaluated for at least a 500 year time frame" [§ 61.7 (a)(2)]**
- **Range of assumptions and data adequate to encompass distinct events and long term processes**
  - Meteorological
  - Infiltration
  - Geologic processes
  - Land use
- **DO NOT consider Global Climate Change**

TECHNICAL POLICY ISSUES

Role of Engineered Barriers

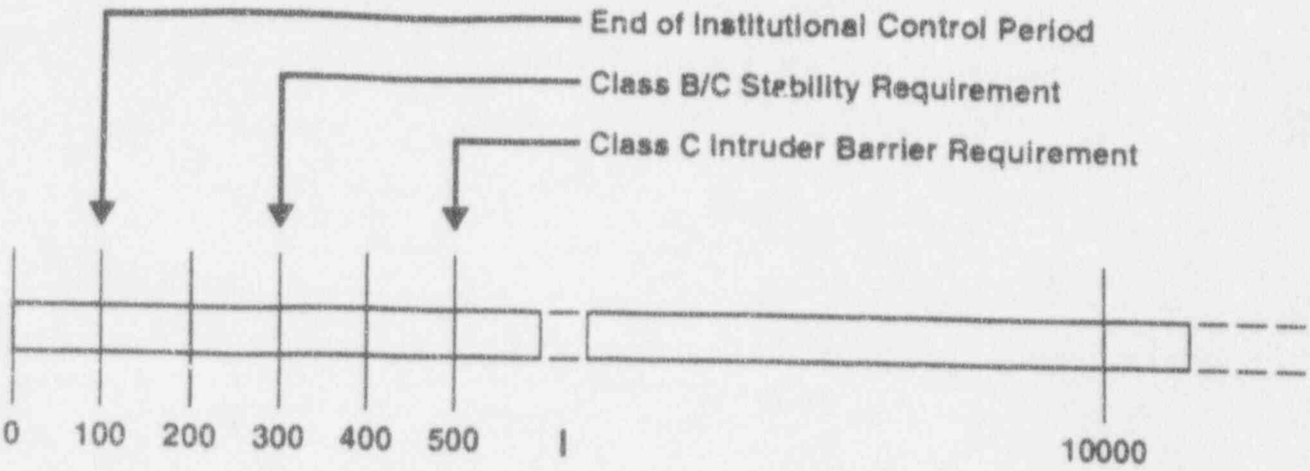
- **Encompasses human made materials and natural materials reconfigured to perform specific function**
- **Considerations:**
  - Waste inventory characteristics
  - State of knowledge about engineered barrier materials
- **Reasonable assurance of service life and behavior characteristics**
  - Justified and defensible (materials, interaction & integration, quality, and system)
  - Generally for > 500 years assume degraded condition
  - Considerations for performance assessment past 500 years include: natural site characteristics, backfill, buffers, and chemical barriers

TECHNICAL POLICY ISSUES

Time Frame for Performance Assessment

- **Objective: provide period of analysis long enough to reasonably demonstrate compliance with § 61.41**
- **Considerations and Concerns:**
  - Long-lived radionuclides
  - Parent/Daughter dose potential
  - Inventory limits
  - Assumptions may become invalid over long time frames
  - Manipulation of variables and processes to move peak beyond a specific time frame
- **Discussion of Possible Approaches**

Part 61 Requirements:



Credit for Engineered Barriers

FOCUS ON ENGINEERED BARRIER PERFORMANCE. Characterize Site/Facility/ Inventory, Evaluate Significant Processes and Events, Consequence Analyses, Sensitivity and Uncertainty Analyses.

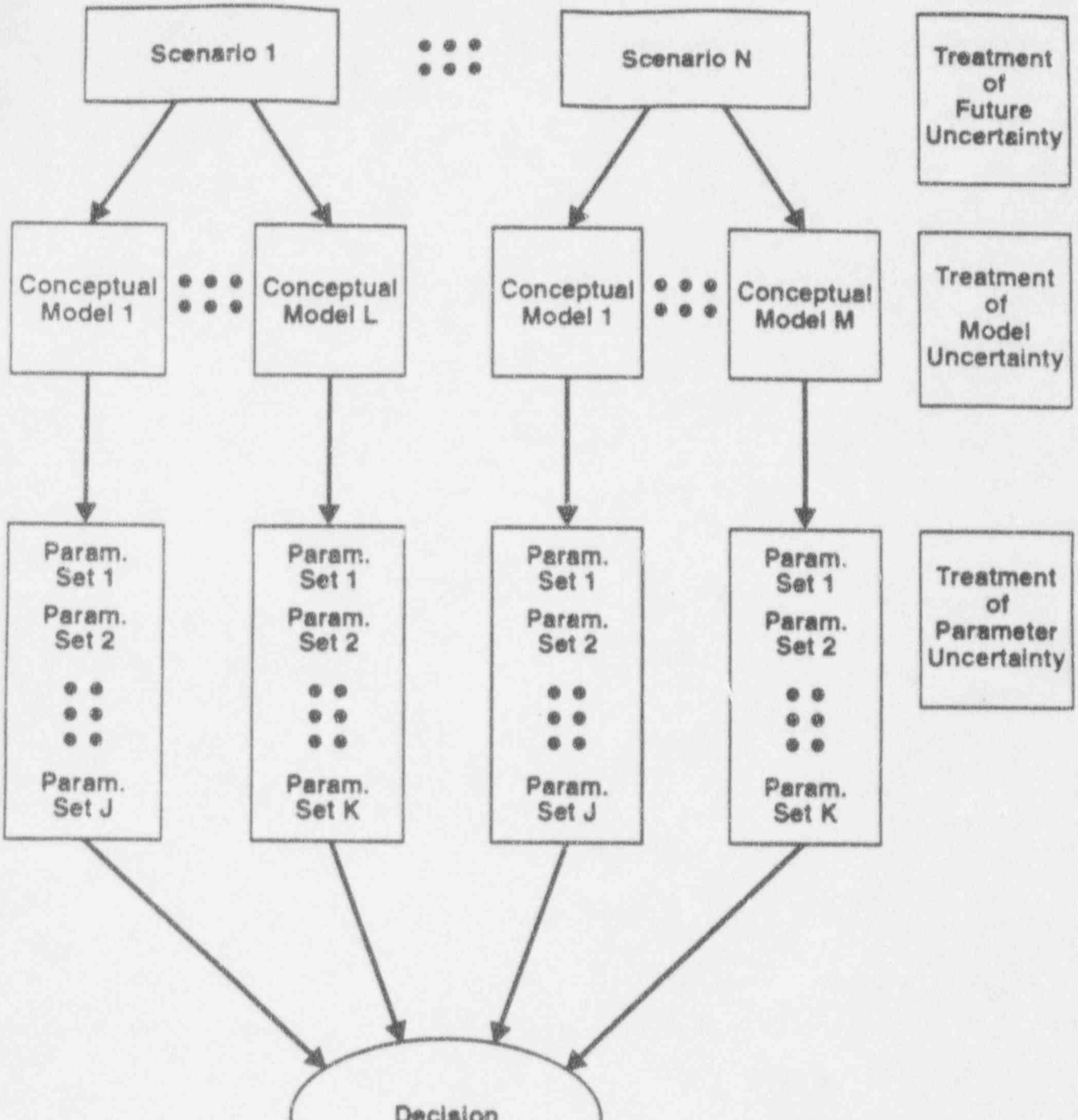
Credit for Site Characteristics (and Degraded Engineering)

FOCUS ON SITE PERFORMANCE AND LONG-LIVED RADIONUCLIDES. Project Important Processes and Events to Peak Dose, After 10000 Years Continue Model to Peak Dose or Demonstrate That Dose Limit Will Not Be Exceeded By Remaining Inventory.

