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NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON NUCLEAR WASTE (ACNW)

173[RD] MEETING

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WEDNESDAY,

SEPTEMBER 20, 2006

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VOLUME III

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The meeting was convened in Room T-2B3 of Two White Flint North, 11545 Rockville Pike, Rockville, Maryland, at 8:30 a.m., Dr. Michael T. Ryan, Chairman, presiding.

MEMBERS PRESENT:

MICHAEL T. RYAN Chair

ALLEN G. CROFF Vice Chair

JAMES H. CLARKE

WILLIAM J. HINZE

RUTH F. WEINER

LATIF S. HAMDAN, Designated Federal Official

NRC STAFF PRESENT:

TOM NICHOLSON

JOHN FLACK

DAVID ESH

JIM SHEPHERD

ALSO PRESENT:

BRIAN ANDRASKI, US Geological Survey

VAN PRICE, Advanced Environmental Solutions

ROBERT FORD, US Environmental Protection Agency

CRAIG BENSON, University of Wisconsin-Madison

GLENDON GEE, PNNL

JODY WAUGH, US Department of Energy

TODD RASMUSSEN, University of Georgia

JAMES S. BOLLINGER, Savannah River National Laboratory

A-G-E-N-D-A

A-G-E-N-D-A

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

8:34 a.m.

CHAIRMAN RYAN: All right. The meeting will come to order please if you could all take your seats.

This is the third day of 173rd meeting of the Advisory Committee on Nuclear Waste. During today's meeting the Committee will continue to conduct a working group meeting on using monitoring to build confidence.

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

Latif Hamdan is the designated federal official for today's initial session.

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

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

It is also requested that if you have cell phones or pagers, that you kindly turn them off.

Thank you very much.

And with that, I'll turn the morning session over to Dr. James Clarke. Jim?

MEMBER CLARKE: Thank you, Mike. I do have a few introductory remarks for those of you who weren't here yesterday.

First, welcome and thank you for attending this ACNW working group meeting on using monitoring to develop model confidence Monitoring, and modeling in particular, but monitoring and modeling interface are of great interest to the Commission and to the Committee. Our focus for these meetings is to answer the question how can we use monitoring to not only demonstrate compliance, but to build model confidence as well.

In a related area the Committee will also be looking at the use of monitoring and modeling to evaluate the reliability and durability of institutional controls. And as we progress through the meeting we would appreciate any facts you might have on this challenging area as well.

The Committee worked very closely with the Office of Research, Tom Nicholson and Jake Phillip in particular, to organize the sessions and select the speakers and panelists. As all of you know, Latif Hamdan of the ANCW staff has played a major role.

Our meetings have been organized around four sessions. Yesterday we looked at the role of models and monitoring programs and licensing and case studies for evaluating radionuclide releases and ground water contamination.

Today we will look at sessions on field experience and insights and opportunities for integrating modeling and monitoring.

We have invited a very capable group of presenters and panel members, including representatives from the Department of Energy and the National Labs, private consulting firms, our universities and waste management companies, the U.S. Geological Survey, the U.S. EPA and NRC.

We do have a very tight schedule. And in fairness to all of the participants we need to stay on schedule. And I will do that as needed, so everyone please stay within your allotted times.

And on that note, we will hold questions until after the speakers have made their presentations and the panel has had an opportunity for discussion.

Professor George Hornberger of the NWTRB and the University of Virginia has agreed to lead the panel discussions. He is, as you know, a former member and Chairman of this Committee. And we greatly appreciate his participation and his leadership role in these meetings.

So, with that, let's turn to our first speaker. Brian Andraski from the U.S. Geological Survey, Monitoring and Modeling to Improve Containment Transport Processes In An Arid Environment.

Brian, welcome.

PROFESSOR ANDRASKI: Thank you.

As Jim, mentioned, I'd also like to thank the Committee for inviting me. I enjoyed the presentations yesterday. Very interesting and informative. And I warned a few people this morning, I hope you all had your coffee because I've heard the next speaker give presentations before, and it could be a real sleeper. So hang in there.

Again the title that was mentioned, Monitoring and Modeling To Improve Understanding Of Containment Transport Processes, and our focus here is on an arid environment.

A number of collaborators that are working on this topic, and all of the folks listed here are with the USGS. Dave Stonestrom and Bob Mitchel with the National Research Program in the Menlo Park, California office, Michel Walvoord, R.G. Striegl also National Research Program, Denver. Justin Mayers is in my office and the person sitting data and Ron Baker from New Jersey and David Kradbenhoft from Wisconsin. So we've got a number of folks.

Let me get organized here. All right. And with that, my time's up, so I'll take questions.

In terms of an outline, the main focus of the presentation will be to give you an overview or a summary of some of the work that we're doing where we're combining environmental monitoring and modeling. The two containments that I'll touch on include tritium and also elemental or gaseous mercury.

The tritium work has been ongoing for some time, whereas the mercury work is something that we've started more recently. We've collected a couple of field data sets on mercury and in terms of the modeling it's just we're in the initial stages but I'll share with you the results that we've gathered to date.

The field site that we're working at is the USGS Amargosa Research Site, which is located adjacent to the nation's first commercial low level radioactive waste facility, often referred to or called the Beatty facility or the Beatty dump in

Southern Nevada.

The overall objective of our work is to try to improve understanding of processes that are controlling unsaturated zone transport of both water and mix waste contaminants in arid environments.

The experimental approach that we use a great deal of emphasis is placed on field intensive research with multiple lines of data. I've listed the types of data that we're collecting at the site, but basically we'd cover the full gamut from basic weather data to simple ground water monitoring in terms of water levels. And we do try to touch on everything in between as well.

In terms of containments that we're monitoring, they include tritium, radiocarbon, volatile organic compounds and also gaseous mercury.

For the VOCs, we analyze for 87 or 88 different analytes.

So these field data then are integrated with modelings that we can test and refine both conceptual and numerical models. And the work that's done, we work under both natural or undisturbed conditions and also have done studies under perturbed or contaminated conditions. And the idea there really, we try to gain an understanding of conditions and processes in a natural setting and then use as somewhat of a foundation to help to identify contamination and also superimpose the contaminate transport processes on these natural processes.

This is an aerial view in the vicinity of the Amargosa Desert Research site. In the foreground is the waste facility itself. We're located about 20 kilometers east of Death Valley National Park.

The waste facility occupies an area of about 80 acres. The western half, which would be on your left, was used for low level radioactive waste disposal, mixed waste contaminates disposed from 1962 through 1992. And the eastern half of the facility is used for hazardous chemical waste disposal.

In terms of precipitation it is an arid site. We average about 100 millimeters or four inches per year.

Dominant digitation is creosote bush, which is an evergreen shrub. But in terms of its sparse vegetation, there's about 5 to 10 percent cover by plants. So 90 to 95 percent is bare soil.

Sediments are highly stratified being formed in alluvial and fluvial sediments. And the depth of the water table is about 110 meters.

This slide depicts the locations of the

various monitoring that we do for tritium. It includes deep unsaturated zone boreholes. And we also collect soil gas samples in the shallow unsaturated zone. And we've also more recently started to use plants as a means of collecting some of the monitoring data to delineate contaminate plumes.

One of the things that stands out here for me is that we're highly unsampled when it comes to deep unsaturated zone monitoring. Basically two boreholes, UZB-2 and UZB-3, are the two boreholes that we use for collecting soil gas samples. As we move up to the surface the red dots represent the soil gas sampling locations. So we have a number. The number of sample points has increased quite a bit. But in both cases the soil gas sampling technique that we use requires about 12 to 24 hours of pumping soil gas so that we can collect enough water vapor or liquid so that we can analyze for tritium. So that's where we turn to a plant technique.

And shown here the little green squares throughout the diagram, there's over 100 points there. And we're able to collect all of those samples in a single day. So that's something that's worked out pretty well for us.

This is an example of some of the results from the plant sampling that we've done, basically using plant water concentrations. And drawing a simple contour map we identify a hot spot here on the south side of the facility and also a hot spot on the west side of the low level waste area. So the plants are handy in terms of using it to delineate contaminate distribution. But we wanted to take that a step further to extrapolate that information to shallow sub-surface transport. And basically just developing relations between plant water concentrations and soil gas concentrations. We put that together. And we did document, essentially we have sub-surface tritium transport that extends out to more than 300 meters away from the waste disposal area.

This is an example of some of the deep unsaturated zone monitoring data that have been collected. Again, for tritium. This data comes from the UZB-3 borehole, which is located about 100 meters from the nearest trench.

A couple of features to point out. First of all, the peak concentration that we see there at a depth of about 1 to 2 meters below land surface. And also high concentrations about 20 to 30 meters or so below land surface.

Both of those peak concentration areas do correspond with a gravel layer in this highly stratified profile in terms of the sediments.

The other point to note is that throughout the unsaturated zone we do have elevated levels of tritium throughout the extent of the unsaturated zone. In contrast, the ground water sample that was collected at this site basically were at or just below detection levels. So most of the action, if you will, is in the unsaturated zone. And that's really where we're placing our emphasis in terms of transport processes.

The initial modeling work that was done was carried out by Rob Striegl and others in 1996. They used two separate models to try to analyze further the field data that had been collected. A diffusive transport model and an advective transport model. The diffusive model was one that was developed by Dave Smiles. Dave's from Australia. He was on sabbatical at UC Berkeley. And I'm pretty sure his work was done in collaboration with US NRC.

Unfortunately, in both cases these numerical models did fall short. As an example, the modeled diffusive transport predicted a maximum extent of contamination of about 15 meters. And as you've seen from the previous slides, were under predicting there by a factor of ten or more.

So the initial conceptual model Rob and co-workers scratched their heads to try and come up with a conceptual model that might explain the observations in the field and, although they didn't feel very comfortable with it, they felt that one potential hypothesis was that things were controlled by lateral sub-surface liquid transport along preferential paths.

Well, with further data collection, again iterating back and forth between data modeling and back to collecting data, that conceptual model was refined. And what we're focusing on at this point in time is still a predominately lateral transport, but the vapor phase dominated transport controlled by stratigraphy. So this is just a schematic to illustrate what we're seeing in terms of the field data suggesting a preferential path for vapor transport here at that 1 to 2 meter depth and then also down at greater depths with the highest concentrations occurring in these very dry gravelly materials that seem to be providing a preferential path for vapor phase transport.

So with that new conceptual model in mind, Justin Mayers took on phase two of the tritium transport modeling. Justin used a much more complex code, the TOUGH2 code which allows for simulation of coupled liquid gas of heat transport in a non-isothermal and heterogeneous domain.

The results shown here are for the reference model, but as you can see things weren't improved very much over those initial models where we predict here a maximum lateral extent of about 25 meters in 40 years.

And just as a reference, I've included where one of our nearest boreholes is located, which would be about 100 meters from that nearest trench.

Justin also wanted to look at the effects of anisotropy and source temperature and pressure forcing. The results shown here are using for a model using anisotropy of 1 to 100, a source temperature of 45 degrees C and a source pressure of 500 pascals.

As you can see, the general shape of the plume now is much more representative of what we observe in the field. The extent of lateral transport reaching out to about 120 meters in 40 years, which does pass through the UZB-3 borehole location. So the general shape of the plume is much improved. But if you do look at the concentrations, we're in the hundreds of becquerels here versus the thousands in terms of what's actually being monitored in the field.

Just a quick summary of what we've seen to date. In terms of the monitoring data, once again, the plant based mapping did allow us to identify a kilometer sized plume adjacent to the waste facility.

We do see that tritium is migrating throughout the full unsaturated zone and those high concentrations, the peak concentrations that we see appear to be tied into preferential transport along these course, gravelly materials.

The phase two modeling results, it basically required a large anisotropy and source forcing to enhance the transport to get it to move out much further than what we were initially predicting. And basically we have reduced discrepancies between theory and measurements, but we haven't eliminated those discrepancies yet.

So at this point where we're at is conceptual model, you know what's missing. One of the questions we're asking is what other processes are we missing that may be enhancing gas phased transport. Two of those that we hope to look in some detail would include potential coupling between organic compounds and tritium and also what might the potential effects be of barometric pumping.

Moving into the monitoring data, again, we've collected a couple of field data sets. Mercury data shown here. Again, deep unsaturated zone results from that UZB-3 borehole.

One of the main things I wanted to point out is that we do see a very strong correlation between the gaseous mercury and the tritium concentrations. So as I noted before, a depth of about 1 to 2 meters and also 20 to 30 meters or so below land surface we do see peak concentrations for both of these contaminates.

I've included also this open triangle, which is a background concentration for gaseous mercury which is measured about 3 kilometers from the waste facility. We have another borehole that we use as basically our control site. So it does appear that the mercury source is from the disposed waste.

Initial mercury transport modeling. This work has been done by Michel Walvoord. Again, I emphasize just some of the initial results that have been generated. Michel also used a more complex model, FEHM, which allows again for liquid gas heat transport and a non-isothermal heterogeneous domain.

The one thing that jumps out, I guess, is that this diffusive model that's been generated or been used doesn't do a very good job of reproducing what we see in the field.

Michel did look at the effects of anisotropy and source temperature forcing, but essentially it had no effect on the shape or the bottled plume that's shown here.

Something that we haven't completed yet is to look at the source pressure forcing and what effect that might have. But that is something that needs to be pursued.

So a quick summary here as well for the mercury monitoring data like tritium, we've do see gaseous mercury migrating long distances through the unsaturated zone apparently in these following preferential paths. The fact that we do see gaseous mercury in great distances in the unsaturated zone does confirm the dominance of gas phased transport in these desert soils.

When it comes to the initial modeling results, as we saw the diffusive model doesn't give a very good approximation of what we've observed in the field. Unlike tritium, adjustments in anisotropy and source temperature forcing didn't give us any indication of a preferential flow pattern in the initial modeling results. So here again looking at the conceptual, what do need to incorporate to try and improve our simulation of these processes?

The first one that I mentioned, source pressure forcing but also perhaps barometric pumping. So things that we need to still pursue and look at in greater details.

In terms of conclusions, fairly simple. I guess number one, I feel like we can measure the contaminates.

Number two, we can map the contaminates but at this time our present models and therefore our understanding really can't accurately produce the observed extent or distribution of the transport.

So basically where do we go from here? We are going to continue to collect additional field data to support the work and then integrate monitoring and modeling to explore the questions that have come up and to also use that information to refine the models. But ultimately the bottom line, I guess, is that better process understanding is really needed to further develop and build confidence in the transport models.

And I'll just end with this slide, basically a sunset over the Amargosa Desert Research site. I've included a web address there if anybody's interested in further information or a full bibliography of work that's been done at the site. But I'd also like to acknowledge the USGS toxic substances hydrology program, which is the program that provides base support for operation and maintenance of the Amargosa Desert Research site.

So with that I'll close, and thank you for your time.

MEMBER CLARKE: Thank you, Brian,

Our next speaker is Van Price, Advanced Environmental Solutions, Inc. The title of his presentation is Toward a Modeling Mindset For Nuclear Facility Site Performance.

Van, welcome.

MR. PRICE: Everybody out there still alive? I believe they are. You didn't do your job, Brian.

Thank you very much. And I would also like to say it's a privilege to be here. I'll just move right on.

I think those of you were here yesterday saw and heard many of the ideas and some of the data that I'm going to present.

My message for this talk is well, it's the 21st century, or at least I think it is. And the concept of a model ought to mean more to us than a simulation of flow and transport. It should include data management and visualization and communication with the simulation somewhere in between.

The state-of-the-art today allows near real-time data integration. You can put all of your site characterization data, all of your new monitoring data and do all your simulation and have a rear end to that whole process that facilitates communication. And basically a good desktop computer. And you no longer have to have an IMB 370 system to do modeling.

I've been working with Tom Nicholson's group for the past few years on a project to develop a document on to provide logic and strategy for groundwater monitored at NRC licensed sites. The focus has been on performance confirmation monitoring.

Those of you who have thought about monitoring, the vast majority of all monitoring done since the EPA's groundwater protection regulations went into place in the early '80s, has been compliance monitoring. And if you want to worry about the distinction between these, think of the instruments on your automobile. The big round one is your compliance monitor. If you've got a radar detector, that's your detection monitoring. And there's some other little gauges. There's a temperature gauge, there's an oil pressure gauge. On my car there's ammeter. Well, if those things get out of whack, your whole system is out of whack. So you want to monitor the performance system, you watch your oil pressure.

We're currently in the testing phase. We've been very graciously provided data from DOE sites, and the gentleman from Brookhaven will see some of their data here in just a few minutes. Department of Defense sites and USGS source. I'm not going to show any of Brian's data, but he's been very generous in providing us with data from the Amargosa site.

WE've also begun tech transfer on this project, largely for some of the NRC regional staff. It's primary background is in health physics. They have very little background in earth science areas, so we've run a couple of workshops that basically run through the basics that you would have to at least be conversant about if you were going to review or design a monitoring program. You might say we've given them a little bit of knowledge, which at least made them dangerous.

Here is a very high level overview of the strategy. This figure we put together several years ago. It basically shows an iterative process. You take your site data and you analyze that site data, your original site and facility characterization information, you develop a site conceptual model. Generally there has been some sort of a performance assessment or risk assessment. And generally there is a monitoring program. But by analysis of your available data you can decide what should be monitored, what you should be monitoring. And these we're calling performance indicators. So that's your oil pressure gauge and other things.

And based on sort of a review of the state-of-the-art you can figure which's the best way to test for these things. And based on your conceptual model and perhaps some simulation, you can decide where and when you collect data and compare that to your modeling results. And you feed back through this whole process. That's the gist of it, but we take about a 100 pages or so to describe it.

And we talked also yesterday about what are some performance indicators. Well, initially, the people we were working with thought, well, those ought to be your primary risk drivers. Perhaps that's carbon 14 strontium or something. But we're talking about indicators of system performance. It might be a moisture profile on a cap. It might be once you've plotted your data you see you've got a bull's-eye over here on the contour map. Well, either you've got a bad measurement or you've got a bad conceptual model. It might be non-spatial, you might just have a control chart anomaly that spike it. So these can all be indicators that your system is performing or not performing as you currently understand the modeling.

I mention sort of systems analysis at the beginning of this. If you're trying to think about controls on flow and transport -- let's make this thing do what I think -- then you have to have some sort of a depositional model.

This is California. These are kilometer tick marks and this is a cross section from wells in a couple of California water districts. It shows you if you're in an alluvial setting and this might apply partly to the Amargosa site, that you could expect some complexity. Well, this is sort of like the picture on top of your 1,000 piece jigsaw puzzle and you're only given 12 pieces of the puzzle. Ideally, you would be able to come up with some model of how this overall system is going to function.

You would know that there should be preferential flow paths and fanning out from some central source. For example, you wouldn't know the details, but you would at least have some basic thing once you had a conceptual model based on the way the geology is taken.

I don't have another link on this one.

So to reiterate, and I reiterate two or three times in here, we gather all the puzzle pieces. We conceptualize, we simulate and we revise.

And I reiterate again, you have to have some initial characterization. You'll never build a good model from -- you will rarely build an accurate model from the initial data. So you have to monitor to refine it. And once you refine it, you have something you can communicate to your stakeholders.

Here's some things you can do with a model. I do have a link on this. This slows a plume at Rocky Flats. Originally the VOC was all contoured together. But once people understood the probable flow paths for groundwater and contoured not just total VOC but thinking about the degradation of the VOCs contoured separately, the probable original contaminates and the daughter products from degradation, you could actually begin to understand this.

You can also communicate to stakeholders. You know what stakeholders are, don't you? Have you ever watched "Buffy the Vampire Slayer"? Stakeholders are these people out there who have these wooden sticks and if they don't think your heart's in the right place, they'll try to run it into you. So it's very important to deal appropriately with these people.

You can reverse engineer your model from your observations.

Another thing you can do is evaluate various alternative hypothesis. This is a flood plain of -- can you see that? Well, never mind. There's a big river here. There's an interstate highway with bridges elevated. And there's a little bit of a natural levee. Some developers commissioned a surface water model which was reviewed by a state agency. And the state review noticed that they were giving credit to a natural levee for holding back a 10 foot high wall of water.

Well, I talked with the guy about a week ago who did this review and who gave several speeches on it. He would never say that they deliberately tried to mislead. But you always got to have some skepticism of any model and you've got to have some alternative hypothesis that you can talk about. You've got to have a good review of it.

Now let's look backwards. Probably 40 years ago we could make a model that is good for water resources in the Ogalala aquifer. You could do a model at the scale of a state. Yesterday you heard that at Brookhaven they have good results, good confidence in their model at a scale of a 1,000 feet. But below 300 maybe they don't have the details to adequately capture that. So we have been over the last few decades zeroing in on an ability to model a very scales.

In the mining and petroleum industry modeling has been profit related. There's been a lot of software development. One of the things we have is a piece of PC software that was designed for the petroleum industry. You can put in geophysical logs, you can put in seismic data, you can put in all sorts of subsurface data. And today it's fairly inexpensive. Not too many years back you had to lay out $75,000 to get equipment software. But in environmental applications it's a dead cost. You know, it comes out of your profits, but you got to do it. And you're not likely, do not want to spend $75,000 on software. Well, you don't really have to anymore.

So I'm going to talk about the state of the practice. Twenty years if you wanted a model, just like commissioning a work of art, right? Mike, I want you to come in and paint my ceiling or make me a sculpture. You get it, it's beautiful. You show it to your regulators, they say it's beautiful. You put it on your shelf. It's not dynamic. But in 2006 your model can include not only this once and done simulation of flow, but you can update it with new data. You can keep it sitting there on your desktop and rerun it. It might be on the server someplace, but you can rerun it. And I think it's not far in the future that that could be a routine practice, if not at an individual nuclear facility, that at some central location that sort of thing could be done.

I want to run through an example. Here's a conceptual model. Once those once and done and the shelf. Pretty expensive. It was used to predict what might happen to groundwater contamination after some closure action on seepage basins. These are the H area seepage basins at the Savannah River site. And here's what it said after 45 years.

Well, but you go out and you look at the monitoring data for that site, and this is a nice smooth plume, no zig-zags. If you look at the monitoring data that showed preferential flow paths from day 1, groundwater doesn't outcrop down here in the middle of this creek, it outcrops at what's called a seep line here. So in this case it was not what in the mid '80s. It wasn't really possible to capture all of the details of the site conceptual model. And if I were reviewing it as a regulator, this model, I would say well you show these nice smooth contours. But the field data show a couple of preferential flow paths. I don't think your model gives the valid results.

And Brian Looney and I were working the same group at about this time. And he knows very well I was considered very much anti-modeling. That's the reason for the title of my talk, is toward a modeling mindset. I've more or less been converted. Brian, I admit it.

At about that same time there was a book published that says you've got to have good field data, but you can monitor with mediocre field data and the model can then support your field collection activities.

Here's an example of a simple 2-D model. The contamination source, river, capture well. A simple simulation suggests that some of the flow paths are not being captured by this removal well. And so you might want to monitor down here for that simple model, 2-D.

You can also profitably use simple 1-D models to illustrate a point. Here's distance. You can simulate a release. In this case we had tritium iodine and strontium and peak literature Kds. And you're speaking to your management and you're going to say I need this monitoring program and I need it to run this way. And you're going to say look here. Here's a 1,000 meters. We have a 1,000 well, the tritium has already passed it. You can watch it go by. So you get four quarters of non-detects and you seal your well. What are you going to miss? Well, you're going to miss the real risk if it every appears, if it ever comes.

So you've got to go through this sort of logic and simply 1-D models are very useful in that way.

Here's a slide you saw yesterday. The Brookhaven issue where there was seepage through the vadose zone of 6 gallons a day or a few gallons a day and the plume basically here you've got some warm water, no downward driving force because they're in the shadow of the building. So it skims along on top of the water table until you get out here where rain is allowing infiltration and it's pushing the contamination downward. The flow path is going down a little bit.

Well, you can put -- and I want to again thank the Brookhaven folks for allowing us access to their data. And on my screen up here, the reactor building is here. This is meant to be the seepage. This is the rain shadow of the building. This is the land surface. And here are some of those several thousands of monitoring points that you talked about yesterday. And this is tritium concentration.

Well, the original version of this we could rotate and tilt, we could fly through the plume if you wanted to do that. It always gives me a little -- makes me a little queasy. But you're at a stakeholder meeting. You can say, look, here's the reactor. We know where the plume is. And we can see it. You can see we've got it bracketed. And for your technical people you can say look, it seems to be slanting. I believe there's a road or a parking lot over here that's cutting off infiltration on the right of this figure and the infiltration is a little greater on the left, which might be pushing the plume to the side. And you can also say look, we've got it captured, we've got it cut off.

Simple visualization. I think this is done with the ArcGIS software where you can build a model like this to display your data.

So in summary I'd like to say we need to live in the 21st century. We can easily today with readily available software combine data storage and visualization with simulation and use this for stakeholder communication, hopefully heading off bad reactions.

Okay. Thank you.

MEMBER CLARKE: Van, thank you.

Our next speaker is Robert Ford from the U.S. Environmental Protection Agency. And he will talk to us about, I believe, site characterization to support conceptual model development.

Welcome, Robert.

MR. FORD: Thank you.

Well, I'm going to give you sort of an idea of who I am, where I'm from and a brief overview of what I'm going to talk about in this presentation.

But in the first issue, who I am, I am with the Environment Protection Agency. However, I'm with the Office of Research and Development and our role within the organization of that agency is to support those who make the regulations that you all are probably familiar with, and also to support the enforcement part of the agency, and that's the regional facilities that are scattered through the agency.

A lot of the work that we do related to groundwater falls under CERCLA actions or Superfund if you're more familiar with that terminology. So that's going float up, I'll say up front, that's going to bias what you see presented here. And for what I could see and take away from the talks yesterday, that may be a bias that's different from the NRC perspective. And bear with me on that.

We get involved with primarily the regions with regard to groundwater enforcement actions, active involvement going out and actually designing and conducting a site characterization or field investigation to understand what's going on in the groundwater system. But we also do a significant I'd say at least another half or more of the job that we do is reviewing technical documentation that is presented to these EPA regions from various sources to argue for or against approaches to characterizing a site or conducting modeling exercises as part of our making decisions at a site.

I acknowledge here three individuals. Steven Acree and Elise Striz are also at the ORD Laboratory in Ada, Oklahoma. And they certainly contributed to my thinking that you'll see presented here. And Bill Brandon is from Region I office.

A lot of what I'm going to present is going to be very from an overview perspective. I'm not going to talk about site specific data or any particular site. What you'll see is sort of my take on what one should be thinking about in terms of approaching a groundwater monitoring or a site characterization effort based on my relatively limited experience relative to many of you in the audience of what one encounters in the subsurface where there is groundwater contamination.

And so the first thing that we usually do, both in terms of designing our own site characterization effort or but as well as reviewing or critiqueing site characterization efforts that others are conducting or proposing to conducting, this provides a general list of information that we look at. This is how we begin our accounting.

With regard to contaminate transport, and that is what we're talking about, contaminate transport whether you call it compliance monitoring, performance monitoring, whatever you want to call it, it's contaminate transport that we're talking about in subsurface.

There are physical constraints. You've already seen explicit examples of their importance. Contaminate source mass and distribution. The flow field in the subsurface, the flow field or the flow field in both the unsaturated and the saturated zone. The spatial distribution of those flow paths that carry the contaminates of concern. And the temporal variability of both the velocity of flow and the direction. And I think the example that Steve Yabusaki presented for the 300 area on the Columbia River give you a very explicit example of how dynamic these systems can be.

And then for chemical constraints, there are obviously contaminate properties. Decay rate is obvious importance to the NRC. Some of these other issues may not be, but it depends on what types of contaminates are entering the subsurface.

Degradation rate for organic contaminates that may be released as well. Sorption affinity of any of the inorganic contaminates will be important to know.

Aquifer sediment properties, particularly for integrating contaminates. If there is some sorption that is occurring that's going to define the dynamics and the extent of the plume, one needs to know about that. From the EPA perspective while use of a published Kd may be a first cut evaluation, you don't want to rely on that as your sole support for defining sorption in the subsurface.

And then finally groundwater chemistry. And this from an indirect perspective as it affects contaminate chemical specification which will affect its transport in the subsurface. And also the stability or the characteristics of the minerals that are influencing contaminate transport in the subsurface.

And here's some questions to be addressed through site characterization analysis. Again, reemphasizing that list before:

What are the transport pathways?

What is the rate of fluid flow along critical transport pathways? All fluid transport that's occurring in the subsurface at a given site may not be carrying the contaminates of concern.

What processes control attenuation of the contaminate of transport pathways? That's not an issue, obviously for tritium, but it could be issue for other radionuclides of concern.

And what are the rate of attenuation and the capacity of that aquifer to sustain those sorption processes? Because if you're at near the capacity of the aquifer, many years down the road your plume evolution may change because you've exceeded the capacity at a given location within the plume.

So what does one look at in terms of characterizing hydrogeology? Here are some of the goals.

Again, identify the pathways of contaminate transport relative to compliance boundaries or risk receptors.

Establish a monitoring network that allows collection of data to identify both the spatial heterogeneity. We've seen important example of how that can be critical.

Temporal variability. Again we've seen hydrologic and characteristics of the site, we've seen examples of that.

And also temporal variability of the biochemical reactions that define the properties of the aquifer that are dictating contaminate transport.

And then finally establish the groundwater monitoring network that supports collection of samples that are representative of aquifer conditions. Any of us can make a model. Any of us can run a model. That model is only of use to a given site. It becomes a tool for making site decisions when we populate it with data that is collected from that site. And therefore, that data is the goal that we're mining.

When we bring up a sample, that's a commodity that's very important. So we should make whatever effort we can to ensure the integrity of that sample before we carry out any chemical analysis that would support a contaminate transport model.

And I want to also point out that the way you put in a well does make a difference. The type of well, and the type of well that you have to rely on differs from site-to-site. If you can rely on geoprobe as your method for obtaining groundwater samples, more power to you. That is great. That's the ideal situation. There are a lot of situations out there for which you cannot use a geoprobe to get to depths to retrieve groundwater samples. And the way you put int hat well could impact the types of samples, sample characteristics as you retrieve groundwater samples. You can alter the hydraulic conductivity at that well screen, you can also alter the geochemistry right around that well screen such that it's no longer representative of what's going on down below. And therefore any data that you collect from those samples are going to be biased and not reflective of reality.

We are not in the business in Ada, Oklahoma of making models, for the most part, or carrying out extensive transport modeling simulations like you've seen. We do generate some model, but they're usually very simple and they're used as sort of screening tools for guiding how we develop the site characterization effort.

These next two slides just cover one simple one that's been developed called Optimal Well Locator. The objective of this tool is to see to evaluate all the locations where you have wells adequate to capture the plume and its evolution in time. And it's based on basically defining the flow field and then inferring what the contaminate plume that would develop from that based on basically the model, which is an over simplification in many cases but it is still useful as a screening tool.

So here are three views. On the left is quarterly hydraulic monitoring data that's been used to generate a plume. At one corner later in the year the potential metric surface of groundwater has been evaluated again, and the resulting plume has been modeled. And you can see that things are moving around. And we saw explicit examples that plumes move around. And therefore, and what the tool is then to essentially generate a composite over the time frame of which you've collected data to see, you know, do I have wells located within the extent of that plume or are there regions where I really have very poor coverage based upon my anticipated expectation of how that plume would behave.

Since many of the contaminates that we deal with under Superfund actions do not behave conservatively in the subsurface, we spend a great deal of effort in terms of characterizing water chemistry as well as aquifer sediment chemistry relative to understanding how contaminates are being transported. And here are some goals with regard to this aspect of the site characterization effort.

One wants to identify what reaction mechanism or processes are controlling contaminate transport. With tritium you'd better know hydrology. You might be able to just get away with a good knowledge of hydrology in the subsurface. With reactive contaminates that react with those aquifer mils, you need to know more.

You want to collect data that supports evaluation of the conceptual site model and to verify performance of identified transport processes. You need to verify that indeed your concept of what's going on in the subsurface is actually happening.