TECHNICAL POLICY ISSUES

Treatment of Uncertainty

- **Complex interactions of system components in PA modeling make *a priori* determination of "conservative" analysis difficult**
- **Considerations:**
  - Future state of system
  - Conceptual model uncertainty
  - Parameter uncertainty
- **Approach:**
  - Multiple conceptual models and scenarios
  - Develop ranges of parameter values
  - Propagate parameter uncertainty through different models using Monte Carlo or similar techniques
- **Interpretations of distributions in terms of § 61.41**


Scenario 1
Scenario N
Treatment of Future Uncertainty
Conceptual Model 1
Conceptual Model L
Conceptual Model 1
Conceptual Model M
Treatment of Model Uncertainty
Param. Set 1
Param. Set 2
Param. Set J
Param. Set 1
Param. Set 2
Param. Set K
Param. Set 1
Param. Set 2
Param. Set J
Param. Set 1
Param. Set 2
Param. Set K
Treatment of Parameter Uncertainty
Decision

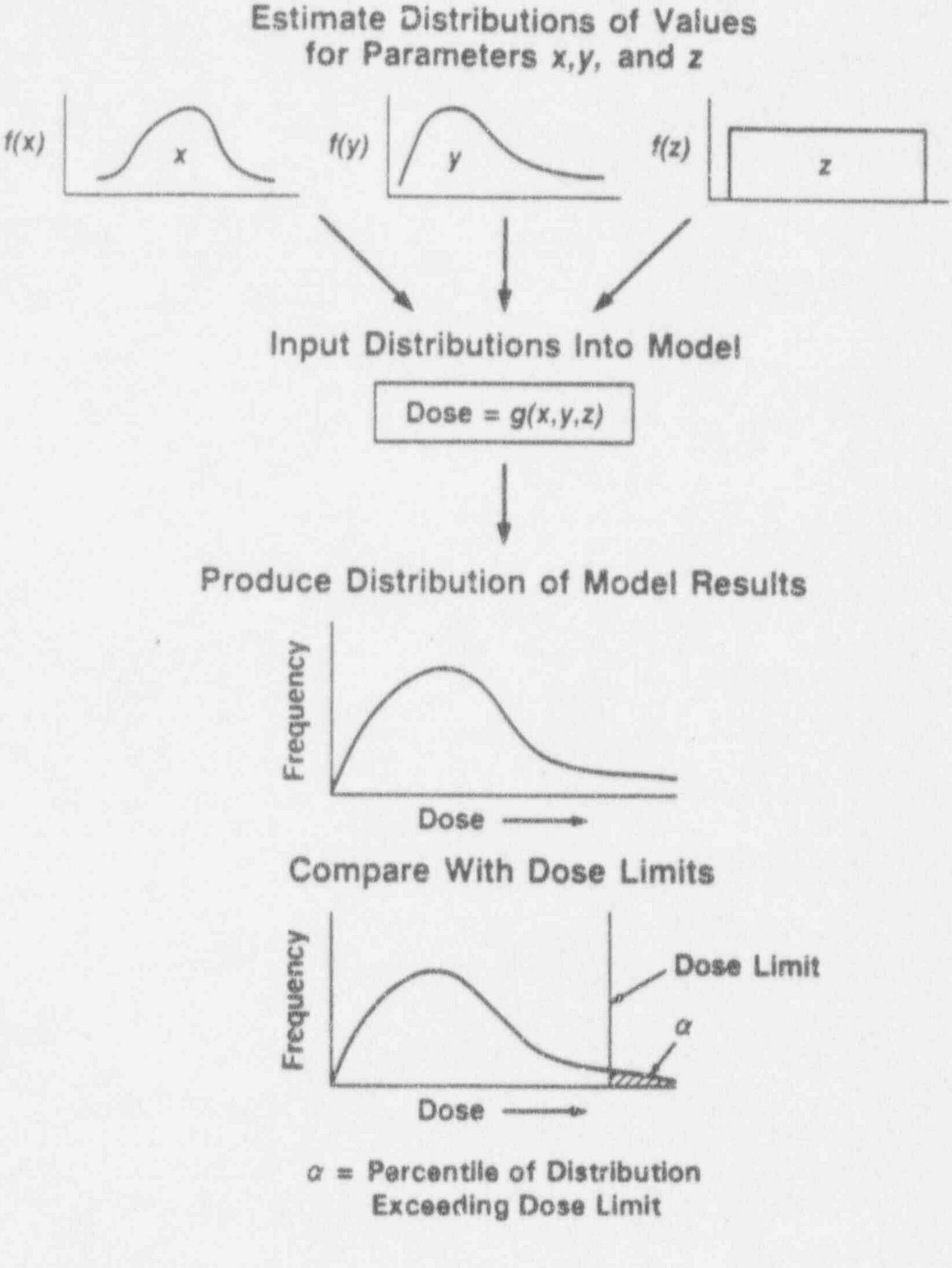


Figure 6. Conceptual approach to parameter uncertainty analysis (modified from Hoffman and Gardner, 1983).

TECHNICAL POLICY ISSUES

Role of PA During Operation & Closure

- **10 CFR 61.28 (a)**
- **Update during operations when significant changes made**
  - Real vs. hypothetical inventory
  - Design Modifications
- **Confirmation of engineered system performance**
  - Demonstration unit(s)
  - As-built properties
  - Field performance
- **May update PA for closure with site monitoring data from operational period**

BTP REVIEW PROCESS

Schedule and Milestones

- Draft BTP sent to Federal Agencies (DOE, EPA, USGS) and sited and host Agreement States for comment (1/14/94)
  - Comments received to date
    - DOE/PATT
    - DOE/NLLWMP
    - USGS
    - EPA
    - New York State
    - NRC contractors
  - Will begin formal evaluation in April
  - Awaiting some State input
- Workshop on BTP in Summer
- Revisions and Federal Register Notice by end FY94
- Management Decision on Policy Issues

U.S. NUCLEAR REGULATORY COMMISSION
LOW-LEVEL RADIOACTIVE WASTE PERFORMANCE ASSESSMENT PROGRAM

John T. Greeves, Director
Division of Low-Level Waste Management & Decommissioning
Office of Nuclear Material Safety & Safeguards

for
Advisory Committee on Nuclear Waste

Working Group Meeting on LLW Performance Assessment

Bethesda, Maryland

March 22, 1994

BACKGROUND ON LOW-LEVEL WASTE PERFORMANCE ASSESSMENT

- 10 CFR PART 61

  Requires technical analysis to provide reasonable assurance that performance objectives will be met

- Documents provide general guidance (1988)
  - Standard Format and Content Guide (NUREG-1199)
  - Standard Review Plan (NUREG-1200)

- Development of Performance Assessment Methodology
  - NUREG/CR-5453, Volumes 1-5, NUREG/CR-5532 (1989-1990)
  - Provides specific technical methodology for LLW PA

DEVELOPMENT OF LLW PA PROGRAM PLAN

Staff Requirement Memorandum, June 1991

- Plan developed jointly by NMSS and RES through PAWG
- ACNW Review October 1991
- ACNW letter to Commissioner Rogers, December ,1991
- LLW PA Program Plan (SECY-92-060), February 1992
  - Integrated staff/contractor activities
  - Phased process
  - Enhance staff LLW PA capability
    - In-house modeling
    - Code maintenance & validation
    - Research
    - Develop guidance document
    - Key technical issues and staff approach to resolve
  - Coordination with DOE and EPA
  - Coordination with IAEA
  - Coordination with Agreement States