And when you collect samples, you want to do so in a manner, as I indicated before, that maintains sample integrity. And you want to be collecting information that characterizes the factors that are controlling contaminate transport in the subsurface.

I'm going to throw up some cartoons in the next few slides to sort of illustrate some concepts and so that we're sort of operating on the same page.

This is very idealized plumes for a range of situations with a decaying radionuclide. Where I'm assuming here that there is conservative physical transport, an uncontrolled source. And all I'm looking at is a relative difference between what the transport velocity in the subsurface is relative to that decay rate. And that, in many cases, is going to have a significant influence on how that plume evolves. You have situations where it may remain stable. We saw an example of a stable tritium plume. It may be shrinking if you have a very rapid decay half life or a slow transport time. Or that plume could be expanding.

Now I want to introduce the concept that may or may not be well accepted. And this is in particular for contaminates that undergo nonconservative transport. They are partitioned from the aqueous phase groundwater to the aquifer sediments. Now typically we're thinking about primarily groundwater, and that is important. We definitely should be thinking about that. But for those nonconservative chemicals, particularly long lived radionuclides, we also need to understand what's going on in those aquifer sediments. And what I have here is an illustration of an idealized situation where again the orangeous colors are defining that mobile aqueous plume. And I've shown another characteristic here, and that's sort of the blue hash, but what I'd call the immobilized solid phase plume.

Now attenuation of a mobile plume is certainly a good thing, and that's an objective that we would want to achieve. But we need to be cognizant of what the future of that immobilized plume that's now stuck on those aquifer solids may be in the future. And here is a situation. The last bullet lists what three situation I could imagine could be the case and the time scales that are of importance for compliance monitoring at NRC sites, and certainly are of importance for monitoring at Superfund sites.

You could have a situation where there's a decline in mass and spatial distribution due to decay of that radionuclide, and that would be a good thing. It could remain invariant in mass and spatial distribution for a long lived radionuclide that's never going to come back off that solid, it's not remobilize. That would be a good thing. But you can also have this last situation in which that immobilized plume evolves to a new state that serves as a future source for development of a new dissolved plume. And that could be that the radioactive decay product process produces daughters that have different chemical characteristics and that will not remain immobilize or there could be changes, future changes in groundwater chemistry that could effect remobilization of that immobilized contaminate. And one needs to be cognizant of that relative to projected land use into the future.

Here's an idealized schematic of a plume cross section. Very idealized. And what I want to get across here is some things that one should be thinking about relative to the types of plumes that may exist at their given site.

Now this may be a stretch for an NRC facility, talking about a mixed organic/inorganic contaminate plume. You know, I don't know. I don't know. But I do know that commercial facilities of any sort have usually petroleum products stored on site. Some cases they may be stored in tanks underground. And I can point you to plenty of examples where that's a pervasive problem throughout the U.S. One should not ignore those potential sources of other contaminates that could enter the subsurface. May be not coincident with the release from the reactor, but certainly it may end up being a part of a plume and could affect how that plume evolves.

And so here is an example of sort of the worse case scenario where you've got an organic, an organic, the degradation of those organic contaminate are causing major changes to the geochemistry in the subsurface. And here are sort of three zones that I define here. A highly reduced system with these sort of geochemical characteristics, low DO, high ferrous iron, maybe sulfide, mildly reduced and then oxidized which may be representative of the background condition exterior to the plume.

That was from the water side. Here's looking at it from the aquifer sediment side of the picture here. Again, the same type of scenario where you've got this mixed plume that's impacting the geochemistry. And here's what you see reflected in the aquifer sediments. In the reduced zone you see sulfides, reduced iron minerals, you maybe see anaerobic microorganisms which would be important for organic contaminates but maybe also influencing what types of geochemical conditions exist in the groundwater, grading into a mildly reduced zone and an oxidized zone where there's significant change in the characteristics of those aquifer sediments, which could potentially impact contaminate transport and are important to know relative to the accuracy of any transport model that's developed at a site.

And now to sort of wrap up, with regard to that concept of the subsurface contaminate plume what's the importance of that relative to sample collection in terms of supporting compliance monitoring. I'll reecho or I'll echo what I said before that model is supported by the data that's collected. It becomes a tool if used at a site based on the data that you're inputting into it. If you're putting in bad data, we know the result, the outcome of that is. And potentially leading to inaccurate decisions with regard to moving forward on a site.

We want to properly identify the plume and the plume extent for all contaminates of concern. And they may not exist all in the boundary. We've seen examples of that. And I've harkened back to the fact that, you know, I'm saying for nonconservative integrated contaminates you can have a solid place plume. And I think that should be of concern relative to future predictions.

Collection of samples we want to prevent misidentification of plume geochemistry.

And these last two points are more relevant probably from a remediation standpoint, which I acknowledge is different than a compliance monitoring standpoint. But we want to be able to accurately reflect the subsurface conditions so to support our model that is being used to project contaminate transport into the future.

I said I wasn't going to talk about a site, and I'm not other than to point you to a reference point for my perspective. In this case it's for arsenic. This is a site investigation with which we have been involved for many years with Region I outside of Boston. The contaminate concern is arsenic. And I highlight it here because the remedy selection at this site for groundwater is monitor natural attenuation.

And just so you know, arsenic is really a tenuous contaminate to be considered for this type of remedy. And basically we're not doing anything to intervene to prevent plume migration. We're relying on the natural processes that active at site. The only way that we can rely on that and knowingly that we were able to convince the stakeholders is by the level of site characterization that was carried out to support both our conceptual model and any analytical models that were developed for this site to describe contaminate transport.

And here are some website links to the documentation that was prepared to support that remedy decision.

And with that, I will conclude. I have some additional URLs that are listed here that refer to documents that touch on some of the issues that I alluded to with regard to sample collection for groundwater samples and issues of concern with regard to what exactly is going on in the subsurface that is controlling contaminate transport.

And thank you.

MEMBER CLARKE: Robert, thank you.

Our next paper is the first in a series of presentations. When we were planning this meeting we were hopeful that we could include presentations not only what I would call environmental modeling and monitoring, but presentations that look at the performance of an engineered system as well. And our next speaker is Craig Benson. Craig has participated in a prior working group meeting on the performance of cementitious materials.

Craig, welcome back.

PROFESSOR BENSON: Thank you. It's a pleasure to here. And actually Glendon, who is going to speak after me, we have essentially the same title to our talks, but the content is different. I promise.

MR. GEE: Slightly.

PROFESSOR BENSON: Slightly.

Well we're going to shift gears a little bit and talk about caps or covers. And our objective here is really to look at barriers that we put on top of a waste containment facility with the, in many cases, the primary objective of limiting how much precipitation ultimately gets into the waste. We want to limit that with the objective of minimizing the generation of leachate and that may ultimately make it's way into groundwater and cause contaminated groundwater resources.

And to understand how covers behave, we

really need to understand their hydrology. In many applications we use models to predict that hydrology, both in design. They're very commonly used in the solid waste industry where a good bit of my experience comes from in this regard.

I call these research questions, but I think these are very pragmatic questions as well. So first of all, do the common numerical models that are being used for design and evaluation of cover hydrology provide accurate predictions? And I guess I should add a little bit onto the end of that. Using inputs that are normally available in practice.

And then the second question is, well based on the results of the first one, is if there are some deviations between predictions and reality, how can we make changes to our models or our input to get more reliable predictions?

So some pragmatic questions.

First of all, to assess the accuracy of models, the first thing we have to have is data. That's the nightmare. You have a good model, you get some data. Well, I can always show you, perhaps not such a good model. We had that field data in particular. We want to determine whether it actually predicts what we observed in the field. And perhaps you mentioned this, Robert, about the conceptual model being really important, is both our mathematical model and our conceptual model valid? We can look at that through comparisons with field data.

Another important part of that analysis process is to make available as much of the inputs to that model as possible. Eliminate the amount of guessing that goes into the parameters of the model and ground those in truth as closely as possible.

And then finally matching the boundary conditions can be as equally important as well.

I've been involved in a really neat study over the last 6/7 years, and there's others that have been involved in this as well. Glendon Gee was part of this study. Called ACAP, which is the Alternative Cover Assessment Program. Bill Albright of Desert Research Institute as well. Where we constructed a variety of different near full scale cover systems throughout the United States at these different locations here. And I noticed I missed one up here in North Dakota. And have evaluated their hydrology over a relative long period. A long period from a research point of view, 5 to 6 years. Certainly not long term in terms of containing waste.

We're going to use some data here from the

Sacramento site, which is right here. This is Kiefer Landfill in my presentation here today. To make some comparisons of what we observed at that site relative to what we predicted using some typical numerical models.

At each of these sites we constructed large test section. And part of those test sections were essentially a big bathtub where we could monitor all components of the water balance. A lysimeter, as we would call it. We were able to monitor the flux out the bottom, percolation or drainage. We could monitor surface run off. We could monitor lateral flows if that was an issue. Monitor metric potentials and water storage within the cover. Essentially all components of the water balance which are important to understanding the hydrology, except for ET, which we obtained different -- mass balance on it and we obtained ET by difference. And actually this method of obtaining ET turned out to be pretty good. I've compared it to a lot of other data and our ET measurements are pretty reliable, I believe.

These are pretty large test sections. You can see here's a F-150 pickup. And there are two test sections in Sacramento. They're very large test sections. And they represent near full scale conditions.

And we monitored the hydrology in detail over a ten meter by 20 meter record area. You can just see the outline of that. That's a surface water diversion and collection berm on top of one of the test sections that delineates the record area.

During construction we spent a lot of time collecting data on the hydraulic properties of soil, because that's one of the things that are used as inputs to the model. You can only check the models if we have the good collection of data to describe the inputs.

We also looked at characteristics of the vegetation as well.

And we looked at four different models. I picked four models that are pretty characteristic of what people use in practice. HYDRUS-2D developed by Simunek and his colleagues at USDA.

Another model called LEACHM developed by Hudson who is now at Flinders University, which is in South Australia.

UNSAT-H, Mike Fayer's model. Mike's going to speak today. Perhaps the most widely used in the United States for evaluating cover hydrology for solid waste landfills.

And ten Vadose/W, which is Canadian model that's used fairly broadly in the British Commonwealth for doing similar types of problems that UNSAT-H is used. And also used very extensively in the mining industry throughout the world.

All these models are used in practice. Engineers use these regularly to make predictions. And so it was important for us to get a sense for how reliable are they, do they give us the same answers and if not, why?

They all do essentially the same thing. They solve Richards' Equation, which I think I'm the first speaker this morning to show a partial differential equation. I couldn't help myself. I love partial differential equations and being a professor, too, we just got to get it in there. But they all solve this partial differential equation. Different methods. Find an element, finite difference. They solved them in 1D or 2D, most of the time in 1D. But the inputs of these include hydraulic properties of the soils, vegetation properties for root water uptake and again, hydraulic properties of soils over here as well.

We applied boundary conditions to these to solve them. Atmospheric flux boundaries at the surface and then some type of lower boundary at the bottom of the cover.

When I was listening to the other speakers I was thinking about my lower boundary. And, you know, we have groundwater models and we have cover models and then we have waste leaching models. But we don't really have a model that puts all these things together. And that's something that as I was listening that we need to start thinking about is how all these integrate together as opposed to being independent pieces.

I'm going to just to give you this example for data for our Sacramento field site, this is at Kiefer Municipal Solid Waste Landfill in southeastern Sacramento, California on the southeastern side. This is a semi-arid site. It has a little 400 millimeters per year precipitation. It has a precipitation potential to evapotranspiration ratio of a third. So it's a pretty dry site. Warm but seasonal, temperature slightly above freezing in winter and very warm in the summer. If you've been to Sacramento in the summer, it can be very hot. In fact, I was in Stockton, which is just down the road from Sacramento in the summer doing field work and it was 119F when we were doing the field work. For Brian maybe that's nothing. Hot for me being from Wisconsin.

The cover at the site, there's actually two covers there. I'm going to talk about the thinner one. Has roughly a meter thick storage layer, as we would call, this lawyer essentially meant to store water, prevent it from infiltrating into the waste and then release it to the atmosphere via evapotranspiration. Underneath that is roughly a half meter of so called interim cover or soil placed that would normally be placed on top of the waste.

The upper surface of this storage layer tends to get fairly highly weathered, as we'll see in some data. Upper six to 12 inches or 150 to 350 millimeters.

This was constructed out of a very broadly graded aluminum with things from cobble-sized down to clay-sized particles, available on site.

Input data we measured meteorological data on site with a weather station. We field measured vegetation properties to the extent practical. We measured leaf inputs to the models, leaf area index, root density distributions, hydraulic properties we measured, as I indicated, with collected samples, measured hydraulic properties in the laboratory on large scale samples, but using methods of representative of practice. And this is just a summary of the input parameters that we used.

Boundary conditions. At the surface we applied a atmospheric flux boundary, which is available in all these models. It simulates infiltration in the soil surface, evaporation from the soil surface and runoff often computed as an excess quantity. Essentially the difference between precipitation and infiltration.

All these models do the same thing conceptually, but they all do them mathematically in a different manner. They all handle the nuances of it differently and we'll see they all give you a different answer in just a minute in terms of predicting what that surface flux is at the boundary.

Lower boundary we used either unit gradient boundaries or seepage phased boundaries depending on what was available in the models. This has been a great deal of debate in the lysimeter industry of what models should be used for -- or what boundary conditions should be used for model validation and evaluation. And, actually, we found out this isn't so important compared to other components of the models. Surface boundary is much more important.

Let's look at some of the results. I'm going to show you four very complicated graphs here. These represent the four primary components of the water balance. Runoff along with precipitation in this upper graph. Evapotranspiration in the second graph. Slow water storage within the cover in the third graph. And then cumulative percolation or drainage in the bottom graph. And these are all shown as a function of time during the monitoring period. And they're cumulative quantities indicating that we were adding up the water over time. So you can see precipitation is the total amount of precipitation received at the site.

The black lines, the solid black line in each one of these graphs is what we observed in the field. All right. So here's for example runoff in the field.

And then the colorful lines ranging from magenta to blue are the model predictions.

And I think the first thing that strikes out is obvious from this graph. Is we have four models and we get four different predictions using essentially the same input. Virtually identical input to the models and yet we get four different sets of predictions even though they're solving the same basic partial differential equation. But they do it in slightly different ways.

For example, all the models moreover over predict runoff. And because we get less water into the system, we're under predicting evapotranspiration in many of the cases except for largely this LEACHM model. It's pretty close to what you observed in the field.

Our water stored within the cover profile, which is really a key element in our design calculations in most cases, is under predicted by most of the models. Largely because surface runoff is over predicted, except for in the one case LEACHM, which tends to get the peaks fairly close in some cases.

This fluctuation over time which is equally important in the field data isn't captured either.

Another interesting aspect. In one year we had a case where for some reason or another the vegetation was not particularly effective in extracting the water from the cover. And the way we've parameterized our models, which is typical of practice, we don't capture that anomaly.

Finally, at least in this case, all four of our models under predicted the percolation or drainage into the waste which we observed in the field.

Four models, different input.

Oh, I got to the end. We're at the wrong button. Back up a little bit. Okay.

Well, one of the things we might ask ourselves to begin with is we're over predicting the runoff. Significantly that may indicate that perhaps our surface boundary or the hydraulic properties the near surface of the cover are not particularly representative. And if we look at surface layer conductivities over time, we look at how pedogenesis effects the properties of soils used in covers, we see that factors such as wetting and drying, freezing and thawing, ingress of roots into the cover tend to alter those hydraulic properties. And what we see is that over time most of our hydraulic properties or hydraulic conductivities at the near surface tend to fall within a fairly narrow band. But I'm a technical engineer by training, so an order of magnitudes a narrow band for me. For other people that may not be narrow.

This graph shows you essentially these are saturated hydraulic conductivities at the surface over time at different time periods in the study. And samples we collected after construction versus the as-built values. And if there was no change, all the data would fall in this one-to-one line. But you can see that very few of the data fall along the one-to-one line and the further along we went in the record, the more horizontal this band became.

Ultimately, though, if we look at our data over time we typically get surface layers that are on the order of ten to the minus 4 centimeters per second as a kind of typical number. So if we put that into our model rather than the field measured values made during construction, we can see that here is our prediction made using our field data from original parameters. We've put in either a ten to the minus four, ten to the minus three to make the surface layer more permeable. We can drop down the runoff, increase the water that evaporates, increase the amount of water that's stored within the cover and increase the amount of peculation that predicted.

So we can immediately see that perhaps the original parameterization and perhaps our conceptualization of the model wasn't quite right based on the monitoring data that showed us that our predicted runoff wa quite a big different from our measured runoff. And that indicated perhaps that the surface layer was too impervious in our original simulations. And, in fact, it probably was.

And another question is we built this cover and we measured the hydraulic properties of the deeper parts of the storage layer during construction. But those layers, too, undergo wetting and drying, root entry. In fact, when we decommissioned the cover we found roots all the way down to the bottom of the cover at the end of the monitoring. So roots were active in the soil, perhaps altering its structure. So if we perhaps increased the hydraulic conductivity of the storage layer, the lower portion of the cover, it might as well alter our predictions. And we can see that's the case here.

Here's our value using what we called mean or typical values or mean values from as-built and then multiplied by five, ten and 20. And, of course, as we make the cover more permeable, we get less runoff, more infiltration. We get more evapotranspiration. We get more water cycling within the cover and storage. And we get more percolation.

One thing we do see, though, is that even though we're getting more water within the cover, we still don't really represent these large swings in soil water storage that we see in the field.

In summer 2005 we went and dug up this cover and looked at its hydraulic properties. We did a whole series of hydraulic tests and you see they have beautifully blue water here in Sacramento. Actually it has a brilliant blue dye in it. We dug test pits to do geomorphological studies. Really did an extensive amount of characterization of hydraulic properties of that site over time.

This slide here just shows you some of those findings from that. The saturate hydraulic conductivity, which we originally measured to be about middle of the ten tominus six range had climbed by the end of the monitoring period up in this range to on the order of middle of ten to the minus fives, which going back to our previous evaluations is about a factor of ten to 20 higher than as-built. And that's pretty consistent with what our model showed. That if we had about a factor of 20 higher, we got a much better prediction.

This graph, it's just of saturated hydraulic conductivity versus size of the specimen. I should point that out. This star here is just what we measured as-built. And these are all the measurements we did at decommissioning.

This also shows you a very important point is that the scale at which you make the measurements is important. And in practice, in engineering practice we typically do tests on very small samples collected in a thin wall tube, which is roughly 70 millimeters in diameter. And that's down here. All right. These are large scale samples done with a sealed double ring infiltraometer or back calculated from our lysimeter fluxes under nearly saturated conditions. Quite a bit different.

These corresponded very well with the geomorphological changes we observed as well. There was a lot of structure. This just shows you the average spacing between vertical features or cracks as a function of depth in the cover. There was a lot and very consistent structure within the cover system, which is an indication that the hydraulic properties have changed.

There are a number of other factors that we identified as well. I just tried to touch on a couple of important ones here. Certainly we identified accounting for pedogenic effects was important. We wouldn't have evaluated that or accounted for that if we hadn't done a comparison between the model predictions and the field data.

We found another subtle thing, I haven't really talked about this, but little subtles in the model, like the pore interaction parameter used in the conductivity function. Makes a huge difference in the predictions. We see that by making comparison with models and monitoring data.

Matching precipitation intensity, very important as well. Something that's often disregarded, but comparisons of model predictions of modern data showed that very nicely. I didn't show that today, but that's one of the things we found.

Accounting for temporal changes in the vegetation species and their effect on water removal was also an important factor.

And finally this lower boundary conditions, which people have sat in meetings and argued about ad nauseam perhaps is one of the least important ones. And we see that by making comparisons with field data as well.

So just to summarize. We looked at four models, all very much the same, all using essentially the same input and giving very different predictions. And I guess if you're looking at trying to get a permit approved, I want to get the model that gives me the best answer. Well, I can't tell you which one that is. And I can't tell you what the best answer means.

Probably one of the biggest things of these models is parameterization, as I kind of indicated the parameters. As we vary the parameters we get much better predictions.

We wouldn't have been able to get these assessment of accuracy without the field data. You know the monitoring data is really critical to this. Particularly this type of information we got from our decommissioning studies. This really helped us with parameterization and that type of information that you might do on an infrequent basis really can be relevant to predictions at a site, but also to making updating predictions for future cases or other applications.

I think this last bullet I think is really important. We talk about models. You know, I love models. I did my dissertation on all models. I didn't have hardly any data. It was great. You know, they all worked great and they were all exact. That was a long time ago.

You know, they're all abstractions of reality. You know, they're all simplifications. And it's very important that they be compared with the real thing. And that we always be thinking about reasonableness of predictions using modern data if at all possible. And I think of a case history I was involved in at a mine tailings facility in northern Wisconsin where the cover on this facility was perhaps the most significant factor effecting whether it would be in environmental compliance or not. And we were doing the sanity check on the model predictions. And, you know, I'm looking at data that we collected in the field. And the argument that I had with the owners was well the model is not consistent with what our field data is showing. And the argument back to me was well your field data must be wrong because it's inconsistent with the model. It's the other way around. The field data in most cases, not always, are kind of the acid test on which we use to evaluate our models. Good quality field data.

So I'll leave it at that. And I think we're almost at the break.

MEMBER CLARKE: Thank you, Craig. We are at the break. And let's take a break and come back at 10:15.

(Whereupon, at 10:03 a.m. a recess until 10:18 p.m.)

VICE CHAIRMAN CROFF: Folks, can you take your seats.

MEMBER CLARKE: Allen, can you whack that gavel? Three taps and I'm on the microphone for a half hour. It's not fair. Okay, our next presentation will be made by Glendon Gee of PNNL, Monitoring and Modeling of ET Covers. Glendon, welcome.

MR. GEE: Thank you. Thank you very much. I want to give credit to Craig Benson for giving my talk and I'm just going to fill in a few details but I would like to try and couch it in terms of what has been put upon us as speakers and that is to try and provide some guidance or at least some recommendations or suggestions about the way monitoring and modeling can fit together and possible should fit together. And I hope by the time some of the examples that I present today are made, you will catch a bit of a vision of how at least I view modeling and monitoring and their interaction.

Now, I will do some qualification. The qualification is as other people have mentioned, and that is primarily these discussions we've had the last day and a half are focused on groundwater monitoring. We said subsurface monitoring, but, in fact, all of the regulations that I've seen, EPA and USNRC and other regulations are focused primarily on monitoring wells and documentation of that specific kind of monitoring. So when I had a chance to discuss this with Tom and others, I was trying to get an idea, a vision of how flexible we could be in terms of actually recommending monitoring in the vadose zone.

I showed a picture actually, tried to capture the idea that the acronyms run rampant in these meetings and ET, of course means evapotranspiration. You have basically an active biological pump that is moving water out of the near surface and that system then is designed in some of these covers to act primarily as the agent by which water is removed and prevents deep drainage. So when I say ET covers, I'm talking about a large system of covers that include that concept. Talk about indirect and direct measurements that are made. Some of the modeling issues, Craig has covered most of that but I want to put in my two bits.

Evapotranspiration does limit water intrusion. That's the whole idea and virtually all covers are ET covers. Basically, with few exceptions, Hanford tanks being one of them, you have vegetation on the site with the idea that they stabilize the surface and they also act to remove water. Multi-layer ET covers are essentially covers that are redundant. They have systems within them, low permeability layers so on, RCRA caps, the EPA design and recommendation. The Hanford long-term barrier has redundancy built in, low permeability systems incorporated in the engineering design. This is for long-term performance considerations primarily. The problem, of course, is that it takes more engineering and the costs are typically much higher than other systems.

What people are talking about today in the industry are going to simple or mono-fill ET covers. Basically, you put dirt over your waste, you vegetate is and use that as the water infiltration control. The difficulties, of course, are how do you insure that there is not biotic intrusion, other kinds of water intrusion and then erosion and long-term stability issues. Craig has mentioned in passing that we do basically -- when we're talking about water balance or these kind of covers, the ET is part of the water balance, the model inputs to this kind of an assessment include documenting the precipitation, knowing the long-term record, knowing a bit about the climate, so you can estimate the evaporative demand, assess the runoff as Craig mentioned. That's a critical assessment ans incidentally, there as an -- I'm sorry, get the agencies right, an NRC report a few years ago by PNNL that demonstrated at Barnwell that if you change the runoff by simply changing the hydraulic properties of the surface, that the drainage would change by an order of magnitude and whether that makes a long-term effect on the dose assessments, it certainly can make a difference, certainly on the drainage.

And then, of course, as Craig pointed out, the soil hydraulic properties need to be known and tend to be dynamic particularly in the surface. Just as an example at an arid site, which creates an issue about some of the uncertainties, precipitation is known generally within about 10 percent for a given site. ET, similarly, our best measurements water storage similar range of uncertainty. So the drainage at an arid site could be three or it could be 60. And that basically creates a huge uncertainty that for long-term assessments is a difficult thing to manage. So what one wants to know then is can we make this measurement indirectly with less uncertainty or can we use some kind of a system to lower that uncertainty.

The cover monitoring requirements, the LTSM program that Jody will talk about basically has involved a number of sites and you'll see that presentation. But they're looking more on surface inspections, erosions, subsidence, isolation, biotic intrusion, the plant cover. Those things are all documented in a number of these government legacy sites.

The groundwater, of course, most of you know EPA requirements. We're looking at primarily water chemistry and monitoring them with up-gradient, down-gradient wells. In the vadose zone, if indeed the desire is to control water intrusion to low limits, to a millimeter or less a year, then what can we do to make those kind of measurements? The typical thing in the vadose zone is to measure how much water is there. So that's a fairly straightforward measurement, lots of different ways to do that. A less used method is to measure the pressures and that can be done. Finally, if you really want to know the flux, you measure the flux and that can be done indirectly or directly.

Here are some monitoring systems for the vadose zone and these kinds of things are used throughout in agriculture as well as waste management. Pore-water vacuum samples, sometimes they're called solution lysimeters but basically they extract water from the vadose zone and allow you to measure the chemistry. And all of the problems associated with groundwater sampling are included in this pore-water sampling system in spades, because if you pack this with a silicon sand, it may be weeks and months before you equilibrate with the pore water and other issues.

Heat dissipation units for measuring water potential allows you to make measurements, pressure measurements indirectly in the vadose zone. Tensiometers are direct measurements of pressure and then, if course, water content sensors that can be electric or neutron-logging or other systems. But these kind of things are expensive, they require bore holes and so all the problems associated with that, with down-well placement, intrusive placements, particularly at sites that are either have toxic waste or other things make it difficult for placement.

How do you use these indirect measurements? Basically, if you know the unsaturated hydraulic conductivity, an estimate of the water potential gradient, then you can estimate the drainage flux. But you have to know this K and this K is a function of water content and water potential and generally, as pointed out here, typically, an uncertainty of an order of magnitude is very common. And the other option is direct measurements with lysimeters and here are some at Hanford. Basically, large two-meter diameter cans, three meters deep. In some cases, they're irrigated to measure the impact of excess water. Simply look at the profiles, in this case Hanford barrier is constructed in place in the lysimeter, a meter and a half of silt loam over layers of coarse materials and we create essentially what's called a capillary barrier that tends to store water until this zone gets wet enough that it drains.

Craig mentioned the alternative cover assessment program of EPA that, so-called ACAP. Thee lysimeters were 10 by 20 as he mentioned that basically large enough where you could actually construct, simulate a cover and make all of the necessary measurements of runoff, of drainage and of water storage. And when you do that, of course, then you can get resolutions on the order of 10^{th} or 100^{th} of millimeter of drainage with these kinds of systems. So you have a direct measurement, you have a resolution and a lot of the problems of uncertainty go away at least in principle.

Okay, what do we need for modeling. Craig's eluded to it, but I'll just reiterate. You have to have some weather station records, on site precipitation obviously is best. Soil hydraulic properties, he mentioned that plant, leaf, root dynamics. The simplest models, which he did not mention, such as the HELP, EPA HELP code, use default parameters based on general characteristics of the soil, the plant and the weather records. So you can sit down and -- very simply and many people do, run assessments with a simple water balance model that doesn't require Richard's equation but simply does essentially a water budget.

I won't go over the details here on the complex models, but obviously, they require more input information. EPA cover design code HELP, NRC had an infiltration code that we have used to get quick assessments, modified KIM from the Water Resources Research publications. EPIC from ARS, these are the more complex ones that Craig mentioned, that all ET models are limited by uncertainties in plant parameters and dynamics, and I'll try and illustrate that in addition to the uncertainty in the hydraulic properties.

This is a site at Hill Air Force Base in Ogden, Utah. This picture was taken last week basically after 10 years of a sage brush vegetation community growing over a bare aid swimming pool and the swimming pool is essentially the lysimeter. There's plumbing going out the bottom of the swimming pool into a collection basin. At Hill Air Force Base we have about three times the precipitation we do at Hanford, 180 millimeters at Hanford, about 480 at Hill. The main difference is that winter snow melt is the main driver for the leachate. And just adjacent to this site is their operable Unit 1 which contains two large landfills of about 90 acres or more.

And they're spending millions of dollars like many sites on pumping and treating because of the leachate production in those land fills. The tests that were conducted here show that the Hanford barrier which we tested at Hanford under irrigated conditions, performs perfectly well at Hill Air Force Base and that we've not measured drainage after 10 years so we have a fairly long-term record suggesting that by knowing the vegetation, knowing the soil type, we can control the water infiltration. A number of these simple water HELP and EPIC adequately described results from Hill Air Force Base tests. We've done the modeling on bits and pieces and certainly extensively modeled the climate change scenario at Hanford.

Snow melt has caused the capillary barriers the other tests, there are a series of five tests there. I only showed one, but the other five have drainage rates exceeding 50 millimeters per year. Just simply say that snow melt captured on the Hanford barrier at Hill Air Force Base increased the storage -- was captured due to the increase of storage capacity of the silt loam soil. And the models show that the Hanford ET barrier effectively operates under elevated precipitation conditions. So in this particular case, the soil system was adequate, the plant dynamics were such that this system was adequately described with our water balance models.

In contrast, Craig showed some results but this is the Sacramento site that Craig eluded to. I just have some additional data and what you see that spike of percolation that Craig showed but in addition, the last two years, there have been additional spikes in percolation or drainage and how do you explain that when all of the models generally show, if you use the average characteristics, as Craig did, all of the models show that there should be no drainage and yet, in 2002, 2004 and 2005, we have significant drainage, enough to require that someone either modify the cover or redesign it in such a way that it performs better.

Monitoring of an ET cover actually will be a challenge. Craig's mentioned the dynamics in the hydraulic properties. I've tried to show you dynamics in the vegetation can alter the -- what I didn't elude to is Craig showed this but you see the change in storage. Basically, the plant water removal pulls the soil water storage down to something in the 150, 200 millimeter range each year for the first two years, very predictable with the models. But the third year the -- for whatever reason, the plants did not remove the water. And so the dynamics of the plants were not incorporated properly in the model and as a result, it under-predicted the drainage by a significant amount.

Erosion control, that's easy to fix, observable, repairable. Bio-intrusion control is likely repairable but water intrusion still remains the greatest challenge. The time dependence of the plants will continue to be difficult to quantify and this suggests that if you're going to design a system, you may have to have redundancy in the design. Just to reiterate and make the point again and again, because of the uncertainties in the actual measurements of water balance, indirect measurements are too imprecise. So if you're going to spend any money on monitoring, where should you spend your money? Well, water content sensors, TDR and other things are interesting but they -- it is not flux.

The water potential is more direct but it is not flux. Water balance modeling combines all those uncertainties and they remain uncertain as Craig has illustrated.

So direct measurements are really required and as far as I'm concerned the test pads, like the ACAP are reliable and allow you to make these measurements over extended periods of time, which are needed to document the changes in the plant and hydraulic parameters. Finally, the plant parameters in the model remain very complex and an uncertain parameter and cannot readily be engineered and they have no safety factors built into them and therefore, engineers should regard the plant parameters with a great deal of caution.