LLW PA PROGRAM GOALS

- **Develop Improved PA Guidance for Agreement States and License Applicants**
  - Identify and resolve technical & regulatory issues in PA
  - Develop acceptable approaches for PA modeling
  - Provide technical assistance to Agreement States
  - Integrate research results into PA documentation
- **Enhance NRC Staff Capability**

  To Evaluate License Application

  To Provide Technical Assistance to Agreement States
  - Develop and assess conceptual models for PA
  - Evaluate computer codes for PA
  - Analyze sensitivity and uncertainty in PA modeling
  - Better understand phenomena and processes in PA

LLW PA PROGRAM

Implementation

PHASE I (FY 92-94)

Activities:

- Develop Branch Technical Position for LLW PA
- Gain experience with integrated PA modeling
- Implement and evaluate codes suitable for LLW PA
- Identify areas for further work

Accomplishments:

- Draft Branch Technical Position on PA for LLW Disposal Facilities
- Improved Staff Capability
  - Test Case Development
  - Interactions with DOE, USGS, EPA
  - Interactions with IAEA and other Nations
- NMSS User Need Letter Update

LLW PA PROGRAM

Implementation

PHASE II (FY95 and beyond)

- Develop NUREG documentation of test case modeling
- Develop PA approaches suitable for SDMP sites
- Detailed and extensive analyses of SDMP problem areas
- Upgrade and improve models and codes
- Factor new developments in LLW PA into PAM
- Mair´ in Staff capability

LLW PA PROGRAM

- ANNUAL STATUS REPORT ON PROGRESS OF LOW-LEVEL RADIOACTIVE WASTE PERFORMANCE ASSESSMENT DEVELOPMENT PROGRAM PLAN
  - STAFF HAS COMPLETED
  - SENT TO EDO
- COMMISSION BRIEFING ON APRIL 1
- STAFF IS LOOKING FOR FEEDBACK ON SEVERAL KEY ISSUES:
  - Systems approach for PA
  - Uncertainty approach
    - Use as a tool for understanding performance
  - Interpretations of uncertainty analysis results and 10 CFR 61.41 dose standard
  - Time frame for PA analyses
  - Uses of PA methodology for SDMP reviews

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BRANCH TECHNICAL POSITION ON LOW-LEVEL WASTE PERFORMANCE ASSESSMENT

STAFF CAPABILITY

PRESENTATION TO
THE ADVISORY COMMITTEE ON NUCLEAR WASTE
MARCH 22, 1994

JOHN O. THOMA, SECTION LEADER
TECHNICAL AND SPECIAL ISSUES SECTION
LOW-LEVEL WASTE MANAGEMENT BRANCH
DIVISION OF LOW-LEVEL WASTE MANAGEMENT AND DECOMMISSIONING
OFFICE OF NUCLEAR MATERIAL SAFETY AND SAFEGUARDS
PHONE (301) 504-3450

STAFF CAPABILITY

- Staff Technical Expertise
- Staff Development
- Team Coordination
- Hardware/Software Capability
- Future Staff Development

STAFF TECHNICAL EXPERTISE
CORE PAWG MEMBERSHIP

STRATEGY ISSUES/ BTP REVISION TEAM

ANDREW CAMPBELL - TEAM LEADER
TOM NICHOLSON
FRED ROSS

MODEL INTEGRATION TEAM

RALPH CADY - TEAM LEADER
TIM MCCARTIN
MARK THAGGARD

INFILTRATION TEAM

MARK THAGGARD - TEAM LEADER
RALPH CADY
FRED ROSS
TOM NICHOLSON

GROUNDWATER TEAM

RALPH CADY - TEAM LEADER
MARK THAGGARD
FRED ROSS
TOM NICHOLSON
ANDREW CAMPBELL

SOURCE TERM TEAM

TIM MCCARTIN - TEAM LEADER
PHIL REED
ROBERT LEWIS
ANDREW CAMPBELL

ENGINEERING TEAM

Robert Shewmaker - Team Leader
Joe Kane
Ed O'Donnell
Jake Philip

SURFACE WATER TEAM

Tom Nicholson - Team Leader
Robert Hogg

DOSE MODELING TEAM

Robert Hogg - Team Leader
Chris McKenney

AIR TRANSPORT

Chris McKenney - Team Leader
Phil Reed

CONTRACTOR ASSISTANCE

CONTRACTOR	RESEARCH	TA
Oak Ridge National Laboratory (ORNL)	X	X
Brookhaven National Laboratory (BNL)	X	X
Sandia National Laboratory (SNL)	X	X
Pacific Northwest Laboratory (PNL)	X	X
Idaho National Engineering Laboratory (INEL)	X	
National Institute of Standards and Technology (NIST)	X	
University of California - Berkeley	X	
University of California - Davis	X	
Massachusetts Institute of Technology (MIT)*	X	
Princeton*	X	

* Contract expired

STAFF DEVELOPMENT

- PRACTICAL TRAINING
  - DEVELOPMENT OF THE BTP ON PA
  - TEST CASE ANALYSIS
- FORMAL TRAINING
- CODE USAGE:
  - INFILTRATION
  - SOURCE TERM
  - GROUND WATER FLOW AND CONTAMINANT TRANSPORT
  - GEOCHEMICAL MODELING
  - DOSE MODELING
  - INTEGRATED PA MODELING
- WORKSHOPS
  - JUNE 1992: NMSS/RES CONTRACTORS WORKSHOP TO DISCUSS TEST CASE DEVELOPMENT.
  - NOVEMBER 1992: RES SPONSORED WORKSHOP ON GEOCHEMICAL RESEARCH FOR BOTH HIGH AND LOW LEVEL RADIOACTIVE WASTE.
  - MAY 1993: JOINT USGS-NRC TECHNICAL WORKSHOP ON RESEARCH RELATED TO LLW DISPOSAL.
  - JANUARY 1994: RES/NIST WORKSHOP ON PERFORMANCE AND MODELING OF CONCRETE AS ENGINEERED BARRIERS FOR LLW DISPOSAL.

STAFF TRAINING (CONTINUED)

- CONFERENCES AND PROFESSIONAL MEETINGS
    - PARTICIPATE IN THE ANNUAL DOE LLW MANAGEMENT CONFERENCES.
    - PARTICIPATE IN THE ANNUAL WASTE MANAGEMENT (CONFERENCES).
    - ATTEND MEETINGS OF PROFESSIONAL SOCIETIES:
        - AMERICAN CHEMICAL SOCIETY
        - AMERICAN GEOPHYSICAL UNION
        - GEOLOGICAL SOCIETY OF AMERICA
        - GEOCHEMICAL SOCIETY
        - SOIL SCIENCE OF AMERICA
- INTERACTIONS WITH OUTSIDE ACTIVITIES
    - STATE EFFORTS
    - FEDERAL AGENCIES
        - DOE
        - USGS
        - EPA (JUST BEGINNING)
    - INTERNATIONAL EFFORTS
        - IAEA LLW PA TEST CASE
        - INTERVAL
        - COOPERATION WITH OTHER NATION'S PROGRAMS

TEAM COORDINATION

- MANY DISCIPLINES INVOLVED.
- MANY TECHNICAL ISSUES.
- THE EFFECT OF SIMPLIFYING ASSUMPTIONS ONE AREA MAY HAVE AN ADVERSE EFFECT IN OTHER AREAS.
- IT IS IMPORTANT FOR THE VARIOUS TEAMS TO COOPERATE AND EVALUATE ALL PORTIONS OF THE PROJECT TO UNDERSTAND THEIR CONTRIBUTION.