So, I'm finished.

MEMBER CLARKE: Okay, Glendon, thank you. Our next speaker is Jody Waugh. He is with the --

MR. GEE: Could I make an after-thought?

MEMBER CLARKE: Sure.

MR. GEE: Is there time to make an after-thought?

MEMBER CLARKE: Yes, sir, go ahead.

MR. GEE: One of the questions in the focus group was defining programmatic actions, what programmatic actions do you recommend be considered or undertaken that can promote? Well, my view of programmatic is do you have something built into the system that allows you to afford things like long-term monitoring and what should you monitor?

I would suggest you consider looking -- the NRC or other agencies consider looking at some of these long-term facilities that have had these records. If you're going to improve the models, then the longer term records will allow you to do that, so Hill Air Force Base Hanford and other sites that have long-term facilities right now are hurting for financial support. So if you want a recommendation, that's one to consider.

MEMBER CLARKE: Okay, Glendon, thank you. Jody is with Stoller Corporation, Department of Energy at Grand Junction and will talk about performance monitoring and sustainability of engineer covers for uranium mill tailings. Jody, welcome.

MR. WAUGH: Thank you, Jim. It's good to be here. I apologize for my cold. I'm not responsible for my voice or my mind set at this point. Maybe I got this from David Esh. I'm not sure but I'm going to sit down and I'm going to go through this. Basically, in the Department of Energy, we are the long-term caretakers of sites, disposal sites in the Office of Legacy Management and hopefully, we're not the long-term undertakers. Most of what I'm going to talk about we don't have to do. NRC in our uranium mill tailing sites doesn't require us to do this but we do have a mandate to try to improve the way we do long-term stewardship, long-term surveillance and maintenance, LTS&M and our measures for success is if we can reduce cost, if we can reduce risk over time and perhaps, maybe if we invest a little more up front, then in the long-term we can reduce cost and risk for stewardship.

I won't go through who all the sponsors and collaborators are but you'll see some of them here in the room. Also Legacy Management has sites all around the country. I'm going to focus primarily on uranium mill tailing sites and I'm going to use the Lakeview site as a cast study as I go through this. When sites are transferred we ask a set of questions. These are questions that I put together. When the site comes to us, what about that cover? Well, how is it designed, how is it constructed, how is it supposed to work? What and how do we monitor to show that it's actually working? What types of maintenance are going to be required and at what cost to keep it working as designed? What are the risks if it's not working as designed? This is the so what question. Maybe the cover doesn't work. Well, maybe it doesn't matter. Could we design a sustainable repair or renovation if needed to be better long-term stewards. And then finally, the million dollar question or at least the 200 to 1,000 year question is, can we expect these to continue working?

So again, I'm going to use Lakeview as a case study and step through some of these questions; how is this cover designed. Most uranium mill tailing sites, these are disposal cells. Lakeview actually the tailing were hauled from the mill site into a clean site. Most of these covers consist of really three layers and variations on that theme. A compacted soil layer which is supposed to limit infiltration and radon escape, a gravel layer over the top of that, a rock layer which is usually on the surface of these covers for erosion protection. At Lakeview they added a thin soil layer to plant grass but most of them are that. Well, how is that supposed to work? What it's supposed to do, and I'm omitting the radon attenuation, because we're focusing on groundwater here but a target was to have a saturated conductivity of that compacted soil layer of less than one times 10^{-7} and again, this is supposed to continue working for 200 to 1,000 years. What and how do we monitor to show that it's working?

Well, as I mentioned, NRC doesn't require us to monitor anything in the cover itself. We are required to monitor groundwater according to compliance, at Lakeview actually only every five years. And that's considered a measure of the performance of the disposal cell. They said, if you don't see anything down gradient in groundwater, well, the disposal cell must be working. I was going to mention, there are visual inspections. And part of that is there anything new happening, are there any changes from the baseline of what we thought we built that may impact long-term performance. And what are the needs for maintenance; follow-up investigations if there's something happening that we don't understand.

So let me talk a little bit about those follow-up investigations. New conditions that may impact long-term performance and focus on an observation of encroachment by deep-rooted shrubs on the Lakeview cover and how that might effect permeability. In this case, I'm talking about intrinsic permeability and just in a general sense permeability of the ease with which water can pass through. Well, that thin soil layer at Lakeview created sparse grass. This is off the cover, here is on the cover. The reason for that is thin soil over the rock layer, the water moves deeper. It really created a habitat for deep rooted shrubs which really weren't intended at Lakeview or any of these other UMTRACA sites. It didn't only happen at Lakeview. This happens at these sites around the country. This is Burrell, Pennsylvania, rock cover, in a few years we see trees growing into it.

At the dry end, Grand Junction, rock cover. This is a little bit different, it has a protective layer but again, deep-rooted shrubs encroaching. So are roots penetrating this compacted soil layer, are they effecting permeability? And then finally, are they effecting flux, are they effecting percolation directly? At Lakeview, yes, indeed, these shrubs that have grown into the cover are growing through the compacted soil layer. And it's not just a few isolated shrubs here and there. Over time, you see recruitment, you see nurse plants established in the progeny and then they begin to spread from sort of an island ecology until they begin to cover the whole cover.

Okay, how about permeability? What are

the effects of these roots on saturated hydraulic conductivity? We did this with some air-entry permeameter, a little bit smaller scale than what Craig was talking about earlier which based on Craig's figure probably effects our results but we compared saturated conductivity where there are roots, where there aren't. Actually, the top slope and the side slope of the Lakeview cover and upper and lower part of that compacted soil layer. That was a picture of the air-entry permeameters. I didn't mean to move that fast, but the point is, the target was down here and in all cases, the case sat results, saturated conductivity is considerably higher. Up there in that 10^{-4} as Craig found at some of his sites. And this isn't unique to Lakeview. We've done these at other sites, the Burrell Wet Site, the Grand Junction Dry Site, Shiprock which is a Dry Site, Tuba City a little bit the exception but for the most part, we have two to three orders of magnitude greater saturated conductivity than our design target.

Why is this happening? Well, perhaps the soil structure in these compacted soil layers is developing faster than expected. Well, plant roots, burrowing animals, freeze-thaw cracking, nothing we're seeing -- it appears a lot of these cells retain their structure from the borrow material. In other words, when they haul these materials and compacted it to achieve these high bulk densities, that in the lab suggested, well, if we do that, we'll reach that compaction, we'll have this really low conductivity, it wasn't the case. People see dyes in the structural patterns from the Lakeview soil and roots following those plains of weakness in the soil structure.

The next thing we did is, well, let's try to see if we can measure flux directly as Glendon was talking about. And so we used what I call the Geemeter, PNNL lysimeter, install these in a down slope location where we thought it's probably more vulnerable. This is the top slope of the cover. We put these in, in a down slope location, put in three of these so some construction installation, grass. These were put in last fall. This is what we've seen since then. It's a relatively wet winter and spring in the Lakeview area and we see how the daily flux, daily precipitation varied over time, considerable percolation going through. In fact, probably because we're seeing a water harvesting effect by putting these flux meters in the down slope location, our percolation is considerably higher than precipitation that's going into the tailings at this site.

Now, look at the alternative and Monticello is that alternative ET cover. Monticello is a little bit different. It wasn't an UMPTRA site it was a CIRCLA site and it was included in the ACAP program. I won't go through a lot of detail again, but as an ET type cover with a storage layer over a capillary barrier, there was some cobble included to try to keep the critters from borrowing down to that interface. You can see some of the construction, instrumentation that was talked about previously. They wanted to look at the data. You know over a few years, the first several years it's relatively dry and here's water storage, evapotranspiration, precipitation similar to figures you've seen previously, so water storage varied and then all of a sudden in the winter of 2004/2005, you have this really wet year, one of the wettest on record and big spike in water storage. It exceeded the storage limit for that soil as we've measured previously. And we get some percolation at that point. However, it did draw all the way back down to the pre-wet year storage levels.

Total percolation over that entire period now is about 3.8 millimeters, about .6 millimeters per year which, in fact, is still below what our target was. Our target was three millimeters. Through this -- and this isn't in your handout, but based on some questions yesterday, we're not going to be able to monitor with embedded instrumentation for 200 to 1,000 years over time. We've got to do something a little bit different maybe some sort of performance indicator that was talked about before, some sort of -- and this is an idea of what might do that. This is a remote sensing image that John Gladman of SRS developed of Monticello. This is the Monticello cover. What it shows is NDVI, Normalized Deference Vegetation Index and varying vegetation from healthy to more stressed vegetation, you can see there's these areas of stressed vegetation on the cover. There's -- vegetation varies considerably, both spatially and temporally, as Glendon mentioned, it's one of those hard things to parameterize. But this may be one of those indicators.

Here's where the vegetation is being stressed. It may be an indicator of a change of performance from the baseline. What types of maintenance are required and at what cost to keep these designs working? Can we design sustainable repairs or renovations if needed? Going back to Lakeview, well, based on our ET cover experience, maybe the shrub encroachment is the solution and not the problem. Maybe we need to be looking at this different. At most of these sites, we've been required to go out and spray the plants. Anything growing, we've got to kill it. It shouldn't be growing out of the rock. Lakeview is a little bit different.

So as far as long-term stewardship, what are our options? Well, we can keep spraying, we can let them grow or maybe we can try to facilitate a beneficial ecological succession and this is something, a study we're looking at right now is how can we renovate these older covers to make them behave like ET covers because, in fact, without our continued intervention over time, Mother Nature is going to transform all of these covers into ET covers anyway. What are the risks if the cover is not working as designed? And finally, can we expect these covers to continue working for 200 to 1,000 years?

Now, I want to introduce another concept along with monitoring and modeling to help us to understand long-term performance and that's -- and we talked a lot about these, I won't talk so much about that, but also natural analogs, looking at natural settings that are analogous in some way to our engineered cover setting that may tell us what could happen in the future. Well, what do they give us? They give us some sort of tangible clues about future environmental conditions. There may be a basis for designing covers to try to mimic favorable conditions, beneficial conditions. It may become a basis for hypotheses and treatments for the short-term field studies that we've talked about like the lysimeter studies.

They also may be a basis for inferring some future environmental scenarios that we might try to model. What's going to happen way out in the future? And so if we have a real simplified look at a performance modeling process for predicting into the future, you need to define these possible future scenarios. What models go into that, what the parameter ranges in uncertainty are for, as we're talked about before, climate change, some hydraulic properties like the K^{sat}, plant properties like leaf area, calculations and interpret those results in terms of risk and performance. So where do the analogue data fit in? Well, to help us to define these scenarios, what's a reasonable range, a possible future conditions, based on past conditions, based on climate modeling and to help us get an idea of the uncertainty in these parameters that go into it.

There was a demonstration done by Cliff Hall and some folks at PNNL using a platform called FRAMES and I won't say a whole lot about this other than Craig said we need something that ties all these together, all these different models. FRAMES attempts to link the water flux source term, the vadose zone transport, the saturated zone transport, and an exposure pathway. In the demonstrations that Cliff and others did, we begin to identify what those important monitoring parameters are. But let's go look at how the analogues can help us with these uncertainties. Let's -- leaf area index is one we've talked about previously. Currently, we have a really low leaf area in at least 2003, leaf area index on the top slope of that Lakeview cover.

If we look at a chrono-sequence, or a sequence of sites that are analogous to how succession may progress over time, in 20 to 30 years we may see sagebrush dominating that site. Well, sagebrush LAI is about .77 and at Lakeview our potential natural vegetation is dominated by a larger shrub that has greater leaf area called bitterbrush. How about saturated conductivity? We go back to these soils where we -- the borrow areas, the soils that were actually used to construct these covers, where pedogenesis has taken place for a long period of time. How has that effected saturated conductivity? Well, with these area permeameters were 10^{-5}, 10^{-4}. And that may even be higher if we had much larger permeameters, as Craig indicated in his work.

How about climate? Well, here's a couple of sites that represent a couple of climate change scenarios, a dry scenario and a wet scenario based on climate change models. If you go to these analogue sites, and for a wet scenario, same soil type basically as at a Lakeview disposal cell. We have a mixed conifer vegetation and a considerably higher leaf area index. A dry climate scenario primarily sagebrush, doesn't go to bitterbrush, it's not wet enough, basically the same soil type again and a considerably lower leaf area index. These are analogues that can help us understand those future scenarios.

So going back and addressing some of the focus area questions, the focus questions. In summary for our sites, for the Office of Legacy Management, DOE sites, for uranium mill tailings at least compliance monitoring and modeling are not required by NRC. However, we have been doing some limited what

I'll call non-routine monitoring and investigations to better understand how these systems work and hopefully become better stewards and reduce our cost and risk in the long term. And we're finding that many of these low permeability, these older designs, low permeability designs, effect the soil layers really aren't performing as designed. They aren't low permeable. They have higher saturated conductivities because of the ecology of these sites and because of soil development, soil formation processes, pedogenesis.

In contrast the Monticello ET cover does seem to be performing as designed. There has been some limited use of monitoring data for model improvement with regard to the FRAMES platform that PNNL has developed. Recommendations; currently at our sites we only monitor to point of compliance, to see if our disposal cell is working. Well, if it's not and you're at a site where the water -- groundwater was clean to begin with, you may have a big problem if you contaminate the groundwater, if you don't know until you get ahead of the point of compliance. So the recommendation is, let's monitor and model hydrological and ecological performance of these covers as a precursor as an early warning to potential future groundwater non-compliant. Use the soil ecological analogue data to develop some scenarios, future environmental conditions at out sites for modeling long-term performance.

As far as the FRAMES, the FRAMES use, we talked about earlier, the simple water balance codes really FRAMES should have a Richards equation solution for saturated flow and link in another type of model, a vegetation dynamics model such as TerreSIM. All this in situ or embedded instrumentation is great in the near-term from our perspective, from the 200 to 1,000 year perspective but I don't think it's feasible. This isn't going to last you know, point measurements and sensors that are in these covers aren't going to last forever and so they're fine for confirmation measuring and monitoring and modeling in the near term but for the long term we need to put more investment into performance indicators, what sort of change are we seeing from the baseline, like the NDVI, the vegetation index where we saw the dynamic spacial patterns or some sort of surrogates to those for the long term. And that's the end.

MEMBER CLARKE: Jody, thank you and let me thank all of our presenters this morning for very interesting presentations. This brings us to the panel discussion. Dr. Hornberger?

DR. HORNBERGER: Thanks, Jim. George Hornberger, Nuclear Waste Technical Review Board. Again, I'll remind everybody that we have approximately a half hour for panel discussion, maximum. If we don't use it all, that's fine, because the committee, I'm sure had plenty of questions that they would like to address to the presenters. The presentations this morning are fairly diverse and so it's somewhat difficult to find a summary point here to go to, but let me try, never backing away.

It strikes me that we've heard again this morning how monitoring and modeling together can be used to either add confidence to models or to point out deficiencies in the models that we use and that's fair enough. What we're here for -- the NRC, of course, is interested in compliance monitoring and the question that occurred to me is whether people had some advice on how they could seek compliance monitoring design as one of the questions sent out, that could be used to improve models but that are not currently used. And I guess the concern I have is that it's easy to see how we can have iterative approaches in a kind of research setting but are these going to improve our models to the point where they are going to be more useful on the compliance cases as opposed to -- that is in cases where we may not have the luxury of making extensive measurements and installing lots of equipment, that is a limited amount of compliance monitoring. How is that -- can you enlighten the NRC on ways that they might change their program design to help improve confidence in their models?

MR. PRICE: You're looking at me. Van Price, Advanced Environmental Solutions. I guess there are two parts to this, to my answer one of which I can't really address, I can only hint at. NRC probably needs to take a look at their current regulations and how they relate to monitoring today and for what periods of time and for what sorts of things. But another think that I believe everyone really accepts is that one size does not fit all. A monitoring program has to be specifically designed for the site. And you've got to do a careful analysis of that site and you've got to characterize the site in detail before you can design and implement a monitoring program and decide how long it needs to run. That can be contaminate specific, transport parameter specific and so forth. It's site specific.

DR. HORNBERGER: Craig, we're just going

to go around this way.

MR. BENSON: Sure. One of the first things that came to my mind is what does compliance mean because compliance normally has associated with it some regulations, some standard that you have to demonstrate that you've met like at MCL or something like that and groundwater. At least from cover systems, we really don't have anything like that. I think Jody kind of talked about that. I mean, we really -- we design them but the compliance point is really in groundwater and I think our question though, is could you come up with some type of compliance criterion to demonstrate that a cover is functioning as intended? And I think there are -- you could come up with tools, near-term tools, to demonstrate compliance. But I do think long-term you are going to rely on models and the things that we get out of, I think, from shorter terms monitoring are information about parameterization which I think is one of our weaknesses in models, how we parameterize them and we can really gather a lot of information about parameterization from short-term monitoring programs. I think that kind of addressed your question.

DR. HORNBERGER: Yeah, and again, I'll remind you, I don't mean to constrain anyone. If you want to make other comments off my question, that's fine. Brian?

MR. ANDRASKI: Brian Andraski, USGS. My only thought there was, perhaps, a couple of things that were mentioned both yesterday and today and again, as Craig pointed out, in terms of point of compliance, most of the monitoring focuses on groundwater and I think we've seen some interesting work where we have used things like plant sampling, perhaps, maybe more emphasis on early warning techniques that we might use, which in that case would rely something simple, plant sampling or more emphasis on saturated zone monitoring that would provide, perhaps more of an early warning and if that could be incorporated it might be very helpful in the long run. I think a lot of examples that people pointed out perhaps once things hit the groundwater it's too late. So if we could incorporate some early warning monitoring, I think, at least in my eyes it seems like that would be something helpful.

MR. GEE: Glendon Gee, PNNL. It's been my observation that for the last 15 years or more that there's been a -- somewhat of a dilemma in the minds of EPA and other agencies to impose any kind of criteria on how to monitor the vadose zone. The NRC set some guidelines for mill tailing sites in terms of radon emanation. So one could monitor surface gas evolution and the radium content in the surface soil and other things that were somewhat prescriptive, but as I understand it, it was always generally a design basis. You design your system so that it, in theory met that criteria, not necessarily requiring them to go out and make measurements.

I guess I'm thinking along the same lines as Craig in that can there -- if you're going to have monitoring that is required, performance monitoring, there should be some criteria established by NRC and maybe that's the point to start is determine what these early warning measurements might be and try and incorporate the ideas that many of the expensive monitoring systems that are out there now may not be adequate, that geophysics may be -- we haven't talked much about that in terms of the vadose zone. There was some mention by Steve yesterday that he was looking primarily for groundwater issues with geophysics but certainly many things that we've talked about today could be measured on a broader scale with better geophysical tools, so things like incorporating state of the art geophysics into the design of a monitoring system, I think that's a few years off but

I think it's something that we ought to consider basically finding performance assessment, performance monitoring criteria that will be meaningful for early warning systems is where I think we ought to be heading in terms of discussion.

MR. WAUGH: This is Jody Waugh, SM Stoller Corporation. We're of a similar mind set here. You know, we talked about early warning but let me give you an example of a consequence going back to the Lakeview case study that I showed there. All that was required by NRC at this particular site is to monitor the point of compliance wells every five years. I haven't seen anything yet. In fact, they've been monitoring them since the mid-'80s and there's already some discussion of, "Well, we haven't seen anything, maybe we can just stop monitoring. We don't have to do this any more", because we're not looking at the holistic picture, the big picture of the dynamics and the lead/lag relationships here.

Because what we found by going back and looking at these, these follow-up inspections is well, in fact, there's a lot of water passing through that cover. And a slide I didn't show is we tried to put some of those flux meters on the side slope. We couldn't because we augered the hole and it rapidly filled with water because the tailings were saturated. Okay, so if we don't do an early warning there, maybe, you know, in five years from now we'd stop monitoring all together but in 20 years from now, we'd have a big hit at that point of compliance well because we didn't look at the whole system and we didn't do some sort of early warning.

So I'm echoing what my colleagues have said here, an early warning type of monitoring is important.

MR. FORD: Robert Ford with USCPA. First I wanted to give sort of a brief -- a couple brief impressions I have on my steep learning curve during this week. The way I understand compliance as it's being used, I would make that -- to me it's equivalent to contaminant detection. The process of contaminant detection is different than monitoring or site characterization to support a transport, contaminant transport model. They're two different realms. And from the very beginning, that dictates what that monitoring effort will be. I would echo what's already been said with regard to compliance monitoring or at least contaminant transport monitoring by putting wells at some pre-determined point of compliance.

One, there's always uncertainty that you've identified what the most important route for exposure is ahead of the game which we're talking about many years into the future, so certainly land development. We can see in some parts of the country there are dramatic changes that can occur over tens of years and so positioning sampling points for compliance monitoring without foreknowledge of how land use may evolve, to me would indicate, you know, there's always a chance that you're really not capturing the future exposure route.

So what I would advocate really and to echo, you know, what I've heard repeatedly this issue of early -- some sort of early detection approach would be to treat compliance monitoring as a staged approach which would mean you don't eliminate those predetermined points of compliance because, you know, that's what we've already established and as soon as you change horses in mid-stream, that is not received well publicly. But to incorporate additional stages where you do some sort of compliance monitoring near to the point of release, I know an issue we face repeatedly at SuperFund sites is the cost of site characterization and the deeper you have to drill, the more it costs and you know, I don't know if it scales linearly or expedentially, I would probably as a gut reaction say it scales expedentially, so any sort of monitoring system that you can do closer to the point of release, is going to increase your likelihood of finding, detecting that release and having confidence that you've actually detected the majority of the mass of that release. You know, hunting plumes, tracking down plumes is an expensive proposition. And you know, I've -- it meets a lot of resistance and, you know, I'm on the VPA but I can agree with that perspective because it can become prohibitively expensive to try to track plume migration.

So anything you can do to shrink in some points of compliance monitoring or add that as a part of a staged approach where, you know, maybe you modify what the frequency of monitoring at the different stages to try to minimize costs to make it more palatable to these entities that you're forcing to do this effort, I think would be important.

The only other issue I would add in terms of the plume chasing, the farther out you move from the source of contaminant release, the harder it is to find that contaminant. And so as you move closer in, you're going to increase your likelihood that you're going to find that contaminant release if it were to occur and I would suspect that you're going to actually minimize the cost for compliance monitoring which I think is a justifiable goal from the regulatory perspective. We want to make it easier, less costly for these entities to pay for compliance monitoring so that they'll actually do it. That's -- you know, if we can't get them -- if we can't twist their arms enough to do it, then what have we gained.

So and one other thing I would add in terms of establishing what should be included in compliance monitoring and/or contaminant transport monitoring, I think it would be worthwhile to take a step back and evaluate do we really have a complete grasp of these systems that we're trying to monitor. A lot of our focus and we see this in SuperFund sites, a lot of the focus is on the particular waste units, on the particular contaminant, you know, and ignoring the land setting around there or ignoring other potential chemicals that could be released into the subsurface that could intermingle with the contaminant of concern. That has a big impact on your ability to model contaminant transport. It may have less of an impact on your success of compliance monitoring.

But, you know, we've seen that sites that are near rivers, sites that are near large surface water bodies and there's clearly going to be some inter-connection, that should be on the plate up front with regard to conceptual model and how you design and determine what your compliance monitoring process should look like. And as I mentioned before, this may be -- you know, it may be a minor issue. I admit my ignorance here, but you know, we really should do an accounting of what exists at these commercial facilities. I would assume there's some uniformity. Our focus right now is on cooling water or aspects of the particular reactor itself, but what else is on site that could potentially enter the groundwater system or vadose zone system and could impact contaminant transport? And that's something that wouldn't require a lot of cost, but it requires stepping back and doing a complete accounting and figure out well, what is our scenario that we really need to capture with regard to contaminant transport and modeling exposure at some down gradient point of compliance?

DR. HORNBERGER: Let me -- another thing that occurred to me as we're going through -- I think that everyone agrees that early warning is a good thing. Groundwater contamination is a bad thing. Nevertheless, we do wind up sometimes at least --

especially with respect to modeling, being interested in projections of potential -- at least potential groundwater contamination. And a question that comes to me is how or whether we can use either data collection or monitoring data to justify some simplifications.

As an example, we've heard -- we've seen this morning Robert gave an example of Redox changes in groundwater in a plume. We also have heard about potential uranium transport. We know that, for example, water chemistry effects things like absorption very strongly. And yet, what have we heard about today, KD's. So we use these approaches that we know we can't justify in a scientific sense. So how do we do that? How do we reconcile these discrepancies, if you will, between our knowledge base and how we model things and how we do long-term projections and how, again, we can integrate this with monitoring? Does anyone have anything they can help enlighten me?

MR. BENSON: I'll chime in a little bit and I want to go back to some of those other questions. Craig Benson from Wisconsin.

I think, first of all, you evolve through that by collecting data and observing how things perform relative to how you expected them to perform. And from that perspective alone, a monitoring system serves a very valuable function because it allows you to essentially apply the observational method and incrementally improve models or simplify them, whatever the need be. So I think from that perspective, the -- and particularly kind of this -- a monitoring system that's not necessarily groundwater compliance monitoring but containment system monitoring to see is the lining system functioning properly, is the cover system functioning properly, are the leachate collection systems functioning properly? Are they consistent with our models and if they're not, well, maybe then we need to upgrade our models or simplify them, whatever it may be.

I would argue that some of these monitoring systems to look at the containment system, really can be designed and constructed to last a very long time with very little intervention with some careful engineering. You can really develop what you might call passive systems that don't require a lot of everyday detailed intervention by somebody on site. Now, a lot of what -- you know, what I've done and what others have done for research, of course, we have all this tremendous detail, we're taking measurements every 15 minutes, do you don't need to do that for compliance or performance monitoring per se, you need to do that for research but not for compliance.

You can design passive systems that collect flows and measure them in a very simple manner and then store that information on a server and somebody in Jody's organization can look at a whole bunch of sites on the web very simply, keep an eye on them and monitor them and evaluate them with regard to performance criteria fairly simply. I think that's possible and doable. We designed a prototype system like that for the Fernald low-level facility.

That essentially had a variety of different monitoring points in it, collected data, it stored it on a server and then you could click on different things on the web and it would pop up and tell you what's happening at that facility. And that one had a lot of bells and whistles to it but we could distill that down to something very simple with some simple lysimeters and some simple -- for example, they monitory uranium concentration and the leachate collection system. You could develop a few sensors for that that are easily replaceable and monitor that for relatively low cost over a very long period of time and develop that confidence. That's a longwinded answer to your question but something I feel pretty strongly about.

MR. FORD: I'll chime in on KD. Firstly, KD and the term, the parameter KD that's determined, one can determine and is published in different compilations and the term sorption are general terms or parameters. They capture a wide range of chemical processes. Teasing out what all those particular processes are that are active at a given location in the subsurface is not a straightforward process but one thing that can be done in a straightforward manner since the propensity for a contaminant that isn't like tritium, and is not going to be attenuated, to partition to the aquifer sediments is dictated one, by the water chemistry and also by the properties of the sediments or soils at the given site.

And so having a knowledge, developing a knowledge on water chemistry through a collection of water samples in the aquifer underneath the facility we can do that. That can be done in a straightforward manner. We would have to request though that whoever is doing that analysis do more than just look at what I would call the contaminants of concern. You have to do a full suite of measurements that don't add a huge amount of cost to the analysis of the water samples and doesn't really add any difficulty to the collection of those water samples, and with regard to understanding the influence of the sediment, the aquifer sediments, any of the drilling activities that we do and many of the technologies that we've talked about for putting in wells, can also be used to retrieve aquifer sediments. And it's fairly straightforward to conduct bench top experiments with those aquifer sediments with the groundwater samples as your water matrix and whatever your contaminant in spiking in your contaminant concern, to measure sort of a site specific KD and you can even do that for different parts of the aquifer and get a handle on what is the variability of that KD -- quote unquote "KD characteristic" of the aquifer. And that's something that can be done very -- in a very straightforward manner without too much cost or complexity.

And that's a very valuable effort because the KD's that are published in available compilations, EPA has their own, they're only reliable to a certain extent and I would hesitate to apply that across the board for every location within the US. It really is important to have a sort of a site specific measure of that propensity for contaminant partitioning that's going to be dictated by whatever the groundwater chemistry at that site is and whatever the sediment properties. And, you know, the test I described doesn't mean that you have to figure out what all those sediment properties, you just have to figure out what the impact on contaminant partitioning is.

MR. GEE: Glendon Gee, PNNL. It seems to me that compliance monitoring objectives are at odds with model parameter monitoring objectives. At the DOE site at Hanford one of the issues that concerned DOE officials was that they did not want to be caught with a contaminant getting into the groundwater that they didn't expect. And the monitoring wells that were placed 100 meters below the waste, in some cases provide surprises, in some cases are still monitoring and not giving them any indication over the last 35 or 40 years that there is any problem and yet, there's 100 meters of vadose zone in which things can and are happening that cannot be predicted from the groundwater sampling that's been done in the past and possibly in the near future.

So we have the issues of trying to get compliance monitoring in line with getting the model parameter monitoring and so I guess I would just issue again an urge to look at near warning systems that can give people early indications of problems rather than at compliance points that are far enough away that our generation won't recognize them.

DR. HORNBERGER: Okay, I think we'll move to the question period now. Jim?

MR. BENSON: Can I say one more thing on the end of that, just for a moment. I think it compliments what you said, Glendon. In Wisconsin for solid waste landfills, we do the same thing, monitor the groundwater at some compliance point, I think it's 150 feet from the limits of solid waste. But for years, we also put this large lysimeter underneath the liner, 40 meters square or so and the idea was to monitor for water quantity and quality and that data was collected. Unfortunately it was never really analyzed. It was put in a shelf, but we went back and mined that over the last few years, all that water quantity and quality data and the things that you see is that we see VOCs above MCLs at the base of our landfills coming at the bottom of the liner.

We're probably not going to see that in groundwater for a long, long time but the early warning system really simple shows it's there. Now, whether it will ever get to the groundwater, you know, that's another issue. I don't know but I think that kind of dovetails in with what both of you gentlemen had to say.

MR. WAUGH: Can I make one more comment briefly? This will be brief. This is just sort of the rest of the story for something Craig had mentioned before. At the Fernald site, instrumentation was put in disposal cell as an early warning, but there seems to be this culture that we only have to monitor what's exactly required for compliance, not for understanding because now as that site is being transferred to Office of Legacy Management, my first question was, great, you know, where's that data? Well, we don't do that. We don't -- we haven't been collecting that data. All that instrumentation was put in for naught because it's not being used as an early warning.

DR. HORNBERGER: Okay, Jim.

MEMBER CLARKE: Thank you. Here again, thank you all. I actually want to start out this time and make an observation and ask a question. And I listening to what everyone has been saying over the last couple of days, so far, I've tried to distill this down into a way that makes sense to me and it comes out like this. We have monitoring requirements. The questions are what, where and how often. In some cases, we have maintenance requirements for a particular period of time, for example, RCRA facilities, 30 years of post-closure monitoring and maintenance. If we monitor for compliance for X number of years and we don't see anything, one of the issues, of course, is we're monitoring groundwater where we don't want to see anything and where, if the facility is designed and installed properly, we shouldn't see anything at least for the period of record, which is a few decades.

So we have this conundrum between wanting to monitory now quarterly and then not seeing anything and thinking well, gee, maybe we're okay, maybe we don't do this any more, but knowing that if we've done this correctly, we shouldn't see anything for 30 years at least. I mean, I would say the currently favored designs are maybe decades old, early '80s perhaps. So what do we do with that? And I was intrigued with Robert's concept of stage monitoring which you know, could be location and could be time and could be both and so I'd just throw that out to anyone who wants to pick it up and then we need to move on, but I've struggled with this for a long time. I've spent several years working on SuperFund sites in a consulting firm and have seen more than once people after a couple of years want to terminate the monitoring.

MEMBER HINZE: Do you want a response?

MEMBER CLARKE: Sure.

MEMBER HINZE: Well, it seems to me that why are we modeling? We're modeling so that we can build confidence in that model and that model should be able to predict into the future if we have done our job properly. And as a result, this monitoring in the future is just really a maintenance function. And all you have to do is get a slope on it and make sure that your model is correct. You know, the long term monitoring really is -- if you've done your job properly, is not important.

MEMBER CLARKE: Just one follow-up to that and then I'm going to go to -- I think we have to monitor for a certain period and we're monitoring groundwater and I would like to see us monitor other things as well, and I think that the early warning and the precursors is a big part of this and I think we will have to monitor them for some time because of the failures that I'm familiar with usually occurred in the short-term because the system was either not designed properly or more likely is not installed properly or all of the above, and Craig mentioned ET caps that didn't have enough storage and there are clay caps that weren't covered with geomembranes and they dried out and desiccated. So, you know, we're familiar with these kinds of failures. So I would think we would need some monitoring in the short term to confirm that. But then Bill, I'm with you, if we can build the model confidence, then we --

MEMBER HINZE: That's the first time I've ever done that.

MEMBER CLARKE: Could you say that again, please? Did you get that?

MR. ANDRASKI: Jim, if I could -- I don't mean to cut in but I'm going to, sorry, but just to follow up on both Robert's suggestion about staged in time and space and also the comment about the modeling, I think the staged approach would really have good utility in terms of the modeling aspects as well. We've talked about the iteration between data collection and modeling and going back and I think it would have a good application there as well, just a point to maybe tie in.

MEMBER CLARKE: Good point, thanks, Brian.

MEMBER WEINER: Just to make an additional comment on that point and I think Jody made the comment, when you have construction on a site, it can change the way the groundwater moves. I have had this happen on property that I own so, I know about it first-hand, and I think any model is really going to have to look at that since we're modeling for the future any model will really look at that. The question I wanted to ask is for the whole panel; many people today and yesterday mentioned that there are large uncertainties in -- particularly in input parameters, and I wondered whether anyone had tried to add to the model a method of distributing the input parameters and then looking -- since you may know you know, the limits, you know, your smallest value and your largest value or whatever, or at least your largest value and may have some idea of how these are distributed or at least you can try different distributions, and this is a fairly easy thing to do.

We have done it with a model. You just -- you put in distributed input parameters, run your model a number of times to sample on those parameters and what you get out is either a CDF or a CCDF or just a distribution itself and I wondered if any of you had considered that. The silence is deafening.

MR. ANDRASKI: I'll jump in, Brian Andraski, USGS. We haven't followed that approach specifically but the modeling work that has been done, we've done just the basic sensitivity analysis to look at effects of various parameters, but we haven't gone in and developed a distribution function. So we haven't followed that approach exactly but we have looked at trying to feather out the more important or less important parameters, a little different approach.

MEMBER WEINER: Let me make an invitation. If any of you are interested, I'll be glad to show you how we do it.

MR. WAUGH: This is Jody Waugh --

MEMBER WEINER: It would please me.

MR. WAUGH: I was waiting for one of the modelers to answer that question because I'm not a modeler, but some of the activity that was done at our sites with the FRAMES platform and PNNL developed is a probabilistic platform and so for the input parameters, you input distribution for those data.

MEMBER WEINER: Yeah, that's very good if you have the program that can do it. What I'm suggesting is that you can put a program on top of whatever model you're using and just sample and run it. And that's a good one. My other questions were mostly directed at Robert and I was very interested in a lot of what you had to say. I'm a little -- I was a little disturbed and maybe I misunderstood that you said the model shows you where you need to monitor. And is that a little bit like saying if you drop your car keys at night, you look for them under the street light because that's where the light is? And I'm asking that you clarify that.

MR. FORD: This is Robert Ford, EPA. It was the heat of the moment. A model -- and as a follow-on to your earlier question about, you know, doing sensitivity analysis of whatever form as part of the modeling effort. The model helps in making decisions about where to monitor but that is -- the caveat to that is only to the extent that it accurately represents what's going in the subsurface. And I think we've heard a consensus that you really only get to that level of confidence through iteration and, you know, unfortunately, that's really the only methodology we have right now for establishing our level or increasing our level of confidence.

And so you know, I would qualify that statement by adding on that one has to revisit through data collection and determining the performance of the model to represent reality to really support the use of the model to, you know, make decisions about where to put monitoring points in your program. With regard to the sensitivity analysis, that is an important exercise. You know, if you do have some level of confidence in the model and representing reality in the subsurface, it's an important tool for designing the monitoring program not only in terms of projecting, you know, where the plume may end up some time in the future, but if you have some chemical processes that incorporate, you know, a component of that model, certainly doing parameter sensitivity analysis as well as with the hydrology really tells you where you're going to get the most bang for your buck in terms of expenditures to collect samples and data at the site. The one thing you want to avoid is putting a lot of effort into collecting data that really -- which -- whose variability doesn't really impact contaminant transport that much and so the modeling provides you with a tool to at least assess that in a first to around to see, you know, if I change some of these chemical parameters or if I change flow parameters, what impact does that have on the plume, you know, my projected plume development and that may really point you to, you know, I need to be very careful, I need to focus on collecting certain types of data and be very careful on how I collect that and maybe collect that type of data at a greater frequency than you might collect other types of data and in so doing minimizing the overall cost of the effort.

MEMBER CLARKE: Okay, Mike?

CHAIRMAN RYAN: This is a real interesting discussion. I'm going to come at it from a practitioner's point of view for a minute. I have a site and I have disposed of some material, I have to build a system to do that. I have a half a million bucks a year to monitor. What do you guys want me to monitor first and why? What's my best chance of getting in compliance, whatever that is with my new site?

I think you've all spoken to bits and pieces of this question but to me that's the sum question that we need to think about as we tend to chase our own ology whatever our own ologies are and then we tend to chase the compliance points, whatever they are. I mean, it's obvious when you say it out loud that if the compliance point is 500 feet away from the disposal unit and you get a positive hit there, the horse is already out of the barn, that's too late. There's nothing you can do. You know, when you think about -- I think about the fact I'd much rather be trying to figure out the behavior of infiltration water without contaminants in it than figuring out groundwater movement with contaminants in it. So maybe I ought to spend more time in my cap arena. Again, I want to try and emphasize that question because I think it is the thought question that I take away from this morning's entire session and that is that if you put yourself in the position of that facility general manager or vice president and he's got a half a million bucks and you need to tell him how to best spend it so he can be in compliance and be ahead of the curve in terms of facility performance, that's the kind of thinking that I think many of you have offered specific comments on. Is that a fair summary?

MR. PRICE: I'll take a beginning stab at that. Half a million bucks you can do a lot. You haven't told us what's your inventory. You haven't told us what's your design. You should take a systems analysis approach to your whole site, establish data quality objectives, what you want -- what the desired outcome is to be, what your design parameter is to be, what your subsystem design parameters are to be and what you expect in the way of performance from the subsystems and the system and start there as a point of departure and what is the surrounding environment.

CHAIRMAN RYAN: Absolutely.

MR. PRICE: And start with that as a point of departure for deciding what to monitor, when to monitor and where to monitor. Certainly, it would include constituents of your inventory, it would include background water quality chemistry and perhaps soil mineralogy and characterization to start with and it would include things that are not necessarily risk drivers but might be precursors to a plume. For example, Jim Shepherd talks about a site where nitrate is right ahead of the uranium. So you -- and I showed you this morning a slide where the tritium was a precursor to other bad actors.

CHAIRMAN RYAN: Sure.

MR. PRICE: So a systems approach.

CHAIRMAN RYAN: Well, I think you've hit the key. It is a system and we can't subdivide it when we really want to think about compliance. And to me compliance comes in many forms. It's not just a radiological constituent at some point in the water. It may, in fact, be the kinds of things you've mentioned and perhaps many others.

MR. PRICE: Yeah, I think the thinking that we've evolved here over the last few years with Tom Nicholson is we sort of refer to these other things and many of the earlier warning system, warning attributes that you would try to measure, we call performance indicators because they're not required by law that you meet some regulatory compliance standard, but they are indicators of your performance of your system.

CHAIRMAN RYAN: And let me, if I may, I think it's the same issue with the surface ecology, if you will. I mean, I think that's -- if that's operating correctly, you're doing your job in terms of reducing infiltration or managing the water, but you know, people drive their trucks over and inspect plants and see their growing and that may be a bad think. So you know, maybe there's some indicators right on the surface that you can begin to think about.

MR. WAUGH: This is Jody Waugh S.M. Stoller. I agree with that. I think at most of our sites we are concerned about water infiltration moving through but we need to get back and look at the entire system. Let me give you an example. Loman, Idaho, our first concern was water infiltration, but we found out that in these tailings the radio-nuclides were bound into mineral form and water infiltration wasn't a problem at all. In fact, the way it turned out, we were concerned about pine trees growing on the cover because over time we get blow-down and the tree would fall and it would leave a big cavity and we'd have erosion and washing these tailings into the surface water. That was a greater risk. That was a greater problem.

So if we had focused on monitoring flux, which would be my first answer to your question if you wanted to monitor just one thing, at most of these sites that would probably be it. But we've got to look at the whole system and where the risks lie.

CHAIRMAN RYAN: Well, I think the systems approach always carries that exact caution with it. You know, Robert, you made a comment about measuring KD's. Just from my own experience is I'm always a little cautious because if I'm using a tracer, I have really no guarantee that tracer, which is probably something nitrate that I add to the experiment, that it's going to behave in any way like the bound species that might be wrapped up in God knows what organics or other matrices and it may or may not behave the same as the tracer. So it's always tough to take that lab experience, although we need to keep trying. I mean, your point is well-taken, but it's the existing and real system that I think is the best teacher, sometimes. Thank you. I just wanted to get your reactions. Yeah.

MR. BENSON: Could I react to that?

CHAIRMAN RYAN: Please.

MR. BENSON: Yeah, I want to make a couple of assumptions. You said this is commercial and you had to dispose of this waste and you have so much, half a million dollars a year. So I kind of put that into my thinking here and I'll make an assumption that the owner is interested and concerned about both long-term environmental and financial risks, long-term, not short-term but long-term so the thinking way down the road perhaps, of how this might effect him. And I'll assume it's an engineered disposal facility, it's not a dump. So it's a containment facility. It's been designed and we have an estimate of how it's supposed to perform and I look at the biggest potential cost from failure at that facility probably would be groundwater contamination because it's the hardest to fix. You know, I think Robert demonstrated that nicely.

So if I'm going to put some monitoring system in I want to know what comes in through the cover and what comes out of the liner. If I know those are working pretty good, and I think there's

Jody's issue as well, but if I know those two functions, those two barriers are working well, I'm pretty confident about how it's going to work. I'm less worried about groundwater if I know what's coming out of the bottom liner is in compliance and consistent with what my model has predicted. So that you can do for a half a million bucks a year.

CHAIRMAN RYAN: You've got the job.

MR. BENSON: I have a contract here.

(Laughter)

VICE CHAIRMAN CROFF: Based on what I've heard and things that I've read previously, it seems that the objective function for cover design is trying to design it to last for as long as possible, hopefully until the hazard is gone if it's decaying away but as long as possible. Has any consideration been given to designing the cover to facilitate maintenance and to facilitate monitoring with the expectation it may not last for the life of the hazard especially for very long hazards and in trying to facilitate, maintaining it at a lower cost an d designing it to be monitored and if any of that's been thought of, what would that kind of a cover look like?

MR. BENSON: I'll start a little bit and maybe Jody wants to chime in because this is something we've been talking about in the last six months or so. I think if you -- this issue of what do you do if it fails is a big one, you know, what do I do? That's one of the reasons people don't like to monitor them by the way because they may find out if it fails I'm going to have to fix it. Well, the reality is we ought to know if it fails and then we ought to have some strategy if it does fail to repair it. And at least I think in some environments if you come up with a system that's consistent with the environment, you can rehabilitate it so that it mimics the natural environment.

And so if you come up with a rehabilitation strategy that's consistent with its environment, it's likely to be fairly low cost and have long term success. I think you can do that in some parts of the country. In other parts of the US you probably can't do that because they're too wet. Another project I worked on dealt with this specific issue. In Northern Wisconsin there's a mine tailings facility again and what to do with the cover over time. Well, there was actually a financial instrument set in place at the beginning that had periodic sampling of the cover, inspection and repair of the cover if needed, that provided imperpetuity, financial assurance to do that. So that's another -- you know, so there's a couple of different approaches that you could take. One would be where you've got more difficult hydrological conditions, you just go in and repair it every so often.

In another environment, you could go in and reconstruct the cover in a way that's more sustaining and I think you can do that in more arid regions more readily. That's my thoughts on that, Al.

VICE CHAIRMAN CROFF: Okay, anybody else?

MR. WAUGH: Craig opened it up for me to respond. I guess I should. Jody Waugh, S.M. Stoller. I didn't put a lot of focus on that in my presentation but what we were seeing at the Lakeview site is the way it was designed it really isn't sustainable. Mother Nature is changing it and we're trying to understand how Mother Nature is changing it and essentially help her out. And Craig and I and Bill Albright are currently working on a project on how we can renovate some of these older existing covers that really aren't behaving, aren't working the way we thought they would, so that they do a better job of mimicking what Mother Nature would do otherwise.

You know, we'll tweak it a little bit so that we find what are the most beneficial long-term natural processes to mimic and then try to do those. And basically, it's have good storage for water storage and get an idea of what vegetation Mother Nature would put there eventually and try to start with that.

MEMBER CLARKE: If I could just add to that; I worked with Jody a few years ago on an evaluation and a road map as it was called in those days and I still remember very well, Jody, your comment, "Don't fight Mother Nature. And you know, Mother Nature will win, let's try to work with Mother Nature and not fight it". And many of the barrier designs that we rely on in some settings are fighting Mother Nature.

MR. WAUGH: I'd make one last brief comment to that, this is Jody Waugh, S.M. Stoller. Some of our sites are on the Navajo nation and it was interesting in working with the Navajo EPA, Navajo Nation Environmental Protection Agency. They have a logo and below -- the logo has the earth and has a woman holding the earth and the words below it, "Help Mother Earth Heal". That's the approach.

VICE CHAIRMAN CROFF: Glendon, do you --

MR. GEE: Glendon Gee, PNNL. I remember in my early days in North Dakota that North Dakota was concerned about in lignite mining, the reclamation process in lignite mining and basically along the same lines that Craig had mentioned that there were severance taxes that basically stockpiled and were used for the reclamation purposes and maintenance of those sites. After the mining operation and the reclamation there was still money allocated. And so there are mechanisms in place in these areas for continued monitoring if people have foresight. North Dakota did.

VICE CHAIRMAN CROFF: Okay, thanks.

MEMBER CLARKE: Okay, thanks, Allen. Bill?

MEMBER HINZE: Getting at the confidence in the models, I'd like to go back to those very interesting modeling exercises you carried out, Craig. In my world, those would be an inversion technique and inversion techniques are noted for their ambiguity and the non-uniqueness of the results. I'm wondering if that pertains also to the modeling that you did using those four models and changing the boundary conditions, et cetera and if it does, how do you minimize the ambiguity and evaluate the ambiguity and that's really part of the monitoring scheme.

MR. BENSON: Craig Benson, Wisconsin.

That's a tough question. Just to start off, our simulations were all forward simulations. They weren't inversions. So we weren't doing that process, but I agree with you, that's a complicated ill-posed problem because you've got several competing parameters all of which could be optimized to get the right answer, you might say. Although I think you can constrain these problems with our understanding of physical processes so that you can constrain those different components into reasonable ranges to do inversions which are both perhaps mathematically sound and also physically reasonable at the same time, good monitoring data.

MEMBER HINZE: When I used to have an editor's hat, I basically refused articles that didn't conduct some type of sensitivity study to really evaluate where these models occur and it seems to me that that's a very important part of understanding where you have to monitor, at what depth, what frequency, what you're interested in modeling. This is all part of testing that model. Do you have any comments on that?

MR. BENSON: I believe a sensitivity analysis is really valuable, I mean, because it does give you a sense for what the key parameters are and what the possible ranges are of your predictions.

You've got a central parameter set that tells you about where you think things should be but then by sensitivity analysis you can get a sense for how far you may deviate from that. So you know, we always do sensitivity analysis in our work and it's particularly valuable. And I think you could probably use monitoring data combined with sensitivity analysis to get a sense for you know, am I really -- you know, if my monitoring data doesn't agree with my mean trend, but I still may be within compliance because I'm within a range that I define with my sensitivity analysis.

MEMBER HINZE: And develop a range of confidence in your model, if you will.

MR. BENSON: Yeah. Yeah, I think you can define thresholds for -- threshold compliance performance monitoring that way, right?

MEMBER HINZE: Right. Thank you.

MEMBER CLARKE: Thank you, Bill. We probably have time for one more question from the staff maybe or anyone from the committee.

MEMBER HINZE: I'd like to ask a detailed question of Brian. You were looking at both tritium and gaseous mercury. Were you looking at -- you didn't explain why you were looking at gaseous mercury. Was this another way of fine tuning, of developing confidence in that model or were you interested in this as a contaminant or where are you going?

MR. ANDRASKI: Brian Andraski, USGS. Do you want me to tell you the real story, we can go to lunch and I'll tell you? Essentially, we're looking at a number of different parameters but how it started out, I'll try to give a quick synopsis, was a person in the biological resources discipline of USGS contacted me and was interested in perhaps looking at mercury transport in plants and the person called and said, "Do you have mercury at your site, I'm interested in working in a desert environment". And I said, well, we looked at the waste inventory. There was some indication that mercury would be present so we followed up with the soil gas sampling. So that's how we legitimately got started.

But where we took it from there was we felt -- we were confused by the tritium results that we were getting and we originally classified mercury as a well-behaved contaminant only transported in the gas phase and we thought, okay, we're having trouble with tritium, let's take a look at mercury. We're going to be able to peg that one right off the bat.

And so it was -- one thing that did help us is that -- so we want to look at multiple contaminants, gain insight into transport from one or both or more and try and feed that information to get a better understanding.

Ultimately, the one thing that we did show was that our hypothesis or conceptual model where we feel that vapor phase transport of tritium is number one, the mercury work that we've done does support that but -- so as I said, we did get into it in a round about way but we're using that information to try and build understanding of other transport processes.

MEMBER HINZE: So it's really leading to an enhancement of the confidence into your model?

MR. ANDRASKI: Yes, and trying to gain -- yes.

MEMBER HINZE: Sometimes it's really very helpful to look at a new parameter that isn't necessarily in our normal bag of tools.

MR. ANDRASKI: Right, right, yeah, good point. Thank you.

MEMBER CLARKE: Thanks, Bill. Let's break for lunch and resume at 1:00.

(Whereupon, at 12:00 p.m. a luncheon

recess was taken.)

CHAIRMAN RYAN: This is a very proud moment for, I think, the agency and Michelle and certainly for me. As of August 89th, Michelle Kelton has finished 35 years of government service.

(Applause.)

CHAIRMAN RYAN: Thank you all very much, and as part of the service, we want to present you with this service award and, of course, the service pin that goes with it and a letter from Dr. Watkins recognizing her outstanding contributions to the regulatory mission. I know we all want to add our congratulations and our thanks, too.

Without Michelle this committee does not function.

(Applause.)

MEMBER CLARKE: Okay, sir. Are you ready?

CHAIRMAN RYAN: Dr. Clarke, it's all yours.

MEMBER CLARKE: Congratulations, Michelle.

I want to give you a little more detail about the agenda. Let me just go through the presentations.

The first presentation will be solely by Tom Nicholson. He'll be followed by Tom Fogwell, and when we get to the panel discussion, Jim Bollinger and Todd Rasmussen are going to share with us some information about an American Nuclear Society standard that they have been working on, and then we'll proceed as the agenda shows.

Tom. Tom Nicholson, Office of Research, coupling monitoring programs for modeling.

MR. NICHOLSON: Thank you very much, Jim.

I'd like to just take a moment to make some thank-yous. Usually when we make these presentations we zip through the first viewgraph and move on, but there are a couple of people I want to thank.

First of all, I want to thank the ACNW for allowing the Office of Research to work with Jim Clarke and Latif to organize and identify people. Our expectations have been met. This is an incredible meeting, and we're very appreciative of George leading the panel discussions.

The other group I want to thank are my co-authors. Yesterday Ruth asked the question how is this information getting passed on. How is this information helping in the licensing process?

And if you notice the co-authors, Ralph Cady and Jake Philip from the Office of Research, Jim

Shepherd and Jon Peckenpaugh; Jon right now is on detail in the Office of Nuclear Reactor Regulation, and Jim of course you heard from yesterday.

There are other people in the room besides these gentlemen, but we have what's called a technical advisory group, and the technical advisory group is on groundwater and performance monitoring, and we are actively collecting and distributing information. You heard this morning from Van Price. Van Price working with our group organized and put on two training courses last year, one last November, another one in May in which we brought in agreement state regulators. We brought in people from all four regions, and of course, the NMSS, NRR and RES staff.

So that's one thing that probably is one of the benefits of the activity in the last year with regard to finding tritium and other contaminants at nuclear power plant sites. It has brought the regions and Headquarters, especially Research, closer together, and all four regions are actively involved in this technical advisory group.

Well, the outline of my talk is basically a lot of it will be repeated what we heard earlier. When I talk about objectives, I'm going to talk about objectives in both monitoring and modeling and how they relate to each other, and then we want to talk about the monitoring as it affects the model interface. What are some of the generic technical issues we've been looking at in the last year or so, and then Jim Clark and Latif wanted us to comment on opportunities to build confidence in modeling, the theme of this two-day meeting, and then I have some references.

Well, a lot of these have been repeated over and over in the last couple of days, but as we said earlier this morning, we see it in the systems analysis approach. We are going to characterize the system, and the system obviously involves both the engineered system and the surrounding environment.

The other important part of what we call performance confirmation monitoring is understanding the system and its behavior. It isn't just compliance. It's understanding the system, and I'll go into some detail about that.

And confirming the site and engineered behavior, the argument is how do we think it's going to behave and are there changes to that behavior or the things that we weren't aware of at the beginning when we created both the conception models and the initial monitoring program.

And of course, we've talked about demonstrating compliance.

The last item no one has really talked much about except, well, there's been a few comments, but our friends from Brookhaven have talked about remediation, but the question is how do you decide whether and how to remediate, and we think monitoring and models are extremely important for those sites in which there is noncompliance.

Well, this slide is from my friend Ralph Cady, and the question he asked is why monitor and model. Well, obviously we do it to characterize the natural engineered system.

Now, we have talked about in great detail the last couple of days lots of good examples on the features, events, and processes involved. We want to collect information and we want to quantify that information, the]features, events and processes, and they have to be significant to radionuclide transport and the behavior of the system, not just an academic exercise.

The next one, notice the S in red. Last week Jim Shepherd and I were very privileged to be able to attend an EPRI-NEI meeting on monitoring at nuclear power plant sites, and at that meeting everyone was talking about singular models. One of the strategies that we're developing with Van Price is we want to look at alternative conception models. We don't want to ask the question are there features, events or processes that weren't initially identified that need to be identified and can you capture those in two or three, and this goes to our research at PNNL on conception model parameter and scenario uncertainty.

And then finally, Bill Hinze brought up the issue of, well, if you just have a model and you use that model to go look for -- as a detection system, maybe you can be led astray if you have a preconceived idea based on a single model, and that's correct. We have to look at many models from the standpoint of are there faults, are there fast pathways, are there things that we weren't aware or, and that is going to help guide your data collection.

And notice we used the word "sampling." Robert Ford was very good this morning and he brought up the issue of it isn't just the water, but it's also the matrix. It's the soil, the sediments that we want to look at, as well as the water then to stay in the system.

And then finally geophysical methods, and we'll talk about that in some detail.

Now, this is my favorite viewgraph. Almost every time I talk I always have this one, and the reason I love it is because we have an engineered system, and the engineered system here is failing. There's a well failure and there's also a diversion box in which you have a faulty joint seal.

Now, what's interesting about this figure is that we want to look at alternative conceptual models, and we brought up the issue of natural precipitation. We've heard about infiltration. We've heard about infiltration and groundwater movement, the creation of perked (phonetic) water systems. Notice all of this occurring above the regional water table and the well itself obviously becomes an inadvertent pathway.

This is extremely important to us for a variety of reasons. We brought up early this morning, and Robert Ford brought up the idea of a tiered monitoring program. That's what we're thinking about. We're thinking about how do you look at the performance of the engineered system and what kind of corrective action might be appropriate if you could detect these premature leaks and failure systems.

And then surrounding the engineered

system, you have backfill. And at nuclear power plants and other industrial facilities, it's this backfill in which the contaminants are moving. That's where you want to do the sensoring and quickly find it early on.

So we have the engineered system. We have the dynamic interface, and then, of course, we have the environment.

Well, to confirm the behaviors within envelopes of expected performance, Van earlier this morning brought up this issue of a systems analysis approach. If you model the system, and I'm talking about detailed models, not health physics models; if you're doing detailed modeling, you should have some idea as to the behavior of both the engineered system, the dynamic interface, and the environmental setting, and we want to ask the question are the changes to that or the information coming from the monitoring program that tell us we have to revise and refine our conception model.

The last item here is a site specific model. We don't think that the health physics model can do it in itself. We think that there should be a detailed site specific model that feeds information to the health physics model. RESRAD is a very good code, but it is not meant to be a detailed model of the features, events, and processes for that specific site, and we'll talk about that in a minute, but we probably want to say that it will not be a simple abstracted version as used in PA. You will refine that detailed, site specific model in order to do multiple realizations.

We also want to think about these state variables that may not be in the abstracted or PA model, but they are important to understand the performance, and as Van said this morning, these state variables are performance indicators of the system, and that's what we want to both monitor and model. That's what they have in common.

We've talked about assuring compliance. Notice one of the site specific criteria. The Nuclear Energy Institute has come out with some volunteer industry initiatives in which they're talking about certain notifications with regard to tritium concentrations and volume releases. So in a voluntary sense, they're providing some guidelines, and those could be some of the bases on which to do the evaluation.

A model is extremely useful to demonstrate an understanding of a system. How well you need to understand it obviously has to do with the compliance, and also early indication of failure modes and inadvertent releases.

We heard earlier about the dilemma with monitoring especially with wells is you have point locations. How do you then project those point values to compliance boundaries or other receptor locations?

And finally, what kinds of decisions do we need to make, whether there's a need to and how to remediate noncompliant excursions. So both the monitoring and the modeling is important both for designing the remediation program. We've heard that from Tom Burke and Mike Hauptman yesterday. They had so much confidence in their models and in their monitoring that they had trigger levels and they also had stopping rules, and that is extremely important.

This is what Van presented this morning. We think this is where the model and the monitor interface. It's this site conceptual model. How you develop that site conception model, how you find it based upon the monitoring data, and how you decide what, when, where and how to monitor, and it's very related. You can't do one without the other.

The analysis of the monitoring data, looking at trend analysis, how you take that information and feed it back into the refined by the site conception model, the performance assessment and further choices of performance indicators, monitoring devices and monitoring points.

And then finally stopping rules. Stopping rules are extremely important.

Well, what are the generic issues? Well, Van brought up earlier this morning DQOs, data quality objectives.

(Pause in proceedings for conference operator interruption.)

MR. NICHOLSON: Based upon the data quality objectives, what are the criteria you're going to be using and what kinds of sensor technology are you proposing to identify, both the performance of the system and its subsystems with regard to engineered system failure modes, the dynamic zone I mentioned before, and the environmental setting? What are the stopping values? How do you determine those? Obviously the data quality objectives can help you in that regard.

Now, there is a disconnect, and I'll acknowledge that. There's a disconnect between monitoring and performance assessment. We think that that disconnect can be overcome, and assessing the monitored conditions to confirm that the performance is within the envelope of the model, you are predicting the performance of that system, its behavior. The monitoring tells you whether there's changes to that behavior or if the behavior is so different you need to go back and redefine both your monitoring program and your conception model.

And the last item I can't stress enough: identifying alternative conceptual flow in transport models on different scales, and we'll go into that in some detail.

Now, this is another one of my favorite viewgraphs. Yakov Pachepsky, at the Agricultural Research Service has developed this for it. Now, Linda this morning talked about water budgets. This is the simplest model. RESRAD to some extent is based upon a water budget model. There's other ones obviously for estimating infiltration and groundwater recharge.

At many sites as you all know, and we've heard about them, you could have a whole range of complexities with regard to the geologic media, and we also hear this morning and from other people that one of the dilemmas is if you have different geologic media in which you could have dual porosity, dual permeability, discrete fractures without matrix or discrete fractures with matrix, how do you parameterize that?

And so here's an example of retention curves that would be developed for each of these various geologic media. It isn't just the geologic media, but it's also the scale involved, and we'll talk about that.

Now, at the bottom here we have model abstraction. The simple models, the PA models are always at this end. The very complex models are obviously at this end, but the question is do you have the data and information to support such a complex model, and does it make a difference. Why are you doing it?

And the answer is because those preferential pathways and fast arrival times may be important. They may not be, but you have to understand the system to look at the various conceptual models.

Well, this goes back to our interface between monitoring and model. What to monitor and model as defined by the site specific performance indicators? They can be water content, hydraulic radiance, flow velocities, fluxes. We heard that the best thing to do was obviously measure fluxes directly if you can rather than indirectly and contain the concentrations.

When we make the statement we're dealing with the whole system, both the unsaturated as well as the saturated zone, and these PIs or performance indicators can be derived from regulatory compliance, performance assessment predictions, and it's the need to quantify system behavior. It isn't enough to talk about it and to create conception models. You actually need to quantify it using numerical or analytic models.

And the other important aspect is both the models and the monitoring have to have the ability to understand changes affecting radionuclide transport. Find those significant changes in system behavior.

CHAIRMAN RYAN: Tom, I'm just going to --

CONFERENCE OPERATOR: Excuse me. We have folks on the bridge phone line. If you could put your phone on mute, please. Every little noise you make is coming through loud and clear. Hello?

CHAIRMAN RYAN: Sorry, Tom.

MR. NICHOLSON: That's okay.

Where to monitor. This has been brought up before. We obviously think that the facility where the structure system components of the engineered system, it may be a spent fuel pool. It may be a condensate tank. It may be a rad waste, and associated with those structured system components, especially with the spent fuel pool, there may be telltales around it. There may be concrete curtail walls, drains, sumps. That is what we mean by facility, and that is obviously the closest then where the contaminants may be emanating from.

The second one, as I mentioned before, is that dynamic interface, the backfill. Now, at some facilities it's this backfill that's the major conduit. If you put your wells out in the environment 100 yards away from the facility, you're not going to see anything, but the contaminant that's actually moving along utility lines, telephone lines, and we can give you examples, it's that dynamic interface and how it is affected by storm runoff, infiltration, rainfall events, releases from tanks.

So that requires a different perspective than just monitoring the facility and its performance. This is important because we want to think about corrective action. This is important because this is the transition zone that takes the contaminants from the facility to the surrounding environment.

And then the surrounding environment, obviously we worry about the neighborhood. We worry about are there nearby wells, pumping wells, springs, discharge, surface bodies.

David Scott gave a very good talk on Yankee Rowe and identifying Sherman Spring. The idea is that you have to look at the various pathways and receptor locations, and then you may have to trace back. We would prefer obviously to monitor with sensors and other devices close in, and then understand the dynamics, the transients in the zone, and then using more conventional views of monitoring in the surrounding environment.

And this is what I was just talking about. When to monitor is as important as where to monitor. These events, how often do the release events occur?

It was interesting this morning. We heard about low level waste. We heard about liners. We heard about covers. Well, one thin I think about is from a plumbing standpoint. You want copper pipes in your house because they leak; it isn't a catastrophic leak as if you have a PCV pipe break. The last thing you want is a cataclysmic break, and these release events either can be slow leaks or they can be catastrophic releases, and the amount of fluid that comes out is also going to drive the contaminant. So it isn't just the release. It's the event and the dynamics of that release.