HARDWARE/SOFTWARE REQUIREMENTS

- LLW PA USES BOTH SIMPLE AND COMPLEX MODELS AND CODES.
- ENHANCED "486" PCs ACQUIRED IN 1992.
  - ADEQUATE FOR ANALYSIS WITH MANY INDIVIDUAL LLW PA CODES AND FOR TEST CASE DEVELOPMENT.
  - SYSTEMS CODE REQUIRES 2-3 HOURS PER REALIZATION.
- RES HAS RECENTLY OBTAINED 2 WORKSTATION SYSTEMS.
  - ALLOWS MORE COMPLEX MODELS TO BE RUN (E.G., 3-D FLOW TRANSPORT MODELS).
  - PLATFORM FOR GIS BASED DECISION SUPPORT SYSTEM BEING DEVELOPED BY SNL FOR LLW PA AND REMEDIATION WORK.
- NMSS REORGANIZATION WILL PLACE HLW AND LLW PA WORK UNDER ONE BRANCH.
  - NMSS WILL EXTEND THE NEEDS ANALYSIS CONDUCTED UNDER THE ADVANCED COMPUTER REVIEW SYSTEM FOR HLW TO EXTEND COVERAGE TO LLW.
- A MIX OF 486 PCs AND WORKSTATION SYSTEMS APPEARS APPROPRIATE FOR LLW.

FUTURE STAFF DEVELOPMENT

- With the NMSS reorganization, there will be more interaction of HLW and LLW personnel.
- NMSS Staff Workstation Training
- The Office of Personnel is preparing an advanced computer technology training plan for the Division to facilitate staff's efficient use of advanced hardware and software.
- The Technical Training Center has been requested to evaluate how existing training may be tailored to respond to performance assessment training needs.
- Continue to transfer capability from contractors to staff.
- Incorporate ongoing and new contractor research into the methodology for both LLW PA and decommissioning assessment.
- Enhance in-house modeling capability to conduct and evaluate an integrated LLW PA and to assess decommissioning projects.

T-1

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INTRODUCTORY STATEMENT BY THE WORKING GROUP CHAIRMAN
WORKING GROUP MEETING OF THE ADVISORY COMMITTEE ON NUCLEAR WASTE
TO REVIEW THE NRC STAFF'S COMPUTER MODELING AND
PERFORMANCE ASSESSMENT CAPABILITY IN THE LLW PROGRAM

MARCH 22, 1994

THE MEETING WILL COME TO ORDER. I AM PAUL W. POMEROY, VICE CHAIRMAN OF THE ADVISORY COMMITTEE ON NUCLEAR WASTE. THIS IS THE WORKING GROUP MEETING OF THE ADVISORY COMMITTEE ON NUCLEAR WASTE TO REVIEW THE NRC STAFF'S COMPUTER MODELING AND PERFORMANCE ASSESSMENT CAPABILITY IN THE LLW PROGRAM. OTHER MEMBERS OF THE ACNW PRESENT INCLUDE MARTIN J. STEINDLER, CHAIRMAN OF THE ACNW, WILLIAM J. HINZE AND OUR NEWEST MEMBER, JOHN GARRICK (PRESIDENT OF PLG, INC.), WHO -- ALONG WITH ME -- IS CO-CHAIRMAN OF THIS WORKING GROUP MEETING. IN THE FUTURE DR. GARRICK WILL BE THE RESPONSIBLE LEAD MEMBER FOR ALL NUCLEAR WASTE MANAGEMENT-RELATED PERFORMANCE ASSESSMENT. AS INDIVIDUALS ASSISTING THE WORKING GROUP, WE HAVE WITH US TODAY:

ROBERT BUDNITZ

SCOTT SINNOCK

R. JOHN STARMER

OUR ATTENTION WILL BE FOCUSED ON THE NRC STAFF'S COMPUTER MODELING AND PERFORMANCE ASSESSMENT CAPABILITIES IN THE LLW DISPOSAL PROGRAM. THIS EVALUATION IS TIMELY,SINCE THE TIME FRAMES FOR BRINGING LOW-LEVEL WASTE REPOSITORIES ON-LINE ARE MUCH SHORTER THAN THOSE FOR HIGH-LEVEL WASTE. MOREOVER, IN THE LLW ARENA, AGREEMENT STATES, COMPACTS OF STATES, AND NON-AGREEMENT STATES ALL REQUIRE GUIDANCE IN THE IMPLEMENTATION OF THEIR LLW RESPONSIBILITIES. IN OUR DISCUSSIONS, WE MUST EVALUATE WHAT THE NEEDS OF THOSE STATES OR

GROUPS OF STATES ARE AND WHETHER OR NOT THE NRC HAS DEVELOPED THE APPROPRIATE CAPABILITIES TO MEET THOSE NEEDS IN THE PERFORMANCE ASSESSMENT AND COMPUTER MODELING AREAS. HENCE, THE WORKING GROUP WILL FOCUS ON THE DRAFT BRANCH TECHNICAL POSITION ON LLW PERFORMANCE ASSESSMENT.

AT THE SAME TIME, THE NRC CLEARLY NEEDS (AND HAS) AN INTERNAL CAPABILITY (SUPPLEMENTED BY CONTRACTORS) TO CARRY OUT PERFORMANCE ASSESSMENTS IN THE DISCHARGE OF ITS REGULATORY AND OVERSIGHT FUNCTION. HOPEFULLY, OUR DISCUSSIONS TODAY WILL ELUCIDATE NOT ONLY THE PRESENT CAPABILITIES IN THE AREAS OF INTEREST, BUT ALSO DETERMINE WHAT RESOURCES ARE NEEDED IN THE YEARS AHEAD.

THE WORKING GROUP FORMAT IS INFORMAL, AND I ENCOURAGE PERTINENT QUESTIONS FROM OUR EXPERTS, AS WELL AS THE COMMITTEE MEMBERS. WE DO NOT INTEND TO LIMIT DISCUSSION IN ANY WAY. AT THE SAME TIME, YOU CAN SEE FROM OUR AGENDA, WE HAVE A LARGE BODY OF MATERIAL TO COVER BEFORE THE END OF THE DAY, AND I KNOW EVERYONE WILL COOPERATE IN ATTEMPTING, AT LEAST, TO STAY ON SCHEDULE.

I WOULD ALSO REQUEST THAT ANY OF THE INVITED EXPERTS PARTICIPATING IN THE WORKING GROUP TODAY RECUSE THEMSELVES FROM OR LIMIT THEIR PARTICIPATION IN ANY PORTION OF THE MEETING, WHERE THEY FEEL THAT THEIR OPINIONS OR ADVICE WOULD CONSTITUTE A CONFLICT WITH THE GENERIC GOALS AND PURPOSES OF THIS MEETING.

A FOLLOW-UP DISCUSSION WILL BE HELD AT THE END OF TODAY'S PRESENTATIONS. THIS FOLLOW-UP WILL BE IN THE FORM OF A ROUND-TABLE ELICITATION, WHERE THE WORKING GROUP MEMBERS AND EXPERTS WILL SUMMARIZE THE COMMENTS, OBSERVATIONS AND RECOMMENDATIONS RAISED DURING THE PRESENTATIONS.

THIS MEETING IS BEING CONDUCTED IN ACCORDANCE WITH THE PROVISIONS OF THE FEDERAL ADVISORY COMMITTEE ACT. GIORGIO GNUGNOLI WILL SERVE AS DESIGNATED FEDERAL OFFICIALS THROUGHOUT THE MEETING.

THE RULES FOR PARTICIPATION IN THIS MEETING HAVE BEEN ANNOUNCED AS PART OF THE NOTICE OF THIS MEETING THAT WAS PUBLISHED IN THE FEDERAL REGISTER.

WE HAVE RECEIVED NO WRITTEN STATEMENTS OR REQUESTS TO MAKE ORAL STATEMENTS FROM MEMBERS OF THE PUBLIC REGARDING THIS MEETING. A TRANSCRIPT OF PORTIONS OF THE MEETING WILL BE KEPT, AND IT IS REQUESTED THAT ALL SPEAKERS USE ONE OF THE MICROPHONES, IDENTIFY HIMSELF OR HERSELF, AND SPEAK WITH SUFFICIENT CLARITY AND VOLUME SO THAT HE OR SHE CAN BE HEARD.

SHOULD ANY MEMBER OF THE PUBLIC OR ANY ORGANIZATION DESIRE TO MAKE ANY COMMENTS RELATIVE TO THE SUBJECT OF THIS MEETING, PLEASE MAKE YOUR INTENTIONS KNOWN TO GIORGIO GNUGNOLI, AND WE SHALL MAKE EVERY EFFORT TO FIT YOU INTO THE MEETING SCHEDULE, IF POSSIBLE.

I WOULD LIKE TO REQUEST OUR INVITED EXPERTS TO PREPARE A SHORT WRITTEN SUMMARY ON YOUR OVERALL IMPRESSIONS IN THE AREA OF THE NRC STAFF'S CAPABILITIES IN THIS AREA OF COMPUTER MODELING AND PERFORMANCE ASSESSMENT FOR LLW DISPOSAL STRATEGIES.

PLEASE PROVIDE YOUR WRITTEN IMPRESSIONS TO GIORGIO GNUGNOLI, OF OUR STAFF. HE WILL ENSURE THAT YOUR THOUGHTS WILL BE FACTORED INTO OUR FUTURE DELIBERATIONS.

AT THIS POINT, I WOULD LIKE TO TAKE THIS OPPORTUNITY TO ASK WHETHER ANY OF THE MEMBERS OR OUR INVITED EXPERTS HAVE OPENING REMARKS TO MAKE OR QUESTIONS.

HEARING NONE, I WOULD LIKE TO ESPECIALLY WELCOME THE REPRESENTATIVE OF THE STATE OF TEXAS' LLW DISPOSAL AUTHORITY (THE DEVELOPER), RUBEN ALVARADO, AND MR. SCOTT PENNINGTON OF THE TEXAS NATURAL RESOURCE CONSERVATION COMMISSION (THE REGULATOR), WHO HAVE GENEROUSLY GIVEN OF THEIR TIME AND EFFORT TO JOIN US TODAY IN THIS WORKING GROUP. MR. ALVARADO WILL PRESENT THE AUTHORITY'S PERSPECTIVE AND APPROACH TO LLW PA, AS WELL AS PRESENTING COMMENTS AND RECOMMENDATIONS REGARDING THE NRC's DRAFT BTP ON LLW PA. MR. ALVARADO, THE MICROPHONE IS YOURS.

GENERAL OBSERVATIONS AND CONCLUSIONS
TEST CASE STUDIES

presented by

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for

Advisory Committee on Nuclear Waste
Working Group Meeting on LLW Performance Assessment
Bethesda, Maryland
March 22, 1994

Sensitivity Analyses

Multiple Conceptual Models or Sensitivity to Specific Assumptions

- Cover Performance in Degraded State:
  - Fully functional but with modified K_{SAT} for each layer.
  - No credit for potential diversion within lower drainage layer.
  - Cover percolation limited only by K_{SAT} of clay barrier.

- Solubility of Radionuclides:
  - Ground-water buffered solubilities not considering influence of concrete.
  - Concrete-buffered solubilities.
  - Concrete-buffered solubilities with higher ranges for species affected by organic complexation.

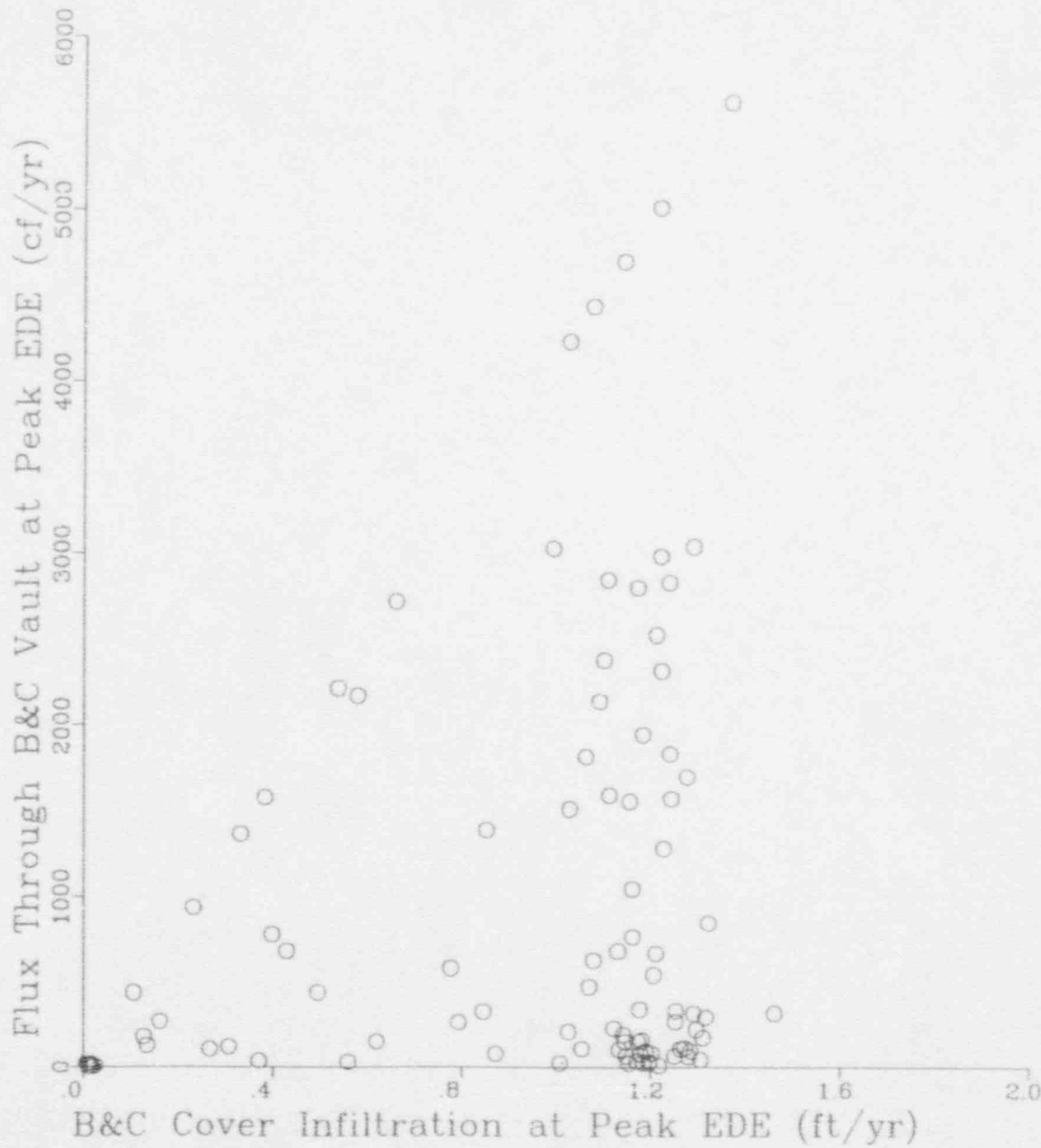
- Mixing capability of the pumping well:
  - vault percolation & inter-vault percolation
  - well-screen length versus plume thickness & interplume thickness.
  - horizontal width of well capture zone normal to ground-water flow.