And of course, it may occur in the unsaturated zone moving quickly to the saturated zone. The dynamic process in the interface zone, we talked about infiltration, percolation, and then in the environmental processes, we heard from Steve Yabosaki (phonetic) about the Columbia River. The groundwater-surface water interaction is extremely important, especially at places like nuclear power plants that are associated with rivers, lakes and the ocean. We want to understand the environmental setting.

This is an example from Phil Meyer and Mark Ruckhold. This is what Steve talked about. The idea is that if you just had monthly fluctuations of river stage with time, you couldn't catch all of the detail, and is daily enough or do you really want hourly?

Well, it goes back to the issue of what process are you trying to understand, and we've heard about the geochemistry, and the geochemical processes, both the water flushing of the river and its interaction, as well as the chemistry. This is important at nuclear power plants as well.

How to monitor, I won't go into much detail, except to say that it obviously relates to how you properly select the instrumentation, the sensor for the parameter that you're trying to monitor. There is a tremendous wealth of information from EPA, the National Groundwater Association. We haven't talked about them, but they put out a monthly magazine on groundwater monitoring and remediation, lots of information. The Soil Science Society of America, the American Society of Testing Materials, and of course, the USGS.

So there is a wealth of information out there on monitoring in an environmental setting.

Finally, innovation, innovative techniques such as fiber optics, geophysical methods that have evolved from performance and model analysis criteria. We had a workshop in New Orleans a year ago, ADU, and the whole premise was on innovative techniques, and DOE at that time was doing quite a bit of work on looking at different sensor platforms and monitoring close in.

The other item I want to bring up on the geophysical techniques, the Office of Research working with Idaho National Laboratory and the USGS has organized and will put on a meeting at the Geological

Society of America in Philadelphia on October the 23rd, starting at 8:30 on the use of geophysical techniques for monitoring. So Willard Phersteig (phonetic) and Susan Harper and a variety of geophysicists want to come and educate us and teach us about how geophysics is extremely valuable in monitoring, not just doing characterization, but following characterization, and as was brought up earlier, the idea that you're integrating over larger volumes as opposed to single point measurements.

And so the interpolation takes on a different nature rather than interpreting from point to point. Now you have to interpret the geophysical signal coming back, and what does that say about heterogeneities, groundwater recharge, infiltration, things of that nature?

A week ago we had a wonderful technology transfer meeting from PNNL. Phil Meyer, Mark Rockhold, and Ming Yeng from the Desert Research Institute came in and told us all about uncertainty. They have developed an uncertainty methodology that looks at conceptual model parameter and scenario uncertainty using a Bayesian updating approach.

And this viewgraph we've borrowed from Phil and we've modified it, and we think that's another way, an opportunity of realizing the interface between monitor and modeling is looking at uncertainty, and it was brought up earlier.

If you want to maximize your ability to detect contaminants while minimizing the number of monitoring wells, then obviously uncertainty is important, and it isn't just a sensitivity analysis of parameters. It's looking at alternative conceptual models asking the hard questions as is there a fault or is there some heterogeneity. Is there a solution feature in my limestone or marble that may be the reason for the pathway, why I detect it in certain places and not others.

Since model probability is conditioned on observation, and that's extremely important, sine model probability is conditioned on observations, these monitoring strategies should be designed to obtain observations and improve estimates of model uncertainty.

Consider conceptual model initially in the monitoring design, and Van has been doing that. So at the very beginning of your monitoring strategy, you have to ask the tough question of what is my conceptual model's alternatives and how do I build a monitoring program that isn't just putting in wells, but putting in devices and geophysical methods, that we find that conceptual model so that you can have a better understanding.

And then finally, to identify the important -- notice it isn't just lots of monitoring wells, but the important monitoring locations that is input to these PA models. So the idea is that you have your site conception model. You have your monitoring program that has been meshed and interrelated to it, and then those detailed site specific models may give rise to simplified models that provide input to your dose assessment models.

And these are important for parameter estimation and model calibration and uncertainty analysis. We're involved with eight other federal agencies' interagency agreement on research into environmental modeling, and we have a Working Group II on parameter estimation uncertainty.

And Mary Hill from the USGS and Eileen Poeter are talking about various model calibration that they use and parameter estimation, John Dougherty, using monitoring data.

Now, the question is what information do you need and how do you process that monitoring data to give you ranges of parameters based upon your conceptual model, your model calibration. What are you calibrating? What aspect of your model?

And then what kinds of uncertainty analysis are you doing? How well can you quantify those?

And then finally, these are a series of references that we had lots of, but we picked these four. The first one, of course, is the work that Van is doing and his colleagues on developing a groundwater monitoring strategy.

The second one is a very good workshop that DOE, Dupont and EPA put on about was it three or four years ago, Jake? And in there, there is a lot of information on geophysical techniques, on monitoring the unsaturated zone. It is extremely valuable.

And then our friend Robert Ford and Steve Acree, they developed a performance monitoring strategy for VOCs using monitor net attenuation, and then our friend Phil Meyer and the people at PNNL have combined conceptual model uncertainty with parameter, and then finally the last item. I brought this for our friends from NEI and EPRI. Last week the topic came up of defining both background and baseline for existing facilities and for those you plan to build new nuclear power plants at. Do you understand?

Well, the answer is, yes, our friends in the regions, Ron Minitz, gave us this Website in which if you want to download data on environmental radiation at various locations throughout the United States EPA has and here's a Website for you to go to and download information.

And that's all I have to say. Thank you.

MEMBER CLARKE: Tom, thank you.

Our next presentation will be given by Tom Fodwell with the Fluor Hanford team, integrating modeling and monitoring to provide long-term control of contaminants.

Tom, welcome.

MR. FOGWELL: First, I'd like to thank the organizers for inviting me to participate in this meeting.

Secondly, I'd like to thank Glendon Gee and Tom Nicholson for --

(Pause in proceedings to adjust microphone problem.)

MR. FOGWELL: I'll repeat the last statement.

I'd like to thank Tom Nicholson and Glendon Gee for presenting my talk. I'll reorganize it a bit.

We have an equipment failure here.

Okay. Is this okay?

PARTICIPANT: Better.

MR. FOGWELL: Good. The outline of the talk goes along these lines. First of all, a very short introduction to Hanford.

Then I give a paradigm for how you would combine monitoring with modeling in the format of remediation, as was suggested by Tom.

Then examples of the integration of several of these parts together, some discussion of some monitoring at Hanford, some issues associated with bringing this whole thing together, and then some examples from around the country of places where people actually attempted to do this sort of thing.

So this is the Hanford site, 600 square miles approximately. It's larger than a lot of other places. The intake for the water to my kitchen is right about there, and so I have a concern over this stuff.

This is a conceptual model that I think was presented by Mike earlier about the different sources of contamination at Harwell. These are the sorts of things that we need to be worried about and modeling and measurement.

Comparing Hanford to the rest of the U.S. nuclear weapons complex, 42 percent of the curies are at Hanford; 60 percent of the high level waste; 25 percent of the waste storage and release sites; 80 percent of the spent fuels; and 25 percent of the buried solid waste. So it's a fairly significant site.

Now, what are we up to in what we're trying to do there? Well, we do the three things that were mentioned by Tom. We do characterization. We do remediation, and we do monitoring, and we would like to do all of those to minimize the cost, of course, subject to the constraints that are imposed on us by regulatory requirements and so forth.

Now, I tried to answer some of the questions up front just to be sure I didn't miss them, but I'd like to highlight some of the ones that I think are more pertinent to my talk.

The first one, I think the answer to that one is that there's not been an adequate paradigm developed and accepted by both the regulatory community and the responsible parties to facilitate the use of monitoring data in the models used to evaluate performance.

Going on to question number three, what

could we possibly do about that? Well, one thought that I had was that if the monitoring were force to in some ways be optimized, you immediately impose some sort of a modeling activity on the monitoring activity. So you immediately start to link the two.

So if you attempt to optimize it, then you have the possibility later on of using the modeling data to, in fact, reposition some of your monitoring and you've established a feedback loop.

So to sum up, I think a system control approach is what's needed, and it puts all of the different parts in place, I think, fairly nicely with the feedback loop as the method for using monitoring to approve model reliability.

Now, this idea I've had for some time, but also I participated in -- well, actually before I went to Harwell -- I mean to Hanford, two nuclear places anyway, I was working at the National Science Foundation as a program director, and there was an ITR program there that I participated in, and this is one of the programs called DDAS, DDDAS that looked at bringing data together with the modeling.

So the old paradigm is a fairly static paradigm. The new paradigm relies on a dynamic feedback and control loop to establish contact between the data and the modeling more rigorously.

So here's a schematic, a general schematic of a feedback control system, and I'll show a more detailed one that's pertinent to our situation later, but I think it should be adaptive in that the model needs to adapt to new information that you get through the sensors, in other words, the monitoring system, and at the same time be stochastic if possible, and we've mentioned that as well in trying to deal with uncertainties.

So the system down here is, let's say, the groundwater system, for instance. The sensors are the monitoring. Then we use prior knowledge together with monitoring data to determine what the system model should be.

That then gives some input to what the controller decisions have to be. This would be the remediation decisions, and we come down here to the actuators. These are actually what you would do in the way of remediation.

That affects the system. That affects the sensors, and you're in this loop, and you have an iterative process naturally this way. We've talked about an iterative process. This produces one naturally.

Now, in greater detail for specifically remediation we have the following components, and let me just go through these. I'm going to emphasize for the first few slides this part up here, but let's start with characterizations.

So you have some characterization of the site. From that you build hopefully a probabilistic transport model. If you don't have enough information, perhaps it could be deterministic.

There's a feedback loop here that's the calibration part, solving in some ways the inverse problem. Then you go over here and you produce the output, which is a probability distribution of the chemicals in time and space.

From that then you determine the risk to the exposed populations together with uncertainties. If you've done this in a probabilistic way you can then start talking about uncertainties at that point.

Now then you have to make some decisions. Am I going to do remediation or what am I going to do next? The first question that you have to answer in that process is are my uncertainties low enough, and if the answer is no, then you have to go back. The only way to remedy that is to go back through another data acquisition process.

If the answer is yes, then for the purpose of remediation, you have to ask are the risks low enough. If they are, then you just go into monitoring, and you start the feedback loop over again. If the risks aren't and you have to do some remediation, then you have some decisions having to do with implementability and so forth for the remediation, and then you end up in a remediation phase here with monitoring, gives you characterization, and goes back to this whole loop again.

So I think that that nicely ties everything together. Now, I'll be referring to this at different parts of the talk where I highlight certain groups like, for instance, to begin with basically is a modeling part.

So here's Tom's favorite picture. It has a few more things to it in our particular case though. We do have some direct injections as well, some of them not inadvertent.

So that's the thing we would like to model. We use the FEPPs process, future events and processes process as well. This is a short version of that sort of a process. What is your inventory? What are the pathways? And then who is going to get exposed?

Now, we actually do have some modeling that has taken place to show that during the operation of the Hanford site there were groundwater mounds that were built up through the massive discharges of liquids that were done there. So let me just go through this, and you can see how it was built up in this period right here, and then hopefully in the future it will start going down, and it will flatten out.

And then the issue becomes at some point what's going on in this area. It's called the gap, the Gable Mountain gap. You'll see it gets very, very flat in there, and the question is does the water go this way or does it go this way.

Now, we convene panels, expert panels to give their advice on what we're doing periodically. The last one we had actually was a panel on decision tools for the Hanford Central Plateau, and these were the panels members that we managed to convince to come to Richland to meet with us on this topic.

The three questions that I asked them to address were how should uncertainties be handled. I think that's important.

The one that's the most pertinent to our discussion here is how should the models be verified and calibrated. For instance, what role should history matching play in the process? That's essentially what we're talking about here.

And then lastly, what would be the technical specifications for a code that you might want to use for these purposes.

They had in their out-briefing -- their report is due in a couple of months. so I don't have that, but they did have an out-briefing, and I took this from the out-briefing on some of the data issues. They had categories of different issues. I thought this was the most relevant.

They suggested to quantify measurement errors wherever possible; characterize spatial variability, of course; up scale and down scale data to a common support or modeling scales. That's an important issue. Quantify data and model input uncertainties as much as possible, and then the issue came up about history matching perhaps in the vadose zone as opposed to the groundwater, and it's not clear that that's going to be quite as easy.

So back to this picture. We talked about some of the things that we would like to model. Now I'd like to talk about some of the decisions that we need to make.

The decisions along the river basically have been made. This is the central plateau where most of the decisions still have yet to be made. This is a schematic showing the division of the central plateau into different regions for consideration.

And then the question is we have so much to do what should be the prioritization of what we should do first. We only have a limited budget each year. Hopefully by the end of a certain number of years we get the whole thing done, but what should we tackle first?

This is a strawman that was based on the modeling that looks like this that was put up. So this attempts to compare the individual regions that I just outlined previously with respect to their future releases, and it shows that typical curve of a spike and then a tail.

Now, we also not only need to use our modeling to make the decision of what to do next, but we need to make the decision of how to do it, and so we have the various remediation alternatives that we have to consider. There's a whole category of removal and disposal actions, and these are either being considered or have been done at our site.

Then there's a large category of immobilization of the contaminants left in place, and there's a whole sequence of things that we've either done or would like to do or have plans to do, including the in situ Redox manipulation barrier.

So those are some of the decisions that we need to make. Now let's look at the monitoring and data gathering activities, what we're doing to filling those gaps.

My basic thesis is that once we have this paradigm, the actual parts for this, to fit into this diagram actually exist. We can actually do this at this time.

As we mentioned before, particularly in the context of a feedback control loop, it's probably really important to know what's happening fast. One of the worst things you can have in a control system is delay because you're always tending to do the wrong thing, like you're turning your shower hotter when you should be turning it colder, and so forth.

So with the delay, you get into more trouble in a control system. So in order to minimize that, sensing things happening in the vadose zone makes sense. The things that are amenable to that are the waste sites, tank farm sites, canyon buildings, disposal facilities like ERDF and IDF, the LERF facility, and the low level burial ground.

So we're involved with a bunch of activities having to do with what sorts of information we can get on our site, and one of them is the field visimeter (phonetic) test facility, which incidentally Glendon, my program, is now funding for this next year. So it didn't get lost.

So this is one of the areas where -- and I think Glendon actually had a picture of this. I had several pictures of this.

This is the prototype barrier that Glendon was talking about. This is in the construction phase, and when it's fully constructed, or was constructed, this is the diagram of how it looks schematically.

We've done some modeling. We've developed a stop model to actually be used for design of barriers, and I think it represents in some ways the state of the art for designing barriers with models.

Currently we're doing water balance monitoring, vegetation and animal use surveys, and stability surveys on the Hanford barrier. What we learn there will be used to design other kinds of barriers, these evapotransport barriers that Glendon was talking about.

Now, this is a sequence of quick snapshots going through a year showing how a hypothetical barrier would perform under certain kinds of loading conditions that are typical for our weather conditions at the Hanford site.

This is also a good example of the feedback between monitoring and modeling because the original monitoring allowed us to put in reasonably correct parameters for the design of the barriers. On the other hand, what we've learned from the modeling has now shown us places where we need to gather more data, better monitoring, and has also showed us that we perhaps could improve on the original designs of these kinds of barriers, particularly with respect to the slide slope stability.

So let me just pace through this real fast. You can see the effect of the seasons, and then places where that would be applied would be, for instance, the ERDF, the environmental restoration disposal facility.

Now, the types of vadose zone monitoring fall into several different categories, and I think Glendon went through several of these. Moisture change. A new one that's being tested out at PNNL is flux measurements using self-potential. I don't know that it has been shown to be totally successful, but we are looking at more geophysical methods.

Then there are the usual moisture sampling methods that Glendon also talked about. But I think the trends in the developing technologies for monitoring in the vadose zone entail more volume integration, better sensitivity. This is the direction that things are going, and less intrusive. And I think that these are all very good developments.

Now, we not only have radionuclides at the Hanford site. We also have a huge carbon tetrachloride problem. I think that Mike mentioned that, as a matter of fact. And these are some of the data that were gathered fairly recently just in a short burst of activity doing some pushes at 20 locations and measuring these quantities here.

This is the results of the sorgas (phonetic) measurements. So we routinely do sorgas measurements as a matter of fact on the site for various purposes.

We also get into more sophisticated geophysical methods involving resistivity, self-potential, induced polarization, and so forth. This is an example for the application of resistivity tomography. This is at the BC Cribs. It has also been used at the tank farms, as well. These are the lines, the shooting lines that they used.

The purple areas here in the results show the areas of higher conductivity which indicates higher moisture and -- well, higher conductivity which we think is indicative of higher moisture, higher nitrate content, and higher Technetium 99 content. And we don't have any other data like this at this particular site.

At a previous workshop, I mentioned this workshop that we had on modeling. Our previous workshop was actually looking at geophysical techniques to define the spatial distribution of subsurface properties or contaminants, and this is a list of some of the things that we went through to evaluate. This is an extension of that list.

So we're proceeding with the development of these geophysical methods. Of course, we have traditional groundwater monitoring, which Mike mentioned, and this shows the non-radioactive components and plumes or depictions of the plumes for those components at the Hanford site, and that comes out of the report that, although not the latest, the report that Mike was mentioning.

And this is the depiction of the plumes

for the radioactive constituents.

So we have an extensive groundwater monitoring program that we try to stay ahead of.

We're also developing some instrumentation for in situ measurement to help with our processes of trying to determine where the Technetium 99 is. So we're in the process of funding development of the Tech 99 in situ sensor at PNNL.

We've already deployed a remote chromium sensor in the 100-D area. We have some advanced cone penetrometer systems. this one actually uses short drilling bursts to augment the pushes.

There's also hydraulic ram approach as well that's used fairly extensively in the tank farm sites.

So places for future monitoring are certainly going to be beneath the TSDs during operation. The liquid retention pools; tapsan (phonetic) barriers were already mentioned. We need to look at protection and monitoring for rapidly decaying constituents in particular. We need instrumentation developed certainly for continued characterization, and of course, we will continue our groundwater monitoring program.

So that's the different parts that go

together to fill in this diagram. There's one part that's somewhat left out here though, and that is how do you deal with all of the data and how do you bring the data together.

Well, we've been working on what's called data access network that we try to use to bring everything in together, and it was originally built on frames, as a matter of fact, which Jody mentioned.

This is a schematic of the details of that particular system.

Now, we've identified some technology needs that we would like to have filled as we proceed into the future, and we've identified them in all of these areas. I'd like to dwell on characterization issues and monitoring issues.

Under characterization, we'd like to know more about Technetium 99. It's difficult to analyze in radiation samples. There are some issues perhaps with its transport properties. Certainly uranium has transport property issues, you might say, and chemical speciation there is a big issue.

Carbon tetrachloride, we're not quite sure about the inventory, where it is, what phase it's in. Has it moved or does it move with the water or not with the water? Does it degrade naturally? Does it degrade in our system? What are its transport properties?

We'd like to have better access to locations in the groundwater because our costs are expensive for drilling wells. So we'd like to figure out a way to decrease the costs.

We're in the process of using more nonintrusive hydrogeological characterization of larger areas based on geophysics, and of course, there are scaling issues, and there are data integration consistency presentation issues.

In monitoring, we would like to deploy optimization strategies for monitoring. There's the whole field of unsaturated zone monitoring, which may people have addressed here today that needs to have greater emphasis given to.

And then there's monitoring for long term stewardship, and this has particularly the good opportunity to feed back to the modeling. And of course, we're always looking to reduce the monitoring costs.

Now, there are some examples that I have here of places around the U.S. where people have taken more or less some parts of this point of view and developed programs that have a bit of this sort of flavor of the feedback between the monitoring and the modeling.

One is HydroImage out of Lawrence-Berkeley National Laboratory. Susan Hubbard, as a matter of fact, is leading that project, and it integrates continuous geophysical data with limited bore hole data to estimate hydrogeological parameters of interest in the subsurface. The software package can be used to significantly enhance site conceptual models and improve design and operations of remediation systems.

This is a schematic of how the different parts of that, of HydroImage fit together, and I'll skip to the last little bar here and show the results of a Bayesian integration that their system performed.

As a result of the NSF initiative, there was sort of an instrumentation of the oil field project developed. The idea here is to link the model with the data in the context in this case of the oil field, but of course, there are a lot of similarities to our situation.

This is a little bit more detailed, not that much more, but you can see that the monitoring is linked to the computational algorithms that are eventually used to depict what's going on.

This is a more detailed schematic of what they have in mind where the simulation models use information that comes from the data, but there's a feedback. There's a feedback through several different modes here, where they go back and forth.

They claim to have had some success with underground pollution problems and with instrumented landfills. So those are certainly pertinent to our situation.

The two more examples are collaboration between INNL and PNNL where the end goal is to be able to click on a location or well and bring up geophysical information, as well as grain size distributions and estimate hydraulic properties. So combining the geophysics with the actual hydrogeological properties is the idea with that project.

And SAIC has an automated knowledge management system that they marketed for years to the petroleum business where they try to integrate the production system in a rational way.

So back to this picture again, those were variations on essentially the same theme where we try to link everything together. There are several things, some specific, some not quite so specific, that we would like to see in the way of future developments for Hanford, but certainly in my opinion we would like to integrate modeling and monitoring better to provide long-term control of contaminants, and if we succeed, there are many places where we could apply that.

Thanks.

MEMBER CLARKE: Tom, Thank you.

George, shall I introduce them?

We have a presentation from Todd Rasmussen and Jim Bollinger, the ANS standard, as I mentioned earlier. I'm not sure who's going to give it.

Thank you.

MR. BOLLINGER: Jim, thank you very much, and I'd like to thank the ACNW for this opportunity to speak.

What I want to do is give you sort of a thumbnail sketch regarding an American Nuclear Society and also an ANSI standard on radionucliide transport and groundwater for nuclear power sites that we're currently working on developing. I'll start with a little background information.

Back in the 1970s, the American Nuclear Society was very active in terms of developing standards to help guide the nuclear power industry.

These standards were developed as a voluntary effort, generally in a working group of experts that were selected by the society.

The working group would basically put together a detailed draft that would then undergo very, very detailed vetting by the ANS. In fact, the vetting process generally takes about 18 months. There are several layers within the ANS that you go through.

After the standard goes through that vetting process, then it's passed on to ANSI for their comment and review so that it eventually becomes an ANS-ANSI standard.

Many of these standards that were developed in the '70s were standards applicable to siting nuclear power facilities and also infrastructure. Unfortunately, those standards are now dated. So many of them are being withdrawn, and we're concerned at the American Nuclear Society, given the potential for a resurgence in nuclear power in this country, that we're not well prepared to deal with some of these siting issues.

So there's a big effort underway right now to basically rewrite these standards. Of course, one of the most important of these is the standard that

I've already mentioned on radionucliide transport at groundwater at nuclear power facilities.

Slide.

The original standard was developed back in the late 1970s. It was applicable both to operating nuclear power plants and to the siting of new nuclear power plants. This standard was accepted in 1980. It was reaffirmed in 1989, and then it was withdrawn in 2000.

Of course, a lot has happened in groundwater hydrogeology over the last 35 years, which was, by the way, an outstanding effort. Reading through this, I was surprised at the insights. This was just a burgeoning science when it was originally developed.

I was asked by the ANS a couple of years ago to put together a working group to essentially rewrite this standard, and having had no idea what I was about to step into, my first official action was to get Tom Nicholson and Todd Rasmussen in the same boat with me because it is a big job as a voluntary effort.

And they have been very, very helpful working with me to basically put together a working group of experts from many of the national laboratories, from the nuclear power industry, from academia, and also from regulatory bodies like the Nuclear Regulatory Commission.

Todd and I now serve as co-chairs. I'm essentially the representative of the ANS to that working group, and Todd is responsible for the technical content of the standard itself.

Our goal is to put together a very robust standard essentially so that we do not come full circle back in three or four decades to have the same difficulties that we're discussing right now. We'd like this to be a very credible effort. That's why we have many folks involved in the standards process who work outside of the nuclear power industry.

Let me give you my own personal viewpoint to sort of conclude. I think there are two issues that over the last few decades have been very corrosive to the nuclear industry in this country. One, of course, is an obvious issue in operational and nuclear safety. It's my personal opinion that many of those issues have been addressed by the industry.

The other issue that I believe has been quite corrosive is issues in the geosciences and environmental sciences, and I do not believe at this point -- in fact, Ruth, we've had many discussions in the Environmental Science Division within ANS about this very issue.

I do lose some sleep over the fact that I think we're going to have difficulty siting new nuclear power plants because we essentially haven't sharpened our pencils and done our homework when it comes to issues in the environmental sciences and the geosciences, and this is why I think these efforts are so important essentially to get guidance out on the table that can be used by the industry in terms of radionucliide transport in groundwater.

So with that, Todd, I'll turn it over to you to discuss the standard in a little more detail.

MR. RASMUSSEN: When Jim had asked me to do this I thought it was more for the design for new facilities, but over the last year or 18 months a number of facilities have discovered that there has been ongoing leakage or releases from them.

So part of this is keeping an eye on the task of what can we learn from existing failures within containment within the facilities. These are just some of the facilities that have had problems, and putting together a preliminary outline for a document, we're trying to build upon what Tom Fogwell, Tom Nicholson, a number of you have pointed out, this interplay between the idea of site investigations, characterization, slowed transport modeling plus monitoring.

How do we meld those three into a coherent framework where you have feedback and iteration on site?

I think one of the important features is .7, this corrective action. I mean, having an anticipatory response framework, expecting that there may be the likelihood of failure at some point, so planning ahead, how do you proceed in the event of a detection? Knowing that ahead of time, what are your triggers? What are you stopping points?

I mean, if we can outline those before the crisis occurs, we would be better prepared to respond in those eventualities. So designing those for both the site characterization issues, trying to feed back in our data in terms of improving our understanding of the system, these are all features that we have been talking about the last three days.

Our challenge is to take all of this paper that has been generated and try and take those ideas and put them into our document.

One of the key features of this, that it's a long term, multi-year process. The need for incorporating expense of peer review, I mean, that's hopefully most of you, and so we're actively soliciting input and feedback from technical and regulated communities to try and put together a farsighted document, and so any contact suggestions, references, thoughts, E-mails, anything would be greatly appreciated.

MEMBER CLARKE: Okay. Thank you, Todd and Jim.

And this brings us to the panel discussion. Oh, we're going to have a break. I'm sorry. You know, missing a break or lunch is even worse than not giving the committee enough time.

(Laughter.)

MEMBER CLARKE: Let's do that. Let's take a break. Let's be back in 15 minutes.

(Whereupon, the foregoing matter went off the record at 2:08 p.m. and went back on the record at 2:27 p.m.)

CHAIRMAN RYAN: On the record. Jim, it's all yours.

MEMBER CLARKE: Okay. Thanks, Mike. Again, let me thank the speakers for very interesting presentations. This brings us to our panel and Professor Hornberger, thank you very much for doing this.

DR. HORNBERGER: Thank you, Jim. George Hornberger again. Again, a reminder we have a maximum of half an hour here and so I was trying to think of something useful for summing up here and so I've been trying to imagine myself as somebody from NMSS who is responsible for actually implementing regulations. Okay, and certainly listening to Tom from the Office of Research, I'm totally compelled that we need to have scenario, alternative scenarios and alternative conceptual models and that we have to integrate monitoring and modeling and listening to Tom from Hanford, I'm totally convinced. I mean, it's compelling that we should use space age techniques like adaptative control systems. After all, supposedly a common filter got us to the moon and back.

But I have this niggling problem and this is what I would like you to deal with and that is I have a sense that I have a whole host of licensees who really should run RESRAD with generic parameters and present a case that that's all that's needed and I've acknowledged I have maybe a relatively small number sites when it's clear that there has to be a lot of monitoring and a lot of thought into long-term performance, confirmation and all that. And then perhaps I have some undetermined number of sites where I really don't know where they are and what I'd like some comment on is some guidance that we might offer to our colleagues at NMSS on how to decide which of these categories any given licensee is in. Is that a fair kind of question to ask? Let's start on that side of the table. Okay?

MR. FOGWELL: One of the Toms will talk. Well, actually the CERCLA process or the EPA process sort of addresses that in their procedures. The idea there is that you start with a simple model and taking the worst case scenario, the worst set of parameters, the worst releases, these sorts of things, use it as a screening tool and decide whether you actually do have a problem. If you can show with that sort of worst case scenario that you do not have a problem, then maybe that's sufficient provided you can convince yourself that in fact you have portrayed the worst case scenario. That would be the caveat for that.

MR. NICHOLSON: I agree. I think one of the dilemmas and Jim Shepherd talked about this with regards to decommissioning is you have to go through a screening process. You have to ask yourself the question what is the nature of the contaminant. If it's a well-defined entity and you can quickly find it and exhume it and take it off site, that's fine. However, if it's gotten into the subsurface, then the question is what is the residual contamination and there are approaches that NMSS is pursuing in that regard. It isn't the -- There's the D&D Code and of course, there's RESRAD and then there's also MARSOOM (PH) and MARLAP and there are ways of identifying the nature of the contaminant, doing the screening and then assessing whether you can leave it onsite and if the residual contamination is a no-never-mind, meaning it's going to have virtually no effect on receptors that are going to be right there onsite, resident farmers.

Then the other issue that NMSS is looking at is end-use and so the argument is how is this site going to evolve and that's where some complications could come in. So my argument would be yes, user screening process especially the established procedures you have today but the value of site conceptual models and monitoring is to test those so-called conservative assumptions that may not actually hold for the screening that you've done.

George Powers is working with the University of Tennessee and they're coming up with radiological surveillance where they're going to ask the questions, "I can identify things on the surface, but what happens when they get below the surface? How do I find those residual contamination levels and then how do they interact with the ground water environment both in the saturated and unsaturated zones?"

So my -- I guess I've been biased ever since I joined the NRC 30 years ago is that when people tell me "Don't worry, Tom. "A conservative bounding analysis says it's a no-never-mind" you find out later that the assumptions that went into that conservative bounding analysis really were not valid or were not fully disclosed. So I think those assumptions do have to be faced very strongly and you have to ask the question of "what's the history of the site, what's the environment today and what is the future possibilities for that site" and then you would move in the direction of doing more complex modeling once you have tested those assumptions and found out that they may not be as certain as you thought.

DR. HORNBERGER: Could you envision providing guidance, written guidance, to regulators, you know, your colleagues, to let them determine when there were thresholds that would implement additional actions?

MR. NICHOLSON: Okay. The technical advisory group that I mentioned earlier, we're doing that. I mean Jim Shepherd is developing both rulemaking and guidance and we're working with Van Price and his people. I mean this is an on-going effort. It isn't something that we're just going to wake up tomorrow and do.

So there's been very good cooperation between NMSS staff and research staff. Now NRR is getting involved and we've incorporated them into our technical advisory group on groundwater and performance monitoring and I must give credit to NRR and the people there. The whole concept of system analysis and performance indicators really came from the Reactor people and especially now that they talk about doing a risk assessment. The one concern I have is it isn't just risk assessment with regard to health effects, but I think environmental risk is something you should also be aware of.

MR. DAROIS: That's a good segue. This is Eric Darois and I'll share with you before I give you an answer of the fact that I was intimately involved with a meeting last week with EPRI and NEI where the topic was this very thing, groundwater, and we spent quite a bit of time not only groundwater, but groundwater as it relates to existing plants and the new construction and where we can feed feedbacks and lessons learned.

But we spent quite a bit of time with this issue, somewhat unresolved, and that is what is a problem and we keep hearing about it over and over again in the last couple of days. You know we all seem to have our own intuitive determination of what a problem is.

First of all, these nuclear plants aren't hundreds of acres sites, I mean, hundreds of square mile sites, I should say. They're typically in the order of one to 500 acres, something like that. And to my knowledge so far after going to a number of these sites, the scope of the problem is relatively minor. Most of what we're dealing with is tritium normally below the MCL. Certainly as it's leaving the site boundaries it's fairly low.

But it doesn't minimize or eliminate the need to understand the system. But on the other hand, I don't think it's worth spending millions on understanding the system. So there's a balance somewhere.

One, the plants weren't designed to leak. That wasn't part of their design spec. It's not expected to. So we're seeing something we didn't expect to see that needs to be identified and defined as well as its impact as it may or may not be leaving the site boundary.

One of the overriding principles in NEI's initiatives and EPRI's initiatives is to not only protect the public health and safety, but also to minimize decommissioning costs. I mean the longer you let a problem go for the bigger the costs are going to be in clean up later.

So I don't know if that aspect of it needs a detailed model. We certainly need some degree of understanding. So I think it's a complicated issue to solve holistically for all sites and the degree of modeling that goes on is going to vary. In my experience, it varies from nothing to probably half or one-tenth of what some of the more elaborate approaches we've seen today. So I don't know if that helps, but that's my perspective.

DR. HORNBERGER: And do you think that the mechanisms for making those decisions as to where a site falls on the spectrum are in place?

MR. DAROIS: Oh no, not at all. The industry is attempting to come up with their own system to figure that out, but it's in absence of any regulatory guidance certainly.

MR. BOLLINGER: My name is Jim Bollinger from the Savannah River National Laboratory. You know when you're looking at the complexity of the modeling, I think you have to sort of consider the risk involved, what type of contaminant are you talking about and what's its location to the nearest receptor and what's the likely transport time. That's one factor.

This is something that we discussed by the way a number of weeks ago in one of our committee meetings. It's amazing how the discussions we've had have sort of been a mirror image of many of the discussions we've had here over the last couple of days, but I think risks are very important and what's the complexity of the system. It may be that you have a very well understood system and you only need a simple model.

I'm a firm believer. Most of my experience is in engineering modeling, not environmental modeling, but we rarely in engineering modeling put together a complex model where we couldn't go get an analytical solution and validate the model. And I get a little disturbed sometimes with very, very sophisticated models that you start with a very sophisticated 3-D model without ever putting pencil to paper and looking at some analytical solutions to make sure that at least your estimates are within the ball park.

I prefer starting with very simple models and then as the system dictates adding complexity to essentially take care of the physics. You know you put together a simple model and then you run that against the data and if you don't have good agreement then obviously you're not matching all the physics through the phenomena. Then you need to start adding layers of complexity, but I think you let the system dictate that.

MR. RASMUSSEN: Todd Rasmussen, University of Georgia. You know when we start a new project hydrologic study we normally say we over-sample in space and time, the idea of getting more data than you think you need at more frequent intervals. But this is normally a reconnaissance grade survey. It's not a high quality data inventory. It's more to get an understanding, a big picture, of the system. It would be like a spotter scope on a high powered telescope. You need a wide field of view with a low resolution image.

As you begin to understand the system,

then you can back off in space and time. You focus in on those critical issues that are unique to your site or the high risk probabilities and so then you develop a better understanding of the system through those highly focused investigations or monitoring. The modeling comes back in as the test of your models, some type of real time forecasting prediction. I prefer to use the word "forecasting." I think predictions are sort of crystal ball.

At this point, I think our level of technology is best a short-term ability to understand the future, so some way of feeding the data back in into your forecasting model. The problem being is that if you're highly focused on a system you may not have the ability to forecast accurately and you may need to improve the comprehensiveness of your monitoring in order to improve your real time forecasting.

MR. DAROIS: May I? I'd like to respond to something Jim said just to put a different perspective on it. You talk about risk and I agree risk is something that should drive us. But, and this is my thoughts and not those of EPRI or NEI by the way, I need to put that qualifier in there, it seems so often that risk really becomes a blend of real health impact and outrage and public outrage basically or outrage from politicians or whatever the case may be. That will often drive us. You know, those two added together will drive what we perceive as risk and how we would respond. So it may not be real health risks that we respond to, but we perceive them as real risk. Thanks.

DR. HORNBERGER: Yes, I think that is a real good point by the way. I would remark that as we discuss this the technical people, the scientists, tend to think of risk as one-dimensional dose calculation and we know from experience that in communicating with the public that is not a good approach. It's multidimensional.

Let me go right to the bottom line. Our Tom from Hanford did address some of the questions, but let me read the last question. To sum up, do you have specific recommendations or suggestions on a path forward? So I think that we've heard that we don't yet have all the answers. We have some work being done. Is all of the right work being done? Is everybody confident that we have a path forward or do we have some new suggestions that people would like to make? Anyone? Tom.

MR. NICHOLSON: One of the ideas that

we're thinking about is how do we couple groundwater monitoring, I should say, subsurface monitoring strategies with uncertainty assessment and Ruth brought up the issue earlier about sensitivity analysis. It's been said many times models are just a mere abstraction of reality today. We don't know how the system may change in the future. We think we have some ideas.

The question is how do you incorporate that uncertainty into both your monitoring and modeling program and the monitoring dilemma is that it isn't just putting in wells. It's understanding the behavior of systems especially how engineered systems interact with the natural environment.

We need to think about, we talked about the work that PNNL is doing for us on conceptual model parameter and scenario uncertainty. The last one, scenario uncertainty, is the one that puzzles people the most because to some people it's highly subjective.

At the same time though, the scenario uncertainty makes you stop and ask questions like "What kinds of future land use may occur with regard to irrigation?" If you apply water to that site, how is that going to change the behavior? We've heard about the Hanford site. The water table is dropping there. Now if you thought about scenarios, then how could that land use be changed especially in the vicinity of the 300 area as that may be used for other things such as golf course, condominiums or whatever.

Then you have to think about scenarios and those uncertainties and the question is "What kinds of information do you need to think in those terms" and closure is a very important part of decommissioning. And I think -- Todd's right. Predictions is a poor word, but forecasting both the environmental setting the engineered system, how it changes.

The other issue I want to bring up and the reason I like uncertainty is, and I'll mention him by name because he was at the meeting last week up in Providence and I'm very impressed, Matt Barvinak from GZA has said on numerous occasions that any industrial site, whether it be a nuclear power plant or any site, it changes with time. We've heard it here earlier this morning and so the argument is that you need to rethink the model for that site and Latif raised the issue yesterday of is there a shelf life to a model. Is a model good for 20 years, 30 years, 40 years, 50 years? Well, obviously, it depends. It depends upon how much changes were to that system that you're trying to represent, both the engineered system, the dynamic interface and the environmental setting.

And so to answer your question, I think uncertainty and addressing uncertainty issues and trying to quantify that might be a way of bringing together the monitoring and the modeling issues and the value of that information. We've heard it today earlier the data is worth a fortune but it's only as good as the data quality that goes into that. Why did you collect it? What was its purpose? What was the measurement error? All the things that you ask about. We have an awful lot, I think, to learn from EPA.

DR. HORNBERGER: I would like to suggest from that comment that the people from Hanford I would love to see some market text rendering of condos on the 300 area.

(Laughter.)

Anyone else?

MR. SHEPHERD: Yes. Can I make a comment on this?

DR. HORNBERGER: Please.

MR. SHEPHERD: Thank you. Jim Shepherd from NMSS. Regarding your open comment and also your opening comment yesterday, no, Mark and I are not about to get divorced. We're simply experiencing one of those interesting moments in a marriage.

(Laughter.)

MR. SHEPHERD: I think Mark's point was that while we here are mostly talking about complex modeling of what's going on in the subsurface and how the source term is in fact distributed, to convert the source term to a dose the model that is used is very simplistic and it doesn't handle source term distribution. So when we say can we do a simple model, well almost by definition to go from concentration to dose, yes we are.

In terms of doing a conservative analysis and what that might be, a real life case, university disposal site. The most common isotope, carbon-14. Default value for kd and RESRAD is zero. So over some licensed life if we have a kd of zero, the carbon-14 will have gone away. If, on the other hand, we assume to pick an arbitrary value of kd of 100, it would all still be there. So when we release that site which of those is a conservative analysis. That's the difficulty we address.

Now certainly for some cases if I have building or a room, a laboratory, that deals with sealed sources, the physical extent of source term is very clear, we can use the simple model. There just has to be the cautions as Tom and others have pointed out, the limitations of what is simple and certainly the definition of what is conservative. Thank you.

DR. HORNBERGER: Any of our speakers from earlier sessions, do they have anyone who wish to make any comments on that wrap-up question? I guess everybody has explored everything.

MR. BOLLINGER: I have one other.

DR. HORNBERGER: Sure.

MR. BOLLINGER: Jim Bollinger, Savannah River. One of the things that we discussed in our working group is the fact that if you're going to put a model together this really should be a highly iterative process. I know in a lot of the other engineering modeling it is that we go off to model something, some process that we think is relatively well understood and simple and of course, the experimentalists love to go into the lab and shame all of our modelers and come back with data that contradicts the model and then you realize that gee, I haven't capture all of the underlying physics. So I need to go another iteration. They need to go back to the laboratory and get some additional data, etc. and that certainly seems to be -- I mean the modeling that I've seen done at Savannah River, and there's some extraordinarily good examples, that's exactly what happened that an engineer working together closely with a hydrogeologist and geologist and geochemist because it is a team effort, they took the best data from the conceptual model, put together a transport model and then iterate it. You know you take your groundwater model. You run sensitivity studies to figure out what the first and second order of parameters are, what are the parameters that really impact transport and then you go back and ask the geochemist and the hydrogeologist how well do you really know these, how well do you really know the leakants in this aquitard or this vertical hydraulic conductivity because these modeling results are highly sensitive to those values. And if the uncertainty on those measurements is very large then that suggests that they need to go back out into the field and take additional measurements.

So I think if you're going to do this complex modeling correctly, it has to be iterative over time. Otherwise, you're not going to end up with predictions or forecasts that in the end are really worth very much.

DR. HORNBERGER: Yes, I think that -- Thank you, Jim. Now I think that's a message, one of the lessons, that we've heard repeatedly over the past two days and I think that it's a good lesson for everybody to keep in mind. You simply have to do it that way. That's the only way to accomplish the things that we want to accomplish.

I think we're at a point where I will turn it back to you, Jim.

MEMBER CLARKE: George, thank you. I think most of you if not all of you were here yesterday when George gave us the song that captured the first session, "Love and Marriage, they go together like a horse and carriage" and I have to admit that ever since he said that I've felt compelled to come up with a song myself.

(Laughter.)

MEMBER CLARKE: No, drummers don't sing. But I'm sorry to report that all I can think of is "Nobody Loves You When You're Down and Out."

(Laughter.)

MEMBER CLARKE: I just want to make a comment and then we'll go to the Committee and I think we'll mix it up and start with you, Mike. But the comment I'd like to make is I was glad to hear Jody mention "consequences" and I was glad to hear Jim mention "risk" and as you know, the NRC takes very seriously risk-informed performance-based decision making and I think that's a piece of this too. All of these sites are not equal. All these issues are not equal.

Risk and consequences especially on engineered systems, I think, really need to factor in and the monitoring needs to be risk-informed if there is the possibility for serious consequences and maybe you need to ramp up the monitoring. But just kind of my thoughts. So, Dr. Ryan.

CHAIRMAN RYAN: Jim, you live in Nashville. I'm surprised you didn't remember the old country song by Tex Ritter "Sit By The Window And We Will Help You Out."

MEMBER CLARKE: I can respond.

CHAIRMAN RYAN: George told me to say that.

MEMBER CLARKE: Just let me bring us back to reality, but as a sidebar here, I think you know that going on 20 years ago, Ann and I bought Tex Ritter's house.

CHAIRMAN RYAN: Anyway, this has been a fascinating couple of days and I'm trying to pull out some themes. One theme that I'm taking away is "one size does not fit all" on how monitoring and modeling work together. I mean I think about some of the experimental facilities we saw relatively small surface activities particularly in the ecology area. I remember those slides. There were relatively small disposal areas and testing areas and so forth as opposed to say the Hanford disposal cell that's the size of Rhode Island. You know it's a very big cell and will be in operation for a lot of years. A number of tanks in Idaho and the type of tanks versus the tanks at Hanford, there's a huge range from a small power plant to a relatively large facility with perhaps three units on it, shared facilities and piping and all that in between as opposed to one contained unit and the broad spectrum of NMSS issues and licensees both at the NRC level and at the state level.

So I think that my thought is that however guidance gets developed on this topic of how do you use modeling and monitoring with synergy, we have to remember that it probably needs to be binned in a way where you can address types of sites, not necessarily small, medium and large but maybe it's arid and humid as one kind of cut. Maybe it's small, medium and large within an environmental setting. Environmental setting is a great way to think about it because what you do in monitoring and modeling is probably very different in both of those. So I think we have to think of what's the taxonomy of sites and facilities that we have to develop to have this make some sense and break it down into chewable bites. So that's one.

The other is I think what we talked a little bit about yesterday and I think Eric spoke to it well on what is the compliance goal and how does the compliance goal relate to the technical business of calculating a dose or evaluating against some concentration reference or responding to what are the very appropriate questions, issues and pressures that come from the public and politics and other needs for environmental protection or other issues that may not be so analytic and crisp in our minds perhaps or other science minds from that standpoint. So we have to think about that.

And the third major theme I think we've heard an awful lot about experience in again various sites, various settings, various levels over the last two days and I just challenge the NRC to think about how do we capture it (1) again across the spectrum of taxonomies of sites and locations and then how do we, what I think is a very important forward looking activity which we haven't talked very much at all about is how do we get this experience into the guides that Jim is working on which is the how-do-you-prevent legacy sites. We never really made the distinction.

We're talking about sites where we intentionally put stuff and cover it up in the ground so it stays there for a long time in a way we like as opposed to sites where we dig stuff up and take it somewhere else because we don't want it in that part of the ground. So there's two different issues there and again that's part of my taxonomy question.

But I think we really need to think about how do we get this into the prevention of legacy sites and then as a former licensee if I do all those things to prevent legacy sites, what's my reward? What's my benefit? Do I have a lower institutional control cost? Do I have a reduced insurance rate? All those kind of things. That has to be factored into the guidance. When I get a thumbs-up that I'm doing things that are appropriate, what does that mean for me? Have I spent my money well and is there a long-term investment? Sure, there's a long-term benefit that I don't have to spend a lot of money down the line if everything works according to the way it should but that should also be recognized by those powers, authorities and interests that help me manage my risks as a business entity.

So with that, I think that's a good place for me to stop.

MEMBER CLARKE: Thank you, Mike. Allen.

VICE CHAIRMAN CROFF: I don't have any questions for this group, but I just want to underscore what both you and George have said on the risk-informing performance-based thing. You took the words out of my mouth.

MEMBER CLARKE: Thank you. Ruth.

MEMBER WEINER: I don't think cosmically the way other members of this Committee do. I tend to focus in on things. Listening to Tom Fogwell, I'm reminded that I first visited Hanford with my students in 1976. In 1986, I was on a committee to remediate or assess the risks of the buried tanks. In 1996 or 1997, I forget the year, I was on a committee to review the Columbia River Comprehensive Impact Assessment. There has been monitoring, subsurface monitoring, at Hanford for 60 years and even if you say, okay, the data weren't so good and if you go before 1957 before sodium iodide, you really can throw that away, it's still a lot of monitoring. It's all been done by the same agency, Pacific Northwest

Laboratories before it became PNNL.

And I happen to know this about Hanford. I don't know it about the other sites. So my question to the panel is what about all this monitoring that has gone before. It's facile to say "Oh, the data are no good. It's done with old instruments" and so on. But that's an argument that then goes every time there is a technical improvement in either data gathering or monitoring. You can say what went before was no good and we have to start over again.

What use is being made of the data that have been collected for the past sixty years and even beyond that? Those data must show something about the movement of radioactive contaminants and other contaminants offsite, something about impacts on human health. I know that they've done studies on the impacts on the flora and the fauna of the Hanford site. That's published work.

So I would like to ask particularly, Tom, with respect to Hanford, but I don't want to settle in on him, but the other members. What about these old data especially with respect to the DOE defense facility sites? We didn't just start monitoring last year.

MR. FOGWELL: I think it falls to me to at least begin the discussion. This is Tom Fogwell for Hanford. I would first start by saying that we could still use your expertise there I'm sure. We'll soon invite you out again so you won't feel that you've been left behind in all of this.

It is something of a frustration to me sometimes that we don't seem to use a lot of the historical data as much as we should. We do have an identified difficulty in actually keeping track of all the data that we have had in the past because it was stored under different conditions. Now we have computers. Before it was stored in files. I mean it takes some contractor to have a bundle of money in order to translate a lot of these things into another medium. Also we have several different databases at the moment.

We're attempting to address that problem with that data access network that I was describing. It still remains a frustration to me and I think we can always do better in that regard. So I hope that we will in the future in fact do better in bringing all that data to bear.

I'm also reminded though that sometimes people view data as being reality, but in fact, there are often times some difficulty with the data as well.

As a matter of fact, sometimes the modeling can show the difficulty in the data because as I was talking with Steve Yabusaki earlier, he's run across situations where they were measuring water levels that were below the Columbia River in the nearby aquifer which didn't seem very likely and so when they actually did modeling of the sites in the different places they discovered that the data didn't really make sense in this context and then they went back and redid the data gathering. But in fact, we don't use as much historical data as we probably should and it's because of the difficulty of access to that data basically.

MEMBER WEINER: But what about Savannah River? I mean the same situation must exist there. I just don't happen to know about it.

MR. RASMUSSEN: If I could say, Van Price -- Or do you want to?

MR. BOLLINGER: No, go right ahead.

MR. RASMUSSEN: Okay. There are a number of people at Savannah. Brian Looney and Van Price who were here, have been historical memory and I'd like to go back to that moon trip with the common filtering, the question of a dusting your trajectory as you move through time and the idea being is that having this historical legacy of data has been real valuable in terms of guiding our trajectory into the future and I have to credit the National Labs in terms of having this wealth of information as opposed to other sites that may not have that background trajectory.

Going where you've been over time is very helpful in predicting your future path. I mean the idea of keeping the goal of the future of where we're going with some ability to update that is key. So I think we build that in as best we can given our resources. The problem has been that we get a telephone book full of data every quarter, thousands of wells for hundreds of annolites and the manpower required to assimilate, it's like drinking from a fire hose. You just simply can't.

Now with computer technology, we need a new paradigm as Tom has said to develop those tools that allow us to assimilate the data and fit it with our models. The question is is that a bottom-up where we do it on our own from the grassroots. I mean we do that at the university for free for the site. Well, we get some money occasionally, but the idea is that it would be nice if it were a top-down directive where this was designed into the institutional structure.

MEMBER WEINER: I would also like you to

comment on the rest of my question and again referring particularly to Hanford. We really -- Good data or bad data, we really do have a very good idea of how those radionuclide plumes move, how fast they move, where they're going and so on even if it is within uncertainty bounds and I think it would be valuable to look at that historical record especially for these sites where there is a historical record and say what has the impact been. What has the impact been on offsite health, on onsite health and if you have to do it, on the environment and I would challenge you to do that.

Now I know that at Western Washington University where I was for many years is a federal repository. We have all of that data and I have had students combing through that for nothing as you say. That's the way we do things with undergrads. But I think that's the challenge that I would like to pose to you is looking at all of the collective monitoring that has been done, what impact has it had and I'll stop there.

MEMBER CLARKE: Okay, Ruth. Thank you.

MR. FOGWELL: Let me just respond.

MEMBER CLARKE: Okay, please.

MR. FOGWELL: This is Tom Fogwell again.

In contrast to the type of sites that Eric was mentioning before where they seldom get to hundreds of square miles, we in fact do have 600 square miles of potentially contaminated site and although it seems like we have a lot of data, the density of that data is not that great as it turns out. For instance, the BC cribs and trenches area, a potential heavy hitter with respect to pollution and therefore risk, it's pretty much unknown whether that material in the vadose zone has reached the groundwater or not and that's where I showed you that high resolution resistivity work where we're trying to come to grips with some of those things.

Getting new data is expensive. So certainly our preference is to use old, the previous existing data. We certainly have a preference in that direction because drilling a new well is just not cheap out there. But the density of the actual information is not as great as what you might think in spite of the, in absolute terms, great quantity that does exist.

MEMBER CLARKE: Thanks.

MEMBER WEINER: Thank you.

MEMBER CLARKE: Mr. Hinze.

MEMBER HINZE: Again, I gather that we're someplace between the Roundtable and the Panel Discussion.

MEMBER CLARKE: You noticed that.

MEMBER HINZE: George talked about the valley of death between research and application. I'm concerned about the valley of death that may occur between ideas, initiatives and innovations that we've heard here and guidance from the NRC. And that's something that I think this Committee needs to look into to address.

The guidance that the NRC needs to give I think it should, first of all, encourage new techniques, new ideas, new approaches and provide the opportunity for this to be acceptable to them. In the same vein, I think that one of the things that I've heard over and over again here and I think Mike mentioned this is the need for flexibility and non-prescriptiveness. I think that's one of the things we've heard. Geoprobes are really great. As someone said this morning, geoprobes are really great but only under very specific conditions. So I think we must worry about this valley of death if you will between the new approaches, the modeling and the monitoring, and seeing that go into guidance.

A second topic that we've heard over and over again the last two days are the words "iterative, feedback loops, staged studies." These are great things and we need them. But it really concerns me how we qualify that in the guidance from the NRC. How do we make that acceptable and how do we give guidelines?

For example, I'm not taking off on you, Tom, but Tom showed us a flowchart several times in his presentation, many, many times.

(Laughter and joking.)

MEMBER CLARKE: Tom, can we see that one more time?

MR. FOGWELL: It was an iterative process.

MEMBER HINZE: And basically it was one of those quadrilaterals that said are the uncertainties low enough. The question I have is how do you determine that. How do you settle on that and you don't want to be prescribe in guidance regarding that because you're dead in the water because of this range of sites that the NRC has to deal with. But you can't just leave that block there and say, "Are the uncertainties low enough that we can move on with the monitoring?" And then if we ask that question, the question is you have the feedback look going there, Tom and presumably you go back and collect more data and you do a better job.

My experience in this racket, this profession, is that we don't always decrease the uncertainties. We can feed more bucks into that, but we also have to be concerned about whether we can lower those uncertainties and we may just have to live with them and we need guidance on that. I guess I'll leave it at that.

CHAIRMAN RYAN: Bill, just a clarifying question to get some more of Bill's wisdom out on the table, it strikes me as you say that that I think the path forward is what we talked a little bit about yesterday which is what is the significance of the uncertainty to the risk you're trying to manage.

MEMBER HINZE: Right.

CHAIRMAN RYAN: I mean I think that's the string you have to pull a little bit and if it's significant to the risk, if that's going to mean below a limit or above a limit, that's a big deal. But if it's --

MEMBER HINZE: The ultimate use.

CHAIRMAN RYAN: Yes.

MEMBER HINZE: You know that kind of thing which came out. I thought that discussion right here at the end was extremely useful.

CHAIRMAN RYAN: I think maybe not so much or maybe a little bit in this meeting, but in past meetings, you know David Esh who does a lot of this performance assessment stuff has talked about that very thing. You know you focus on the things that are important to risk and if it's not so important, it's not important that I need to know it with the precision of something that is important to risk. Is that a fair summary, David, of things you've said? I'm just trying to pull out a practitioner who does a lot of this for a living.

MR. ESH: Yes, I think you hit -- This is David Esh. I think you hit the nail on the head. The problem with all this is the continuum of sites and conditions that we deal with. I mean Mark Thaggard tried to get across that many of our sites are very simple sites and we're talking about Bayesian updating and iterative approaches and some of these sites might not have a single measurement of practically anything. They don't know what a distribution coefficient is and so you're dealing with that situation. Then you're dealing with one of our most complicated decommissioning sites like West Valley with some of the most complicated problems and then we have our incidental waste work that we do and maybe low-level waste activities depending on where that goes.

So when we're talking about monitoring and how you integrate it with modeling and support modeling, we have to really recognize this continuum we're dealing with (1) and then (2) we really do try to use a risk-informed approach and whatever we do we want it biased toward the risk-informed approach. We're really emphasizing those things that matter and in the guidance that we come up with or the processes that we use. So I think it's a real challenge.

It's easy to get locked in and focus on your problem that you deal with at a certain site, but from my perspective down in the trenches, I see all the different types of problems and so when I was working on the guidance for concentration averaging for incidental waste, it seemed like it was a really simple problem, but when you got into it and you started adding in the differences and depth of material and scenarios, types of material, you ended up with all these permutations of things that you had to consider in the guidance.

The same thing applies here in this integration and monitoring and modeling. There's a large number of permutations that you need to consider and you have to be real careful you don't box somebody in, a guy like the first one that I mentioned that doesn't have any information on his site whatsoever and has a very simple problem and you're asking him to do something that's expensive that he shouldn't be doing. But then the other continuum, there are sites that have challenging problems and maybe have some resources. Those are the ones that should be applying this state-of-the-art to solve these types of problems.

MEMBER HINZE: You know I've done a count of the use of the word "risk-informed" at our meetings and I've come up with an average of 212 per day and I think in the last two days we've averaged three.

CHAIRMAN RYAN: What's the uncertainty on that number, Bill?

MEMBER HINZE: And so your point is well taken.

CHAIRMAN RYAN: Thank you, David.

MEMBER HINZE: Do we have time for another slather? I really appreciated something that Tom Fogwell presented and that was the trends in technological development. I think that's very important to us here and he had three things. He had kind of maximizing the value of maximizing the volume, enhancing the sensitivity and minimizing the intrusive nature.

I've had a reasonable amount of experience in true physics through the not years, but decades and those three things are not mutually connected. There are things which are the antithesis. If you want to increase the volume, you're going to do something to the sensitivity.

What I would suggest in terms of trends that we really need in technological development are those that enhance resolution and that may be with your sensitivity perhaps. It may be the same thing, but resolution is terribly important. And surface view physical methods are really great. They have a lot of application, but they are notoriously ambiguous and that certainly goes for ERT. We get these -- Just because they're colored diagrams doesn't make them right and they are beautiful diagrams but the resolution, the sensitivity, of those should be of high concern to us.

And the reason I say that is because I don't want, I prefer, not to see these things be oversold because that will really come back to catch you in the wrong place. So the way that things can be enhanced is I think what you were driving at, Tom, is this kind of connectivity between bore hole and geophysics.

By doing hole to haul or hole to surface you can really enhance the sensitivity, the resolution. You can have a fairly large volume and you minimize the sensitivity. But you have a hole. But there's a lot more that we can do with a hole. I guess I wanted to say that because I don't think we should oversell what we're trying to do.

MR. FOGWELL: Should I respond?

MEMBER CLARKE: Sure.

MR. FOGWELL: Okay. This is Tom Fogwell from Hanford. First of all, I agree pretty much 100 percent with what Professor Hinze has said. I didn't have a chance in my short talk to actually go into some of the details.

MEMBER HINZE: That was a short talk?

MR. FOGWELL: Some of the details that he managed to get into just now. But I certainly agree that there is a tradeoff between larger volumes and resolution and that's certainly manifested in these surface geophysical techniques. The deep you go the less you know basically for those. So they all have to be approached with a certain about of reservations and sensitivity to the fact that you need to worry a lot about what your signals mean.

And that raises the other issue too about the reliability of data in general. People call data reality and this is one example of "data" that has gone through so many assumptions in the inversion process which in fact most instrumentation does for that matter that there's a question about what the reality might be.

MEMBER HINZE: Good show.

MEMBER CLARKE: Okay. Thank you, Tom. I think I would like to take one more question from the Committee. Ruth, did you have one? Then I'll open it up and see where we are.

MEMBER WEINER: I just wanted to get back to something that Professor Hornberger said which was if a site can just apply RESRAD and that everything is okay. I can think of no more conservative scenario than the backyard farmer scenario nor a more unrealistic one. So it seems to me just getting back to that if you apply RESRAD and have some kind of limits, you know what the maximum and minimum input concentrations are, if that's all you need to do that's all that should be required. That was my point.

MEMBER CLARKE: Thanks. Go ahead, Eric.

MR. DAROIS: Let me just follow up to

that. I think that's fine for some of the sites and I'm representing the nuclear plant side of this. The only time that you get folks that can spell RESRAD is when you get into decommissioning.

(Laughter.)

MR. DAROIS: For the operating plants, there are really two problems. One is knowledge of this whole area, but the second is that of a standard. I mean we have, and I think we've discussed this before, the 20.2002 exemption request in the standard that's typically applied. There would be occupational exposure standards, certainly not resident farmer. So there's a little disconnect. You know you can get a 22.2002 approved today and 30 years from now it may be problematic because the standard is different. So I'll just share that with you.

MEMBER WEINER: Thank you for that.

MEMBER CLARKE: Thank you. Any other questions? Staff?

MR. FLACK: Yes. Jim, I'd like to just follow up on a few points that were made on this perspective mostly from the reactor side of things.

CHAIRMAN RYAN: Can you identify yourself?

MR. FLACK: I'm sorry. John Flack from ACNW staff. I guess getting back to the Commission

SRM about whether compliance monitoring helps provide confidence in the PA, it seems like it doesn't provide a whole lot of confidence because it's the data itself. I mean what are you collecting and how are you going to use that and it's going to require more than just compliance monitoring to provide confidence in the PA.

And so taking off on what Mike said earlier about what about new sites, if you were to think about a site now being created how would you go about monitoring that site after all we've learned here today and that gets back to guidance. Well, what guidance would you use to put monitoring in place so you understand the best way to monitor that site even if the site may be found to be unacceptable for some reason because it may turn out that things could get a lot worse if things got out of hand at other sites. And you may not even want to build it at that site.

So it comes back to, I think, looking forward as to what you expect from hereon out with respect to building new sites, if you could do it all over again, what would you do and then go back to the sites you have and look at them from that perspective and then of course there are all different kinds of sites there, some worse than others and so on, would probably be the way to go.

But we certainly need some guidance in this area and that goes back to basically the question again of the way we're collecting data today and for compliance can you use that to build confidence in the PA and it's almost like going back to reactors again and saying the reactors came a long way. They now have PRAs at all the plants but earlier on, they didn't and certainly we weren't monitoring releases to determine how well the plant was functioning inside. I mean we needed to know more about what was going inside and that created the PRA and now we do collect the data and the information that we need to provide confidence that that plant is operating well.

Well, it's not unlike this. I think you have to get more inside and get the right kind of data to understand if that sight is performing the way you expect and I don't think you're getting it now from this compliance monitoring. It's going to require more than that and I think that that was pretty much the message I got from the workshop.

MEMBER CLARKE: Thanks John.

DR. HAMDAN: Jim, can I --

MEMBER CLARKE: Just a second. I want to make a comment, Latif, and then I'll get to you. John brings up some things that I should mention. There are other initiatives that are going forward and as you know, Eric and others, the Lessons Learned Initiative from decommissioning, what are we learning now that we're at the end of the process that we wish we knew when we were at the beginning of the process? How can we use this information to design new facilities? How can we use this information to site new facilities and the prevention of Legacy Sites Initiative as well which actually is going to be rulemaking and guidance, how can we prevent these things from happening?

So there are a number of things going on that all of this will feed into and it's all very good information for it. Go ahead, Latif.

DR. HAMDAN: I'm sorry for the interruption, but just going back to Session 1, if we were to divorce monitoring from modeling, what else is out there that we can use to build confidence in models for ourselves and to sell modeling to other people? I mean is there any technical what else that we can do besides monitoring that will support modeling?

MEMBER CLARKE: Anyone? I think he's looking at Tom.

MR. NICHOLSON: Looking at me? Well --

MEMBER CLARKE: We should ask a Tom.

MR. NICHOLSON: I'll comment on both what John Flack and what Latif has said. They are proposing to build new reactors at old sites and the first question you have to ask yourself is what right now is both baseline and background for those existing sites. Do you know what's in the subsurface? Do you know what contaminants are there? And do you have a good understanding because if we build a new site, the first question that's going to be asked is what's the incremental additional risk that that new site is posing and if you do a performance assessment you have to understand the present conditions.