Additional Analyses

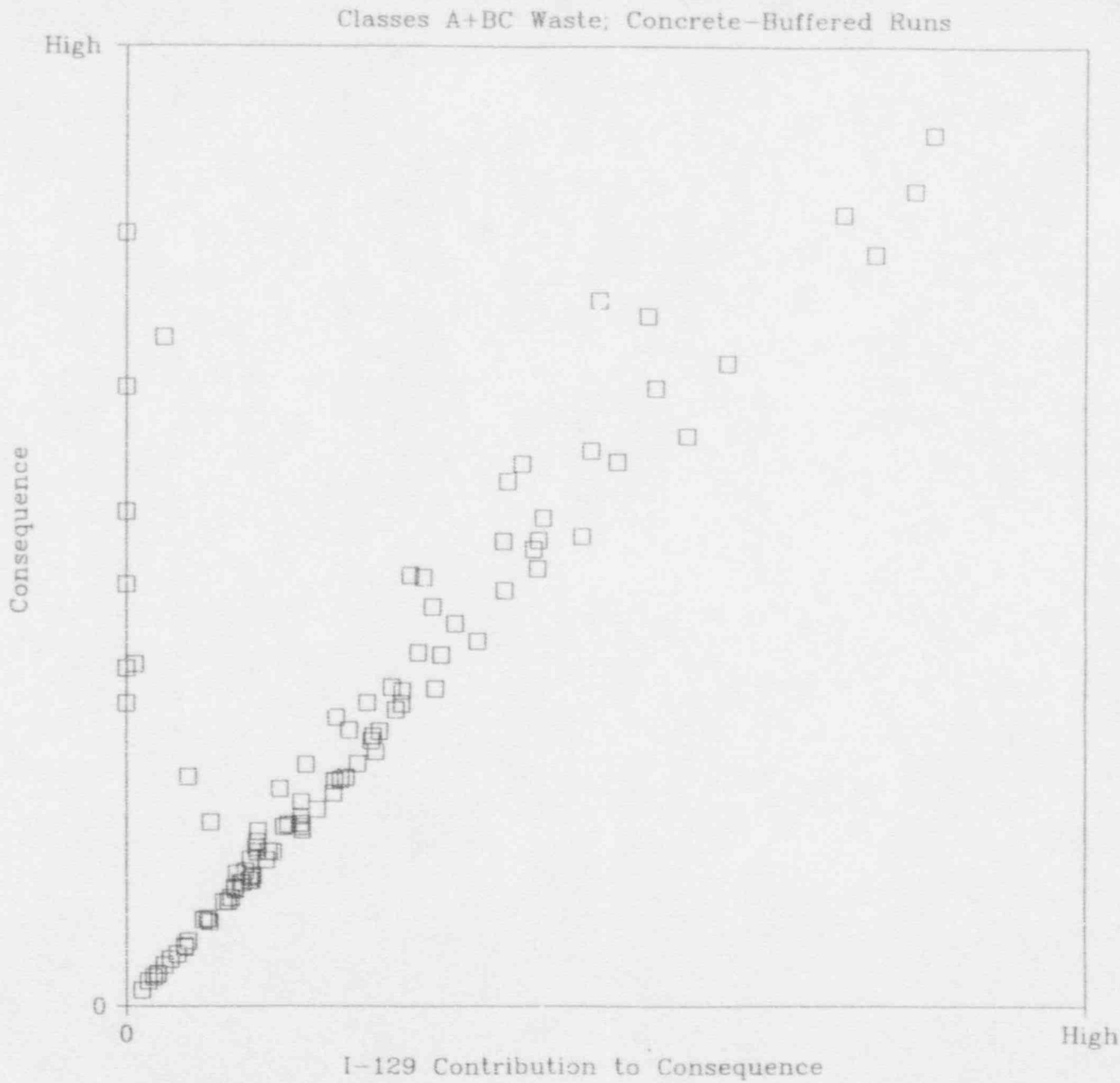
- Duration of "as-built" performance period (i.e., as-built K_{SAT}) for:
  - engineered cover, and
  - concrete vaults.

- Reduced I-129 and Tc-99 inventories.

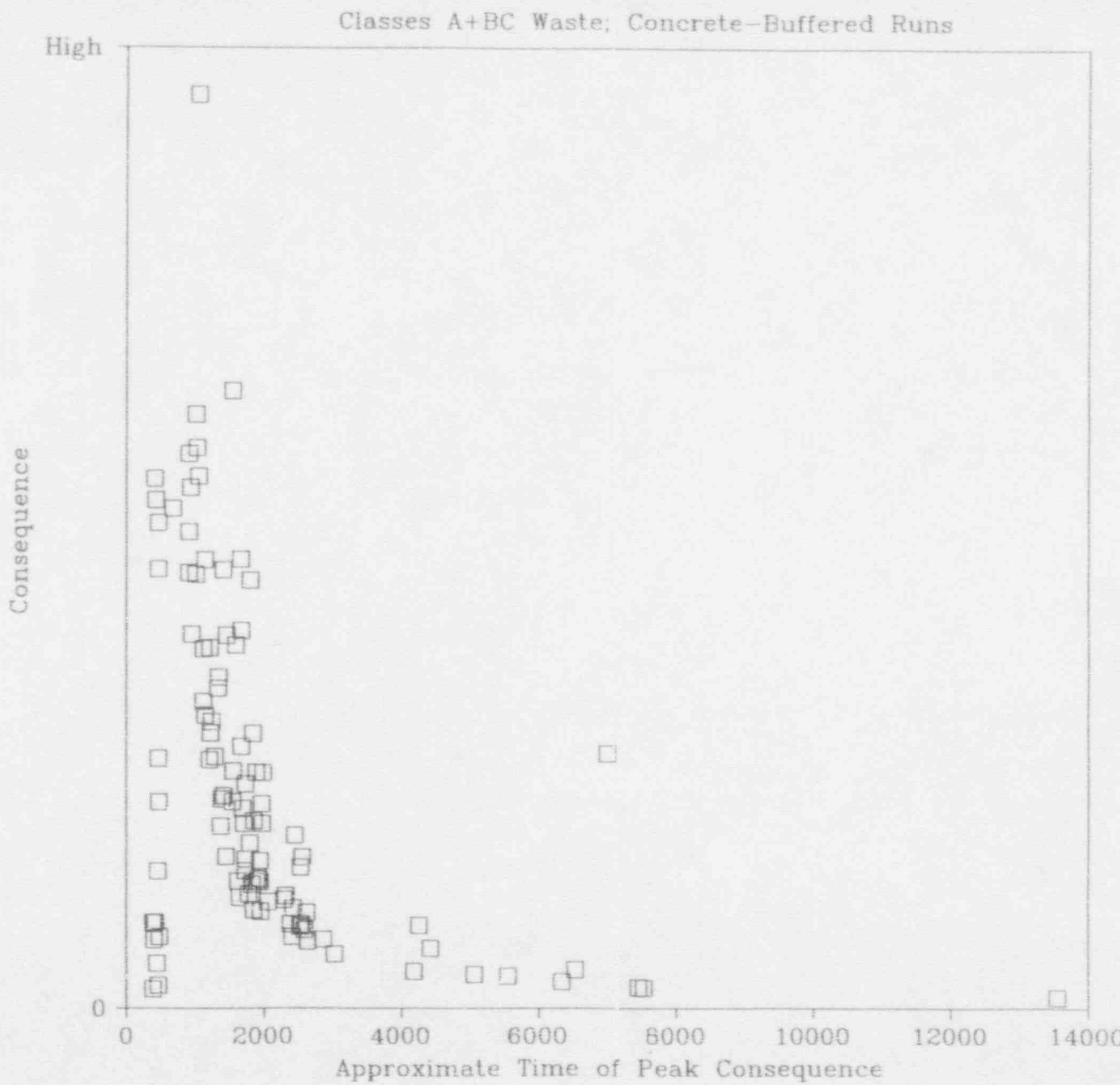
Classes A&BC Waste; Concrete-Buffered Runs



2



Classes A+BC Waste; Concrete-Buffered Runs
High
Consequence
0
0
High
I-129 Contribution to Consequence


Classes A+BC Waste; Concrete-Buffered Runs
High
Consequence
0
0
2000
4000
6000
8000
10000
12000
14000
Approximate Time of Peak Consequence

4

General Observations and Conclusions

For the conceptual model implemented, dose is most sensitive to:

- the flux of water into and through the vault
- percolation through the engineered cover, and
- solubility and retardation for critical radionuclides.

Other observations:

- Flux of water to the clay barrier may have implications to its long-term performance.
- Calculated percolation rates are sensitive to the time interval of the analysis.
- Performance of the engineered cover is highly sensitive to the moisture characteristic relationships.
- Lower percolation rates do not always imply lower doses.

General Observations and Conclusions (continued)

- Predicting concrete crack width and spacing is not well understood.
- Concrete cracking has the potential to significantly increase permeability over the permeability of the intact concrete.
- I-129 and Tc-99 inventories are important and Cl-36 may be important.
- Ingrowth of Ra-226 may be important for large inventories of U-238.
- Detailed geochemical modeling may be necessary to assign solubility values for certain radionuclides.
- Information on radionuclide-specific waste stream, form and type may allow improvements to release models.
- Value of various engineering features will be moderated by the engineering feature with the longest lifetime.
- The conceptualization and treatment the well are important to the analysis. The well discharge should be consistent with the ground-water use scenario.

ISSUES IN DEFINING MODEL VALIDATION

THERE IS NO COMMONLY ACCEPTED DEFINITION OF VALIDATION

- "SCIENTIFIC" CONCEPT OF MODEL VALIDATION

  PROVIDING ASSURANCE THAT THE MODEL REPRESENTS REALITY;MODEL RESULTS ARE ACCURATE

  - SUBJECTIVE DETERMINATION OF MODEL ACCURACY

  - NOT ACHIEVABLE IN PERFORMANCE ASSESSMENT

- REGULATORY CONCEPT OF MODEL VALIDATION

  MODELS ARE ADEQUATE REPRESENTATIONS OF REALITY

  - SUBJECTIVE DETERMINATION OF MODEL ADEQUACY

  - MAY UNINTENTIONALLY MISLEAD (HAVING IT BOTH WAYS)

ISSUES IN DEFINING MODEL VALIDATION

PREFER THE TERM "CONFIDENCE BUILDING"

ITERATIVE PERFORMANCE ASSESSMENT IDENTIFIES DATA NEEDED TO REDUCE UNCERTAINTY AND IMPROVE CONFIDENCE

- USE SITE-SPECIFIC DATA TO DEVELOP AND IMPROVE CONCEPTUAL MODELS
  - DEVELOP ALTERNATIVE CONCEPTUAL MODELS
  - EMPHASIZE CONSERVATISM
  - FOCUS ON REFUTING CONCEPTUAL MODELS THAT PROVIDE WORST RESULTS
- FORMAL TREATMENT OF UNCERTAINTY
  - INCLUDE BROAD RANGE OF CONDITIONS AND DATA
- PERFORM AUXILIARY ANALYSES AND TESTS AS NEEDED
  - INFILTRATION TEST (CALIF.)
  - WATER BUDGET STUDY
  - SPECIFIC DETAILED MODELING
- MAKE PROCESS AS OPEN AS POSSIBLE

U.S. NUCLEAR REGULATORY COMMISSION
LOW-LEVEL RADIOACTIVE WASTE PERFORMANCE ASSESSMENT PROGRAM

John T. Greeves, Director

Division of Low-Level Waste Management & Decommissioning

Office of Nuclear Material Safety & Safeguards

for

Advisory Committee on Nuclear Waste

Working Group Meeting on LLW Performance Assessment

Bethesda, Maryland

March 22, 1994

BACKGROUND ON LOW-LEVEL WASTE PERFORMANCE ASSESSMENT

- 10 CFR PART 61

  Requires technical analysis to provide reasonable assurance that performance objectives will be met

- Documents provide general guidance (1988)
  - Standard Format and Content Guide (NUREG-1199)
  - Standard Review Plan (NUREG-1200)

- Development of Performance Assessment Methodology
  - NUREG/CR-5453, Volumes 1-5, NUREG/CR-5532 (1989-1990)
  - Provides specific technical methodology for LLW PA

DEVELOPMENT OF LLW PA PROGRAM PLAN

Staff Requirement Memorandum, June 1991

- Plan developed jointly by NMSS and RES through PAWG
- ACNW Review October 1991
- ACNW letter to Commissioner Rogers, December ,1991
- LLW PA Program Plan (SECY-92-060), February 1992
  - Integrated staff/contractor activities
  - Phased process
  - Enhance staff LLW PA capability
    - In-house modeling
    - Code maintenance & validation
    - Research
    - Develop guidance document
    - Key technical issues and staff approach to resolve
  - Coordination with DOE and EPA
  - Coordination with IAEA
  - Coordination with Agreement States

LLW PA PROGRAM GOALS

- **Develop Improved PA Guidance for Agreement States and License Applicants**
  - Identify and resolve technical & regulatory issues in PA
  - Develop acceptable approaches for PA modeling
  - Provide technical assistance to Agreement States
  - Integrate research results into PA documentation
- **Enhance NRC Staff Capability**

  To Evaluate License Application

  To Provide Technical Assistance to Agreement States
  - Develop and assess conceptual models for PA
  - Evaluate computer codes for PA
  - Analyze sensitivity and uncertainty in PA modeling
  - Better understand phenomena and processes in PA

LLW PA PROGRAM

Implementation

PHASE I (FY 92-94)

Activities:

- Develop Branch Technical Position for LLW PA
- Gain experience with integrated PA modeling
- Implement and evaluate codes suitable for LLW PA
- Identify areas for further work

Accomplishments:

- Draft Branch Technical Position on PA for LLW Disposal Facilities
- Improved Staff Capability
  - Test Case Development
  - Interactions with DOE, USGS, EPA
  - Interactions with IAEA and other Nations
- NMSS User Need Letter Update

LLW PA PROGRAM

Implementation

PHASE II (FY95 and beyond)

- Develop NUREG documentation of test case modeling
- Develop PA approaches suitable for SDMP sites
- Detailed and extensive analyses of SDMP problem areas
- Upgrade and improve models and codes
- Factor new developments in LLW PA into PAM
- Maintain Staff capability

LLW PA PROGRAM

- ANNUAL STATUS REPORT ON PROGRESS OF LOW-LEVEL RADIOACTIVE WASTE PERFORMANCE ASSESSMENT DEVELOPMENT PROGRAM PLAN
  - STAFF HAS COMPLETED
  - SENT TO EDO
- COMMISSION BRIEFING ON APRIL 1
- STAFF IS LOOKING FOR FEEDBACK ON SEVERAL KEY ISSUES:
  - Systems approach for PA
  - Uncertainty approach
    - Use as a tool for understanding performance
  - Interpretations of uncertainty analysis results and 10 CFR 61.41 dose standard
  - Time frame for PA analyses
  - Uses of PA methodology for SDMP reviews

Texas Low-Level Radioactive Disposal Authority
Performance Assessment

Approach:

- Identify potentially important exposure pathways for the Texas facility;
- determine bounding pathways and scenarios;
- develop simple models for calculating release of radioactivity from the disposal units, environmental transport, and dose; and
- verify level of conservatism through comparison of results from simple models with those from more complex and comprehensive computer simulation models.