And so it goes back to Ruth's question about the history. I need to understand how that system has operated over the time period it's been operating and although there may not be onsite wells, there certainly are wells in the vicinity of that site and their radiological environmental monitoring programs both of surface water and springs and some sentinel wells we'll call them. That's what EPA calls them. So the argument is, yes, you have to look at that and come up with an understanding.

The models that I was talking about are

models that feed into performance assessment. I think performance assessment models do profit greatly by monitoring and to answer Latif's question, I can't think of what else you can do besides monitoring. Now my monitoring is not solely detection monitoring. When I think about monitoring, I think about building an information base, a technical base, to understand the various components of that system and how it behaves and you do not want to be surprised.

And there is quite a bit of information if you go back to the FSARs. There was a lot of good geology that was done. A lot of seismic information was collected. A lot of wells were put in. Also there's design basis groundwater at some of those sites in which they had the possibility of liquefaction. So there is a lot of information to bring up, what Ruth brought up before, a lot of data-mining that's possible. I don't restrict myself when I talk about monitoring to simply detection monitoring. I'm talking about the whole range of information at a site that is possible.

And finally, this summer I was very fortunate. I was allowed to go to a lot of sites and look at them because I'm part of this tritium task force. It's actually called The Lessons Learned Task

Force for Liquid Radioactive Releases and the thing you hear every time you go to a site is "This site is unique." Whatever you learned in your textbooks about hydrology/geology whatever, this site has unique features and you have to understand the environmental setting and the information that goes in hand with the surface water, the groundwater, the unsaturated zone, atmospheric deposition.

You go visit these sites and you learn an awful lot. So there is an awful lot of information already there. I think monitoring is extremely important and I think to minimize the value of monitoring is to say in effect "I'm somewhat comfortable in my lack of understanding in a system" and I'm not that comfortable.

MEMBER CLARKE: Thanks. Go ahead, George.

DR. HORNBERGER: So I'd like to take a contrarian view. I think that there are things that can be done to improve our confidence in models that does not rely site monitoring and I'll just give you an example, one of the things we were talking about last night having to do with surface complexation modeling for absorption of things like uranium in the uranium mill tailing sites.

I think one can make a pretty good

argument that we have a reasonable understanding of how these surface complexation models work but we don't necessarily have a full database on mineralogical controls. So one could argue, I could argue, I would argue, that if one did fundamental research, laboratory research, not onsite research, to develop a database so that we had a better understanding of what various oxyhydroxide coatings and various mineralogies, what the database was for such modeling, we actually could improve our confidence in modeling and not go to the site monitoring at all.

MR. ESH: This is Dave Esh. I agree with Dr. Hornberger completely. I think sometimes we get confused when we're talking about monitoring and model support. Monitoring has a certain role and it's maybe not the completely correct role at this point in time, but it's only a subset of model support we view it. Model support is a much bigger thing that takes into account laboratory experiments and field tests and natural analogues and even quality assurance of the calculations that have been done. There are multiple -- Well, we like to talk about multiple lines of evidence that develop confidence in the analysis. So I would agree wholeheartedly that there are other things that you can do besides just observing the system to develop confidence that you're making a good decision.

MEMBER CLARKE: Thanks. We have had a long and informative -- I'm sorry. Do you have a question?

MR. SHEPHERD: This is Jim Shepherd. Just to give you one example on that, at Sequoia Fuels which we've mentioned a number of times, Gary Starwalt and I did a simple model of the data, just an extrapolation and plotting. The licensee had an MT3 model developed of that same information and they were different. I don't think anything such as what you mentioned would actually resolve those differences. It was only a matter of going back and looking at the data and evaluating the model. So regardless how much confidence we had inherently in a model, we need that site specific information to determine the applicability of that model to the condition at the site.

MEMBER CLARKE: Is that a hand going up?

MR. DAROIS: Just a short hand. In order to not rely solely on a model, you need to make some pretty significant assumptions on what the source term is, whether it's active or passive, but you need measurements of the source in the subsurface environment. So in effect that's a measurement. So I mean you have to ground it somewhere I suppose. That's my only comment.

MEMBER CLARKE: Thanks, Eric. I was about to say I think we've had a great two days and we've had a lot of information and of course, our job is to distill all this and turn this into a letter if we choose to do that and I certainly recommend that we do that. If there are other questions, I certainly would entertain them, but I'm tempted to turn this back to you, Mr. Chairman.

And before I do that though, I would be remiss if I didn't give a thanks to all of you, the participants, the organizing team and Dr. Hornberger. It's been great seeing you and I know these two days you didn't have. So thanks very much.

CHAIRMAN RYAN: Thanks Jim and congratulations to you and everybody you've mentioned for a fabulous two days. I mean it's been a rich experience, I think, not only for the Committee in its work, but also for Research and its work and everybody in the audience. We got a packed house for a couple of days and that's always nice to see that there's a lot of value added for a lot of folks.

MEMBER CLARKE: And if I could add one comment. Many of you, I think, most of you, in fact, I only know of one person who couldn't, stayed for both days and I think that had an enormous synergy with the discussion. Each of you heard each other and it was very productive and again two days are hard to find for all of you and I really thank you for that.

CHAIRMAN RYAN: I think we've covered and we'll take one more round of any member comments we'd like to get in a minute, but I think we've all had a chance to offer summation and summary kinds of views. I certainly have and I don't know that I need or have anything particular to add to that. But let's go ahead and start. Jim, did you have anything in particular you wanted to say?

MEMBER CLARKE: No. I think there is a lot. We've heard several themes. I would be tempted to organize the letter around the session and the themes and that's going to take some thought as to how we do this, but I think we have plenty of things to look at.

CHAIRMAN RYAN: Okay. Ruth, any final thoughts?

MEMBER WEINER: Fine.

CHAIRMAN RYAN: I did learn that just

because it's in color doesn't mean it's right. I love it. I'll use it as a screen saver. But in all, I thank everybody who has been here even with head colds and all of the rest. It's been a really rich conversation for two days and, George, again thank you for coming across the country to be with us and we really appreciate your participation and your thought-provoking leadership here at the table. So with that, I think we are concluded on the record and we will be concluded for today.

(Whereupon, at 3:34 p.m., the above-entitled matter was concluded.)

CERTIFICATE

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

Name of Proceeding: Advisory Committee on Nuclear Waste 173rd Meeting

Docket Number: n/a

Location: Rockville, 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.

Charles Morrison
Official Reporter
Neal R. Gross & Co., Inc.

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UNITED STATES NUCLEAR REGULATORY COMMISSION'S

ADVISORY COMMITTEE ON NUCLEAR WASTE

September 20, 2006

The contents of this transcript of the proceeding of the United States Nuclear Regulatory Commission Advisory Committee on Nuclear Waste, taken on September 20, 2006, as reported herein, is a record of the discussions recorded at the meeting held on the above date.

This transcript has not been reviewed, corrected and edited and it may contain inaccuracies.

Evaluation of Subsurface Radionuclide Transport at Commercial Nuclear Power Production Facilities

Todd C. Rasmussen
The University of Georgia

James S. Bollinger
Savannah River National Laboratory

ANSI/ANS-2.13-1979

American Nuclear Society

evaluation of surface-water supplies for nuclear power sites

an American National Standard

ANSI/ANS-2.13-1979

published by the
American Nuclear Society
555 North Kensington Avenue
La Grange Park, Illinois 60525 USA

ANSI/ANS-2.17-1980

American Nuclear Society

evaluation of radionuclide transport in ground water for nuclear power sites

an American National Standard

ANSI/ANS-2.17-1980

published by the
American Nuclear Society
555 North Kensington Avenue
La Grange Park, Illinois 60525 USA

ANSI/ANS-2.9-1980

American Nuclear Society

evaluation of ground water supply for nuclear power sites

an American National Standard

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La Grange Park, Illinois 60525 USA




Preliminary Outline

Foreword

1. Scope and Purpose
2. Definitions
3. Assessment Methodology
   - Features, Events, and Processes
   - Data Collection and Storage
   - Incorporating Uncertainty
   - Assessment Updating
4. Site Investigations
   - Regional Environment
   - Site Characteristics
   - Facilities Characterization
5. Flow and Transport Modeling
   - Model Specification
   - Domain Specification
   - Analytical Method Specification
6. Monitoring Program
   - Monitoring Objectives
   - Monitoring Methods
7. Corrective Action
   - Response Threshold Definition
   - Alternatives Response Specification
   - Performance Evaluation

References

Current Plans

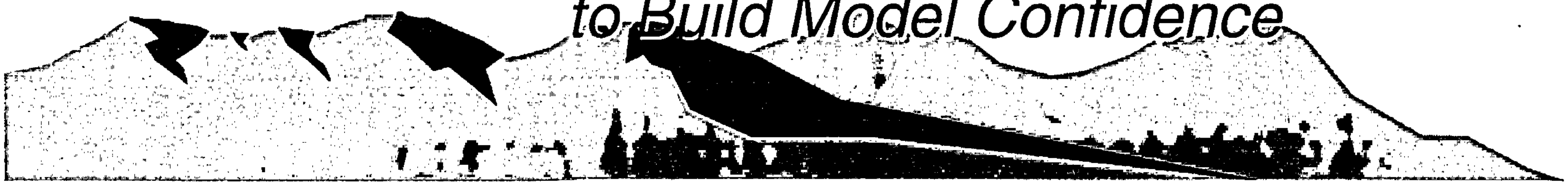
- Long-term (multi-year) process
- Incorporate extensive peer review and commenting prior to approval
- Solicit input and feedback from the technical and regulated communities
- Please contact the authors with information sources and experiences

Integrating Modeling and Monitoring to Provide Long-Term Control of Contaminants

Thomas W. Fogwell, Ph.D., P.E.
Energy Solutions - Fluor Hanford Team

20 September 2006

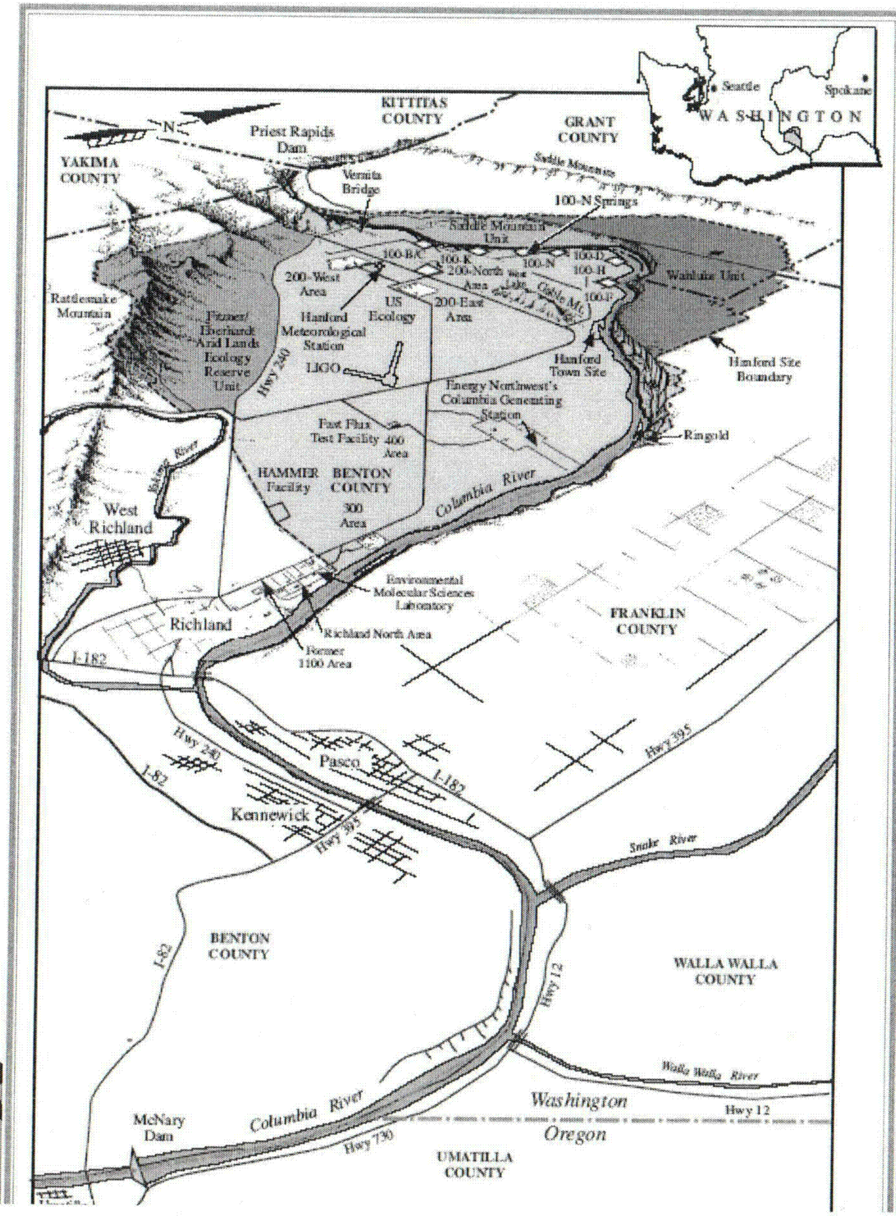
Advisory Committee on Nuclear Waste Working Group Meeting on Using Monitoring to Build Model Confidence



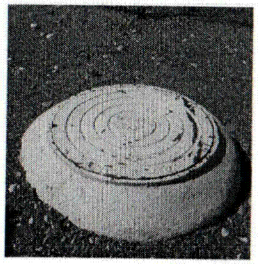
Outline

- Introduction to Hanford
- Paradigm for remediation showing integration of monitoring with modeling
- Examples of integration of the various parts
- Monitoring methods at Hanford
- Issues to address at Hanford
- Examples of integrated modeling-monitoring approaches

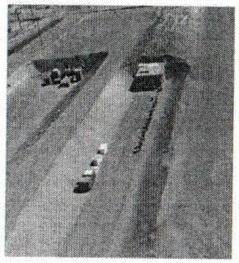
Overview of the Hanford Site



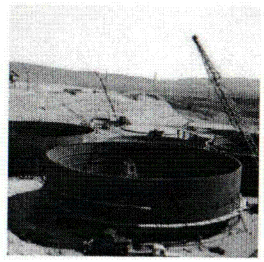
Sources of Contamination



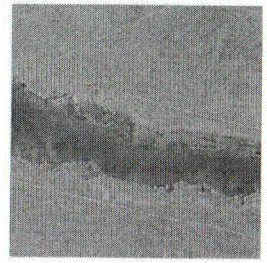
Reverse Wells
Also know as injection wells, reverse well systems served as disposal areas for liquid contaminants.



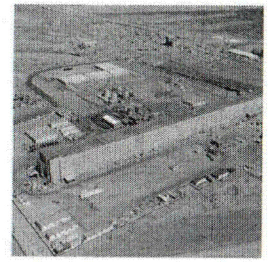
Landfills & Burial Grounds
Solid and liquid wastes in barrels were buried in unlined landfills and burial grounds.



Underground Storage Tanks
More than 53 million gallons of high and low-level waste was placed in 177 tanks at Hanford. Sixty-seven single-shell tanks have or are suspected to have leaked. It is estimated that past releases amounted to about 1 million gallons.

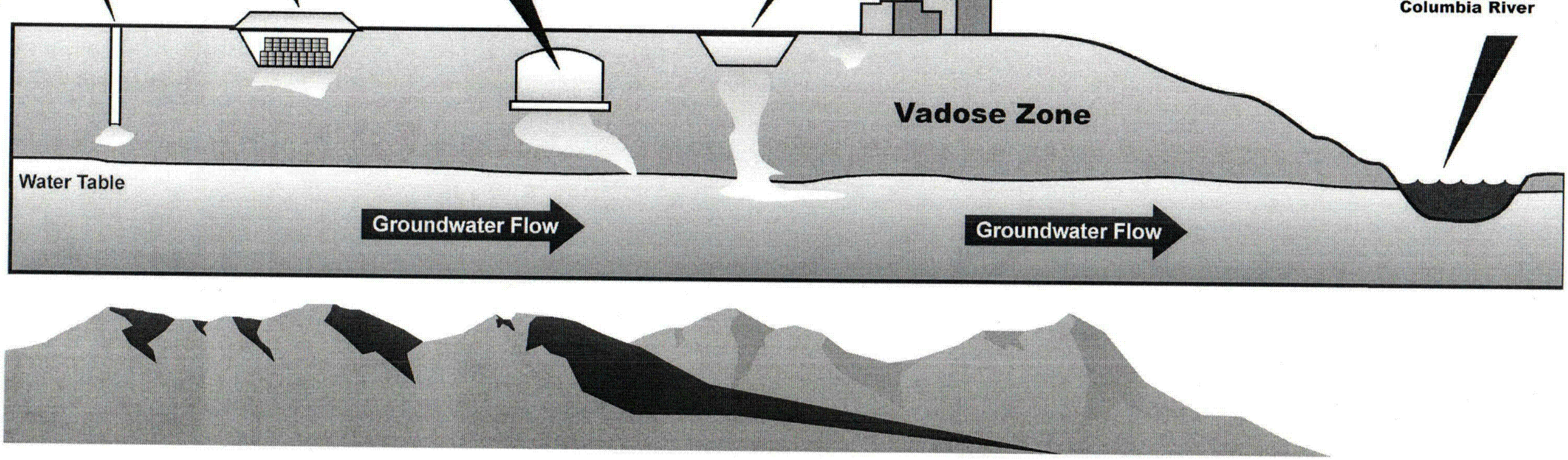


Cribs, Ponds, Trenches & French Drains
Cooling and waste water were directed to storage cribs, ponds, trenches, or French drains (perforated pipes allowing liquid to be released into rock-lined soil-covered trenches).



Plant Waste Discharge
Some facilities at Hanford disposed of waste directly to the soil outside the facility.

Columbia River

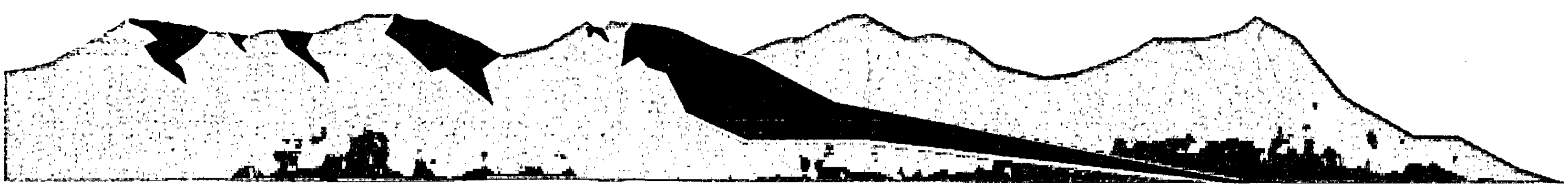


Hanford Compared to U.S. Nuclear Weapon Complex

- 42% (420 million curies) of 1 billion curies
- 60% (204,000m^3) of high-level waste
- 25% (1200) of waste storage and release sites
- 80% (2100MT) of spent fuel
- 25% (710,000 m^3) of buried solid waste

Remediation Strategies

Activities		Minimize
Characterization	$\Longrightarrow$	$\sum$ Costs of all Activities (Present, Probable)
Remediation		Subject to Constraints from Risks, Regulator, Uncertainties, Agency Requirements, - - -
Monitoring		



Answers to Questions

Defining the Problem

Q1. Are there any technical or programmatic reasons why compliance monitoring programs are not designed and compliance monitoring data are not used to support and enhance confidence in models after site characterization has been completed and a site has been licensed?

A1. There has not been an adequate paradigm developed and accepted by the both the regulatory community and the responsible parties to facilitate the use of monitoring data in the models used to evaluate performance.

Defining Opportunities

Q2. Do you know of any specific compliance and other monitoring programs and data at NRC-licensed facilities that could be used to improve models but are not currently used for that purpose?

A2. At Hanford, much more monitoring information could be used to improve models. Many of the sites under NRC pervue are also under RCRA closure requirements. This means the establishment a very prescriptive monitoring program that fails to have a mechanism for improving models.

Q3. What modification in compliance monitoring program design or additional data collection can practically and realistically be instituted so that most use can be made of the monitoring data to improve models?

A3. First, optimizing monitoring automatically entails linking the monitoring with modeling. If monitoring designs were required to be more efficient, thus requiring optimization, then the monitoring automatically becomes linked to modeling. Second, records of decision should be written to accommodate revisions in monitoring as better modeling evolves.

Defining Difficulties/Limitations

Q4. What are the technical and programmatic difficulties and limitations for integrating compliance monitoring programs and modeling at NRC-licensed facilities, with a view to make most use of the monitoring data to increase confidence in model results?

A4. There needs to be a change in the accepted paradigm. The technical pieces of the required paradigm already exist.

Summing Up

Q8. To sum up, do you have specific recommendations on how to improve the integration of compliance monitoring programs and modeling to increase confidence in model results for NRC-licensed facilities?

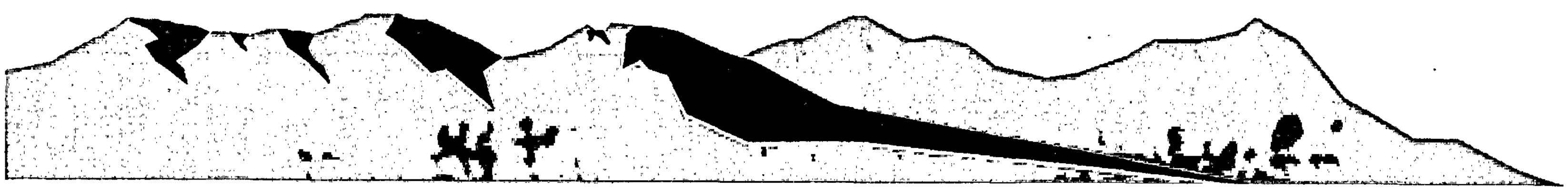
A8. Promulgate requirements to establish this integration as part of acceptable practice.

Q9. To sum up, do you have specific recommendations or suggestions on a path forward?

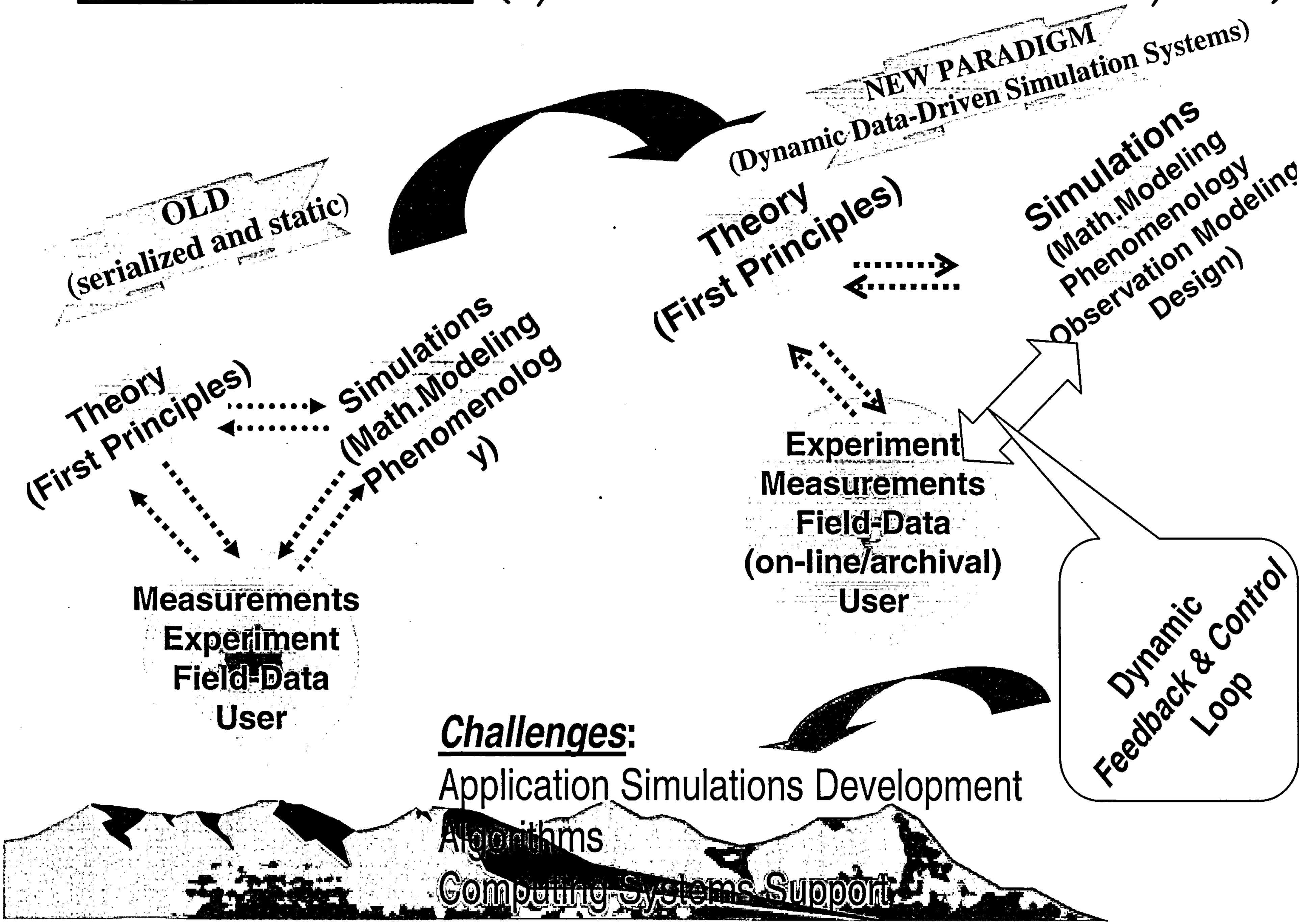
A9. Establish a system control approach with feedback loop as the method for using monitoring data to improve model reliability.

Dynamic Data Driven Application Systems (DDDAS)

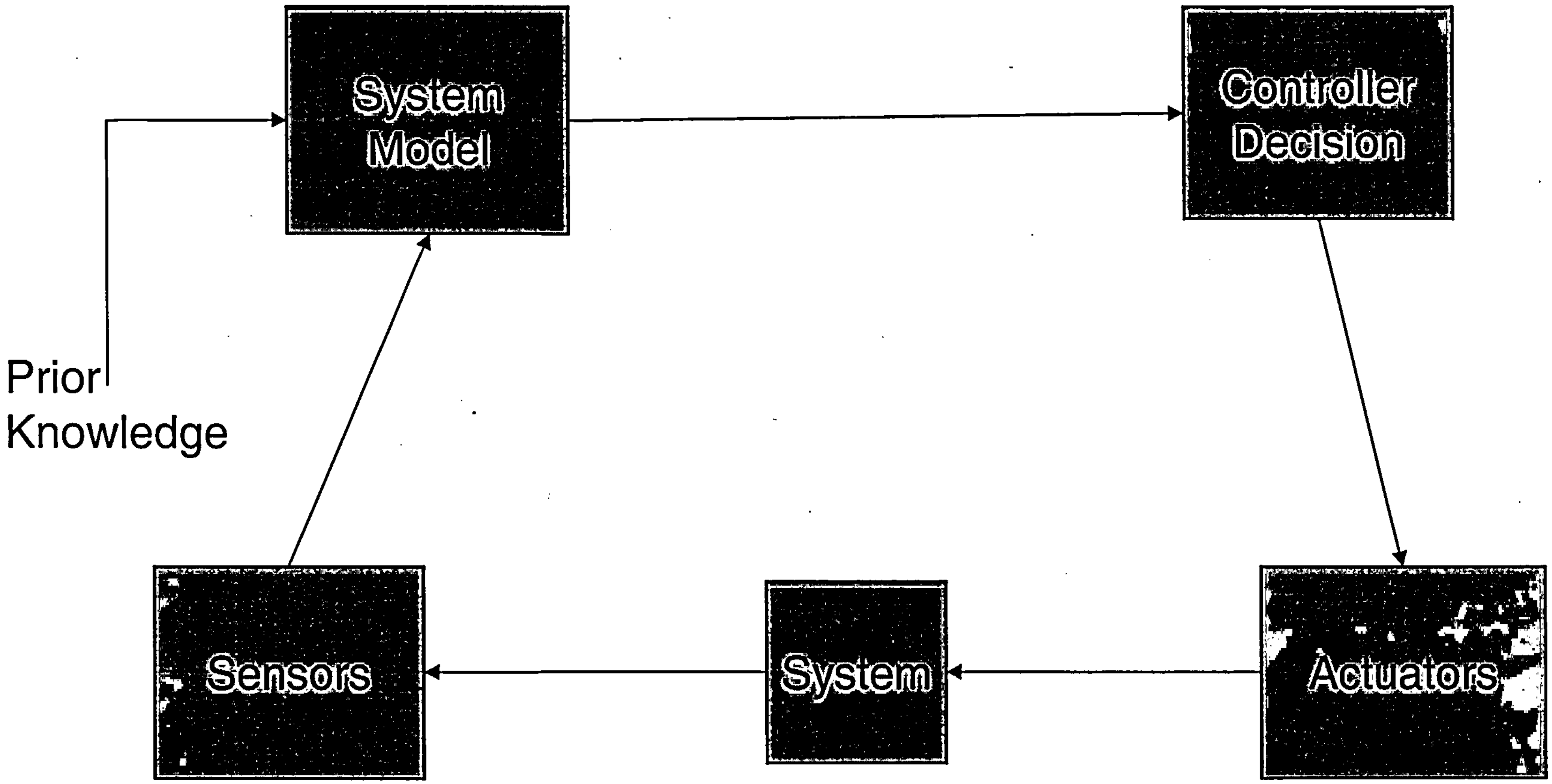
A new paradigm for applications/simulations <u>and</u> measurement methodology

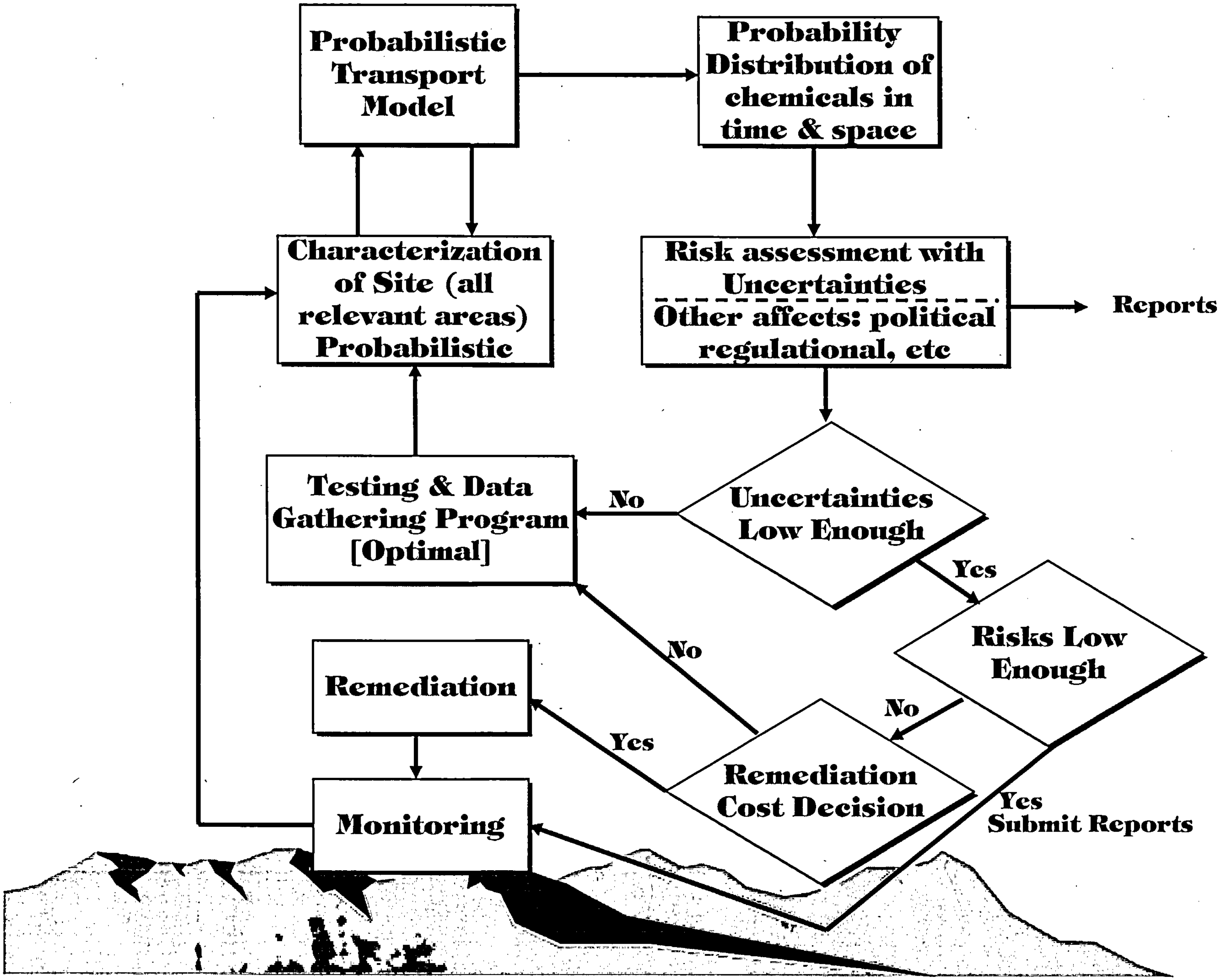


What is DDDAS (*Symbiotic Measurement&Simulation Systems*)