The use of simple models is consistent with the IMPACTS analysis for 10 CFR Part 61, and the overall approach conforms with NRC performance assessment guidance.

Exposure Pathways and Scenarios:

Normal Release Scenarios Used

1. Leachate returning to the ground surface with exposures through direct radiation from the soil and the suspended soil particles, inhalation of H-3 and C-14 and suspended particles, and from ingestion along biotic pathways involving plant and animal uptake.

2. Leachate to groundwater which is captured by a site boundary well with water used for human and livestock ingestion and for irrigation of a garden. The well supplies all of the drinking water, and one-half of the annual plant consumption and meat ingestion is produced onsite.

3. Inhalation of radon and decomposition gases (H-3 and C-14) diffusing upward through the disposal unit cover system.

4. An inadvertent intruder drills through a Class B/C disposal unit bringing ion exchange resin mixed with drill cuttings to the ground surface and resulting in direct gamma exposure from the mud pit.

Use of Site-Specific Data: General site characterization data was used to identify important and bounding pathways. Sierra Blanca meteorological data was used to model infiltration through the disposal unit cover system and estimate the subsurface water flux. The estimated Texas inventory was used in the calculations.

Major Assumptions Used in Performance Assessment: Performance assessment calculations are based on assumed pathways for a facility which is not yet built. Thus all details of all pathways are based on assumptions, including the inventory. Site-Specific characterization data plays its primary role in development of appropriate pathways for consideration.

Major specific assumptions are as follows:

1. The concrete canisters will fail at the end of the institutional control period (100 years after closure of the facility).

2. The Class B/C waste form will fail at 300 years after closure.

3. For calculation of the release rate, the radioactivity may be viewed as partitioned onto the solid waste material according to equilibrium waste-to-water partitioning. For each nuclide, the distribution coefficient gives the ratio of the activity per waste mass to the activity per volume of aqueous leachate:

$$K_d = \frac{C_s}{C_w} \qquad (L/kg)$$

Further, K_d values for a humid environment (Savannah River) are used since they are larger and will result in a greater estimate of radioactivity release.

4. One set of pathways evaluates the impacts due to all released radioactivity returning to the ground surface causing surface, biotic, and atmospheric exposures.

5. The groundwater pathway evaluates the impacts of all released radioactivity being transported to groundwater with capture of contaminated groundwater by a site boundary well. Because the groundwater pathway is considered to be very unlikely, one-quarter of the leachate from the facility is assumed to go to groundwater, with the remaining leachate returning to the ground surface.

6. The intruder-driller penetrates the Class B/C ion exchange waste resin and is exposed to radiation from the mud pit.

Software Used in Support of Performance Assessment:

Hydrologic Evaluation of Landfill Performance (HELP) - Calculation of net infiltration through disposal units

A Field Scale Model for Chemicals, Runoff, and Erosion From Agricultural Management Systems (CREAMS) - Calculation of net infiltration through disposal units for comparison with HELP

Simulation of Solute Transport in Variably Saturated Porous Media (VS2DT) - Simulation of unsaturated flow and velocities in the disposal units and vadose zone

Breach, Leach and Transport (BLT) - Simulation of the radionuclide source term from the disposal units using velocities from VS2DT

Disposal Unit Source Term (DUST) - Simulation of the radionuclide source term from the disposal units. This is a less conservative model than BLT but more conservative than the CRWR methodology.

The Hanford Environmental Radiation Dosimetry Software System (GENII) - Calculation of radiological dose from normal releases scenarios for comparison with CRWR methodology

MICROSHIELD 3.0 - Calculation of radiological dose from crane malfunction accident scenario

GGGGP (also called G^3) - Calculation of radiological dose from skyshine accident scenario

EXCEL - Performance assessment calculations using CRWR methodology for normal release and accident scenarios

Source Term Modeling (C-14)

The leachate flux from the waste disposal units (CRWR Model):

$$\dot{m}_{facility} = q\, A_s\, c_w\, f_L = \frac{q\, f_L}{(\theta_{waste} + \rho_{waste} K_d)\, L_{waste}}\, A = \lambda_L\, A$$

where

θ_{waste}	=	volumetric water content of waste (cm^3 water/cm^3 waste)
ρ_{waste}	=	bulk density of waste (gm/cm^3)
K_d	=	equilibrium distribution coefficient (cm^3/gm)
c_w	=	nuclide concentration in water (Ci/m^3)
A_s	=	surface area of the disposal units (m^2)
L_{waste}	=	waste thickness (m)
q	=	percolation of water through the disposal trenches (m/yr)
f_L	=	factor which accounts for the fraction of the waste which is contacted by water percolating through the liner system and from which leachate generation occurs
λ_L	=	leach rate constant (yr^{-1})

CRWR	-	**4 E-4 Ci/yr**
DUST	-	**4 E-5 Ci/yr**
BLT	-	**2 E-6 Ci/yr**

Other Models Utilized During Performance Assessment Research:

AIRDOS-PC - Computer code which estimates radiation doses to man from airborne releases of radionuclides. It computes air concentrations, ground surface deposition, and intake rates for inhalation and ingestion pathways. US NRC Regulatory Guide 1.109 food chain models are used with dose conversion factors derived from DARTAB. (EPA)

CRRIS: Computerized Radiological Risk Investigation System for Assessing Doses and Health Risks from Atmospheric Releases of Radionuclides - Eight fully integrated computer codes which calculate environmental transport of atmospheric releases of radionuclides and the resulting doses and health risks to individuals. (ORNL)

FEMWATER: A Finite Element Model of Water Flow Through Saturated/Unsaturated Porous Media - Model used to compute unsaturated flow velocities through waste disposal units as input to BLT model for leachate generation. (ORNL)

INGDOS--Calculations for Implementing US NRC Regulatory Guide 1.109 Models for Estimation of Annual Doses from Ingestion of Atmospherically Released Radionuclides in Foods - Model used for comparison calculation of ingestion doses from surface releases of radionuclides. (ORNL)

PATHRAE-EPA: Low-Level and NARM Radioactive Wastes - Model used for generation of Environmental Impact Statement supporting EPA's rulemaking for management and disposal of LLRW. Model used to assess the maximum annual dose to a critical population group. Modification from PRESTO-EPA family of codes to consider modified pathways and simplified dynamics. (EPA)

PRESTO-EPA-CPG: Low-Level and NARM Radioactive Wastes - Model used for generation of Environmental Impact Statement supporting EPA's rulemaking for management and disposal of LLRW. Model used to assess the maximum annual dose to a critical population group. Modification from PRESTO-EPA-POP model emphasizing the calculation of the CPG dose. (EPA)

PRESTO-EPA-POP: Low-Level and NARM Radioactive Wastes - Model used for generation of Environmental Impact Statement supporting EPA's rulemaking for management and disposal of LLRW. Model used to assess the cumulative population health effects to the general population residing in the downstream regional basin of a LLW disposal site. (EPA)