Adaptive Stochastic Control System with Feedback Loop




Probabilistic Transport Model
Probability Distribution of chemicals in time & space
Characterization of Site (all relevant areas) Probabilistic
Risk assessment with Uncertainties
Other affects: political regulational, etc
Reports
Testing & Data Gathering Program [Optimal]
No
Uncertainties Low Enough
Yes
Risks Low Enough
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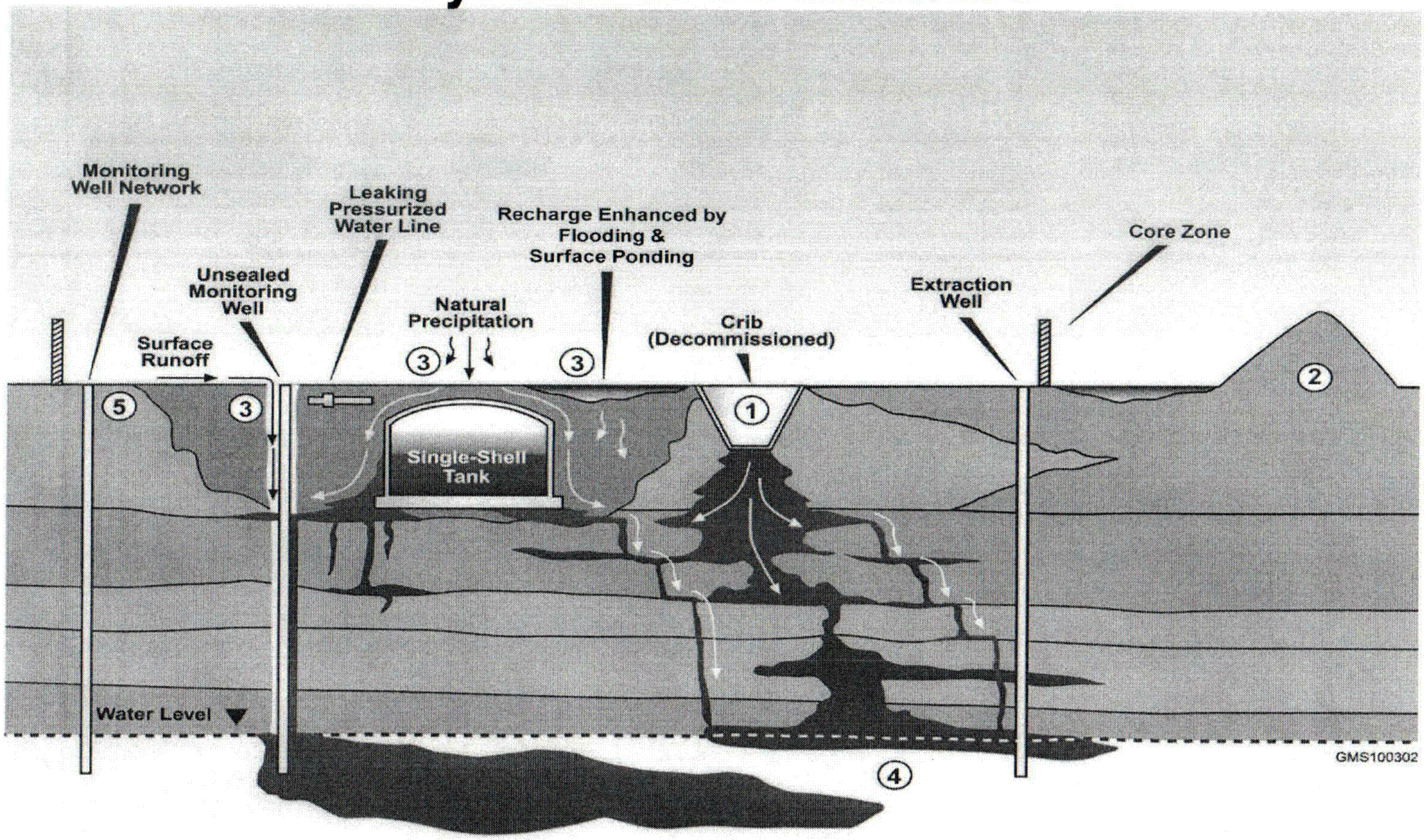
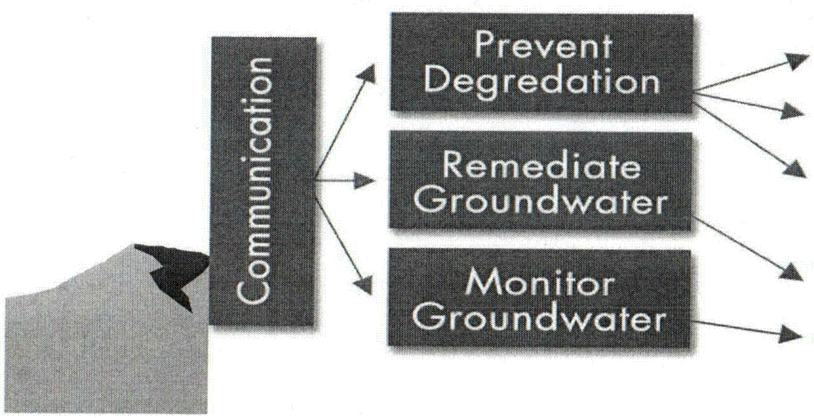
No
Remediation
Yes
Remediation Cost Decision
Yes
Submit Reports
Monitoring

System to be Modeled



Program Elements



Groundwater Protection Functional Areas:

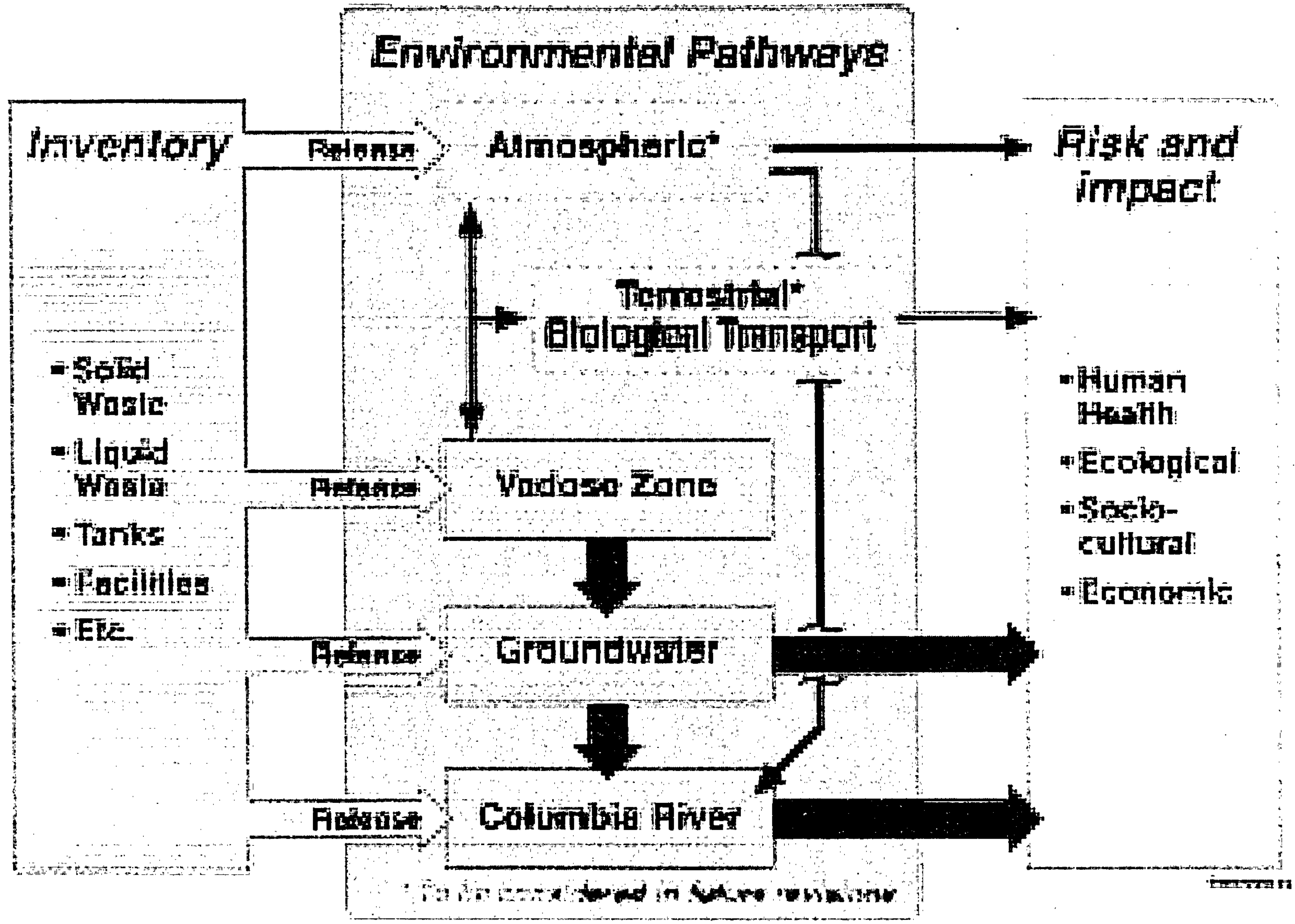
1 – Remediate high-risk waste sites.

2 – Shrink the contaminated areas.

3 – Reduce natural and artificial recharge.

4 – Implement final groundwater remedies.

5 – Integrate groundwater monitoring needs.


Environmental Pathways
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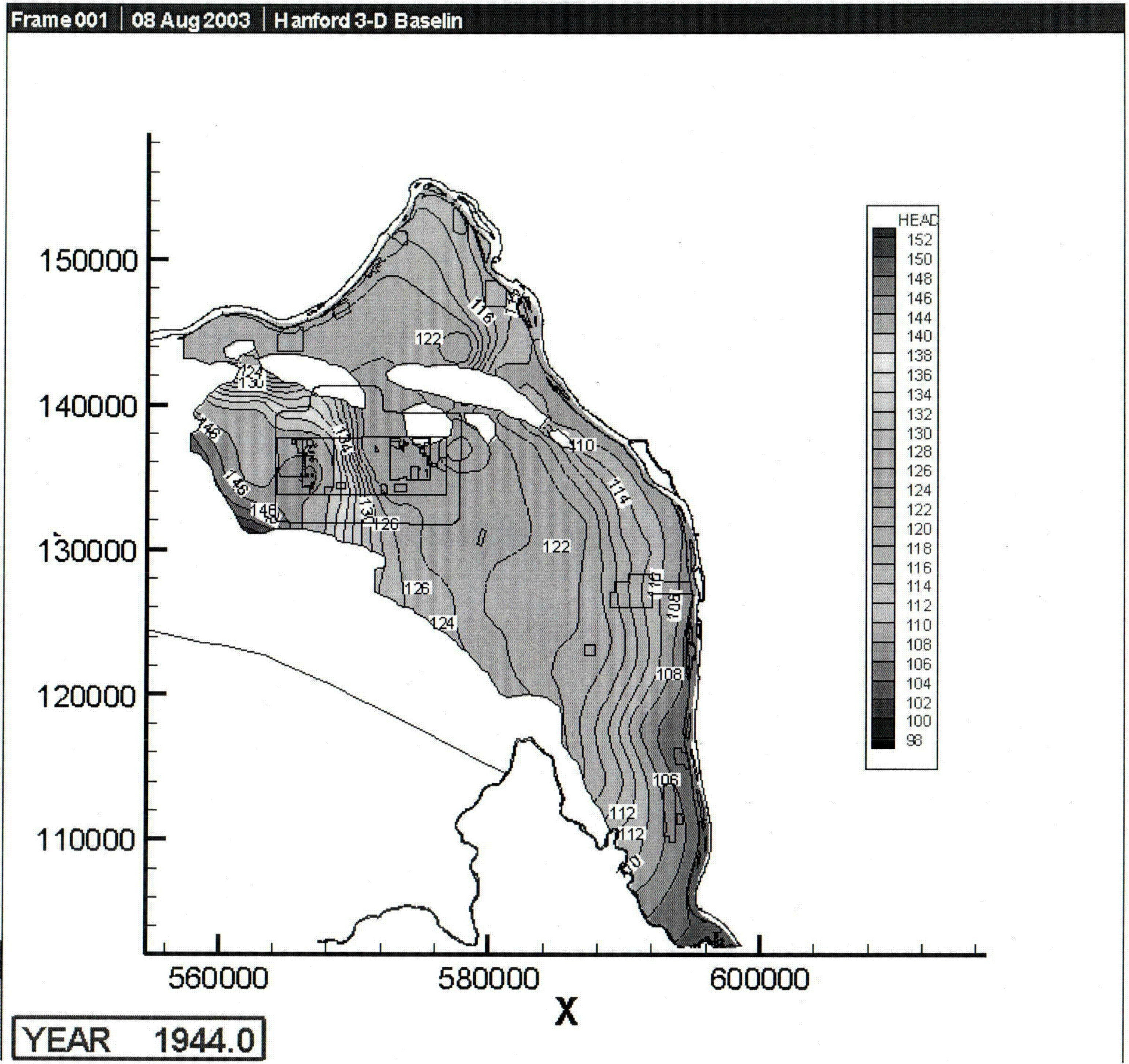
Atmospheric*
Risk and impact
Terrestrial* Biological Transport
Solid Waste
Liquid Waste
Tanks
Facilities
Etc.
Human Health
Ecological
Socio-cultural
Economic
Release
Vadose Zone
Release
Groundwater
Release
Columbia River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Panel on Decision Tools for Hanford Central Plateau

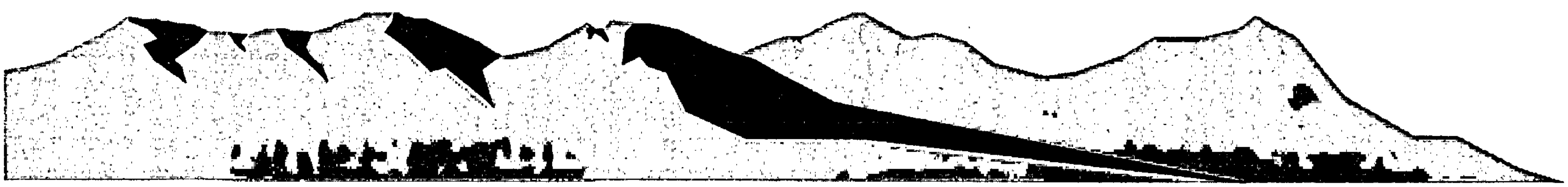
- Michael Celia, Princeton University
- Clint Dawson, University of Texas
- Dennis McLaughlin, MIT
- Shlomo Neuman, University of Arizona
- Dean Oliver, University of Oklahoma

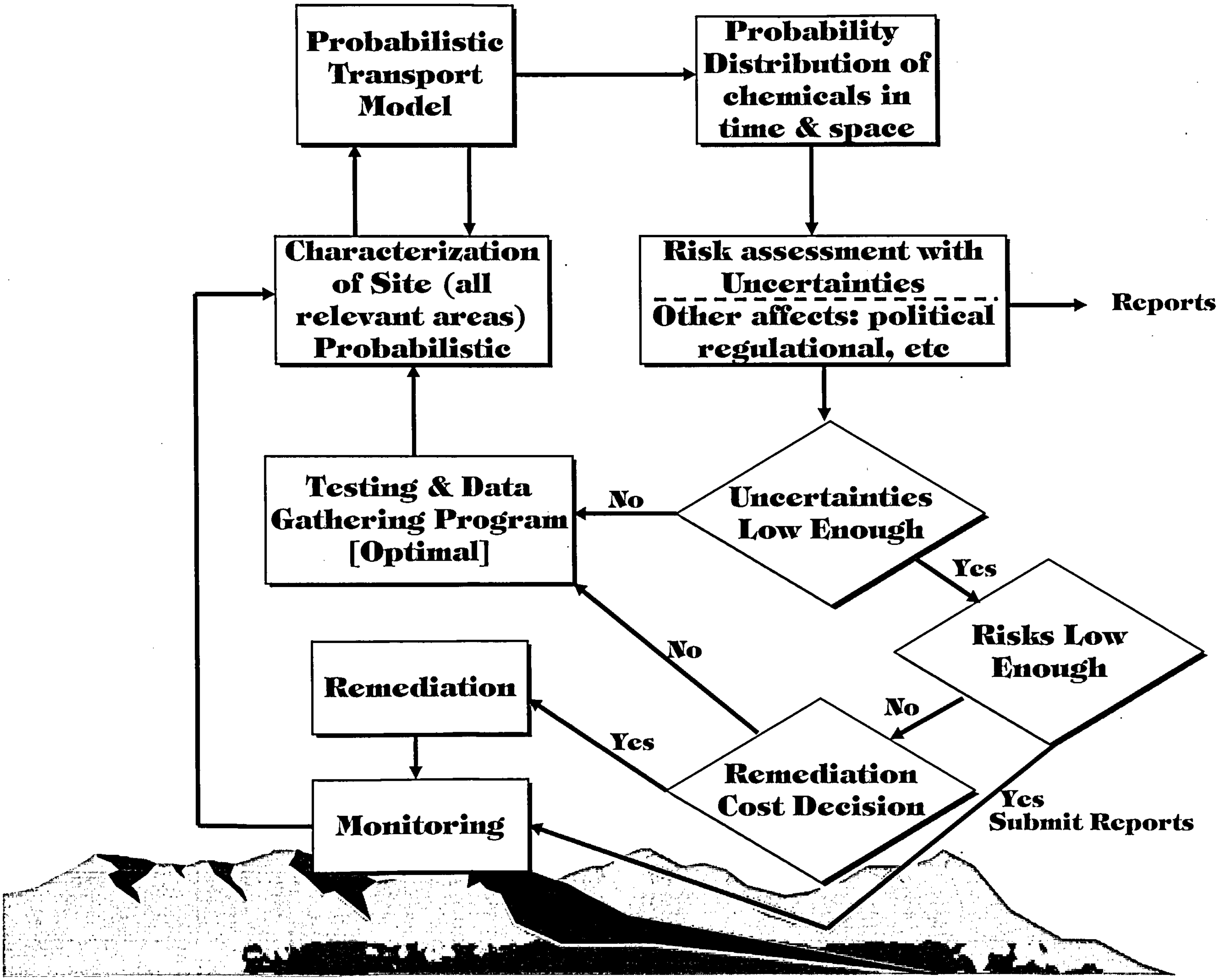
Issues Addressed

- How should uncertainties be handled? How should they be quantified and conveyed to the reader?
- How should the models be verified and calibrated? What role should history matching play in this process?
- What are the technical specifications for computational codes to be used in the decision process for the operable units?

Some Data Issues

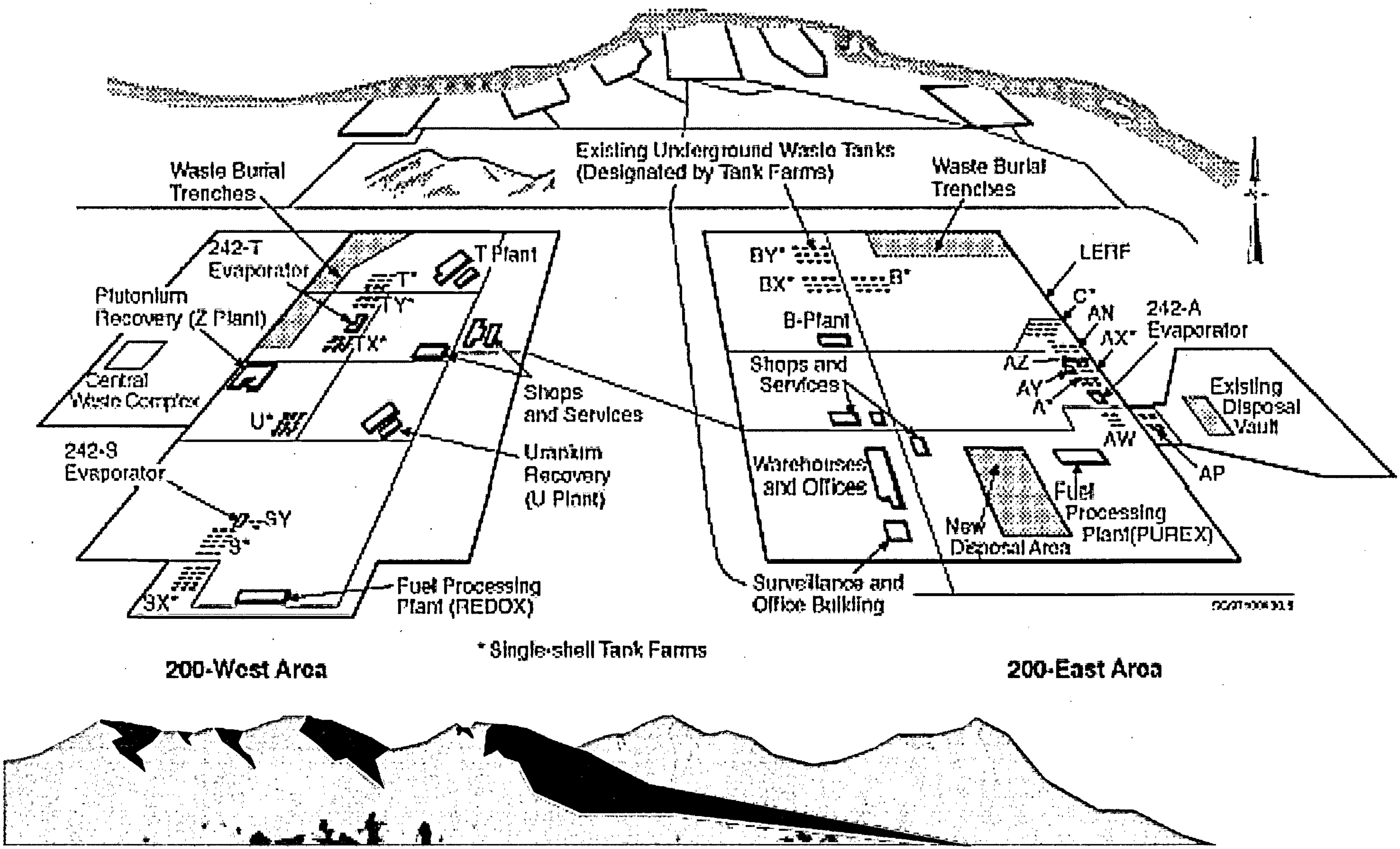
- Quantify measurement errors.
- Characterize spatial variability.
- Upscale/downscale data to common support or modeling scales.
- Quantify data and model input uncertainties.
- Investigate the incremental benefit of history matching in the vadose zone.

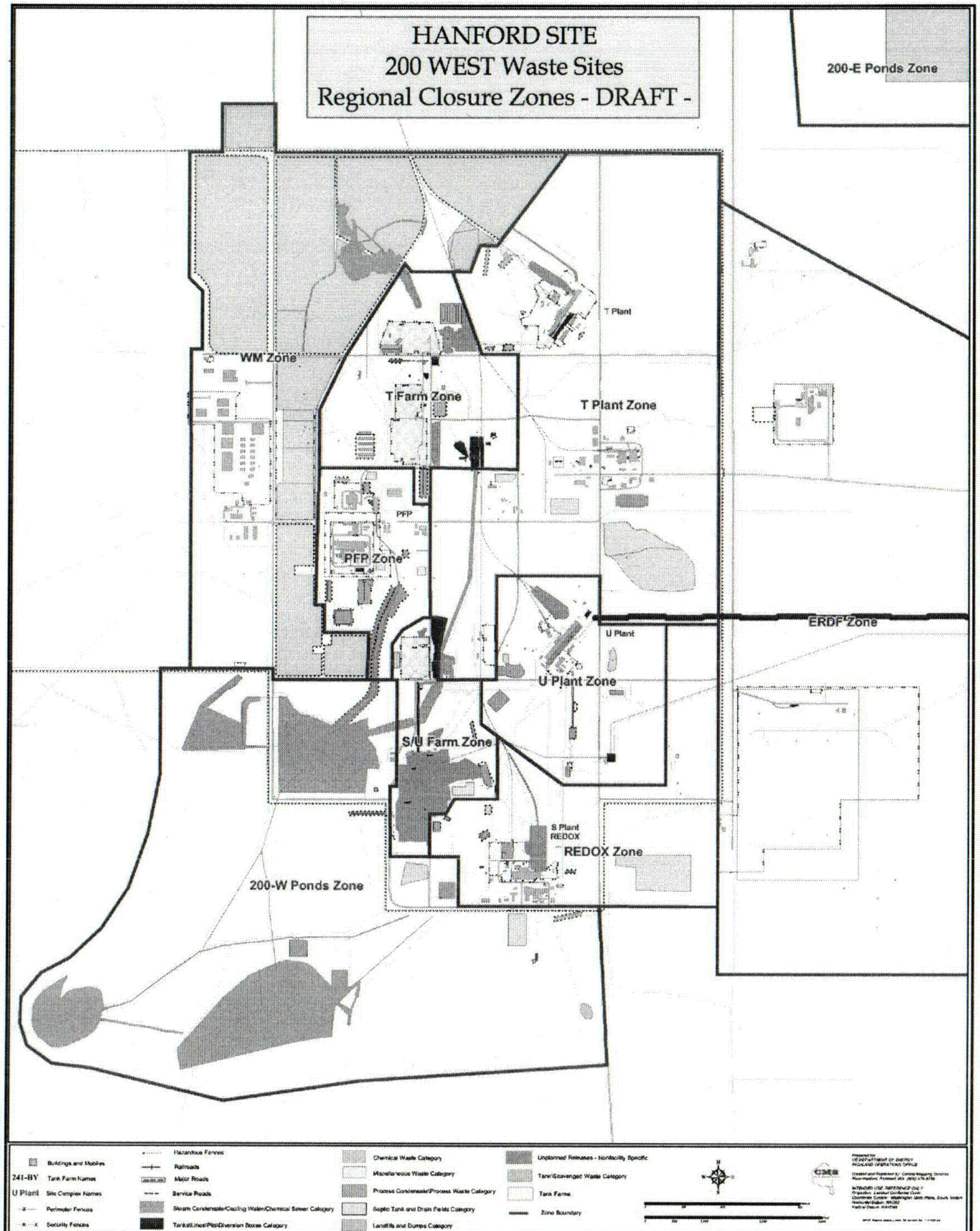




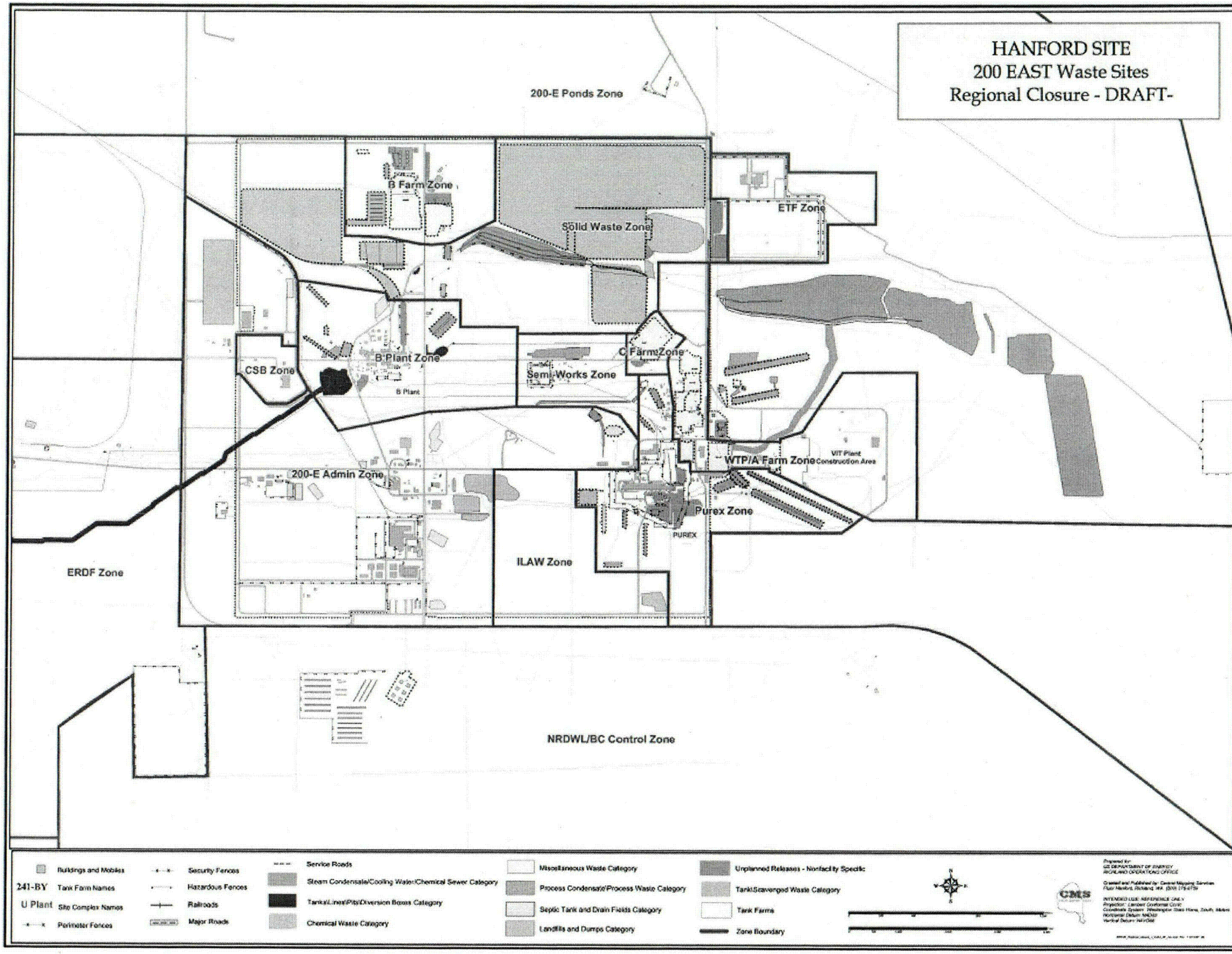
Probabilistic Transport Model
Probability Distribution of chemicals in time & space
Characterization of Site (all relevant areas) Probabilistic
Risk assessment with Uncertainties
Other affects: political regulational, etc
Reports
Testing & Data Gathering Program [Optimal]
No
Uncertainties Low Enough
Yes
Risks Low Enough
No
No
Remediation
Yes
Remediation Cost Decision
Yes
Submit Reports
Monitoring

Central Plateau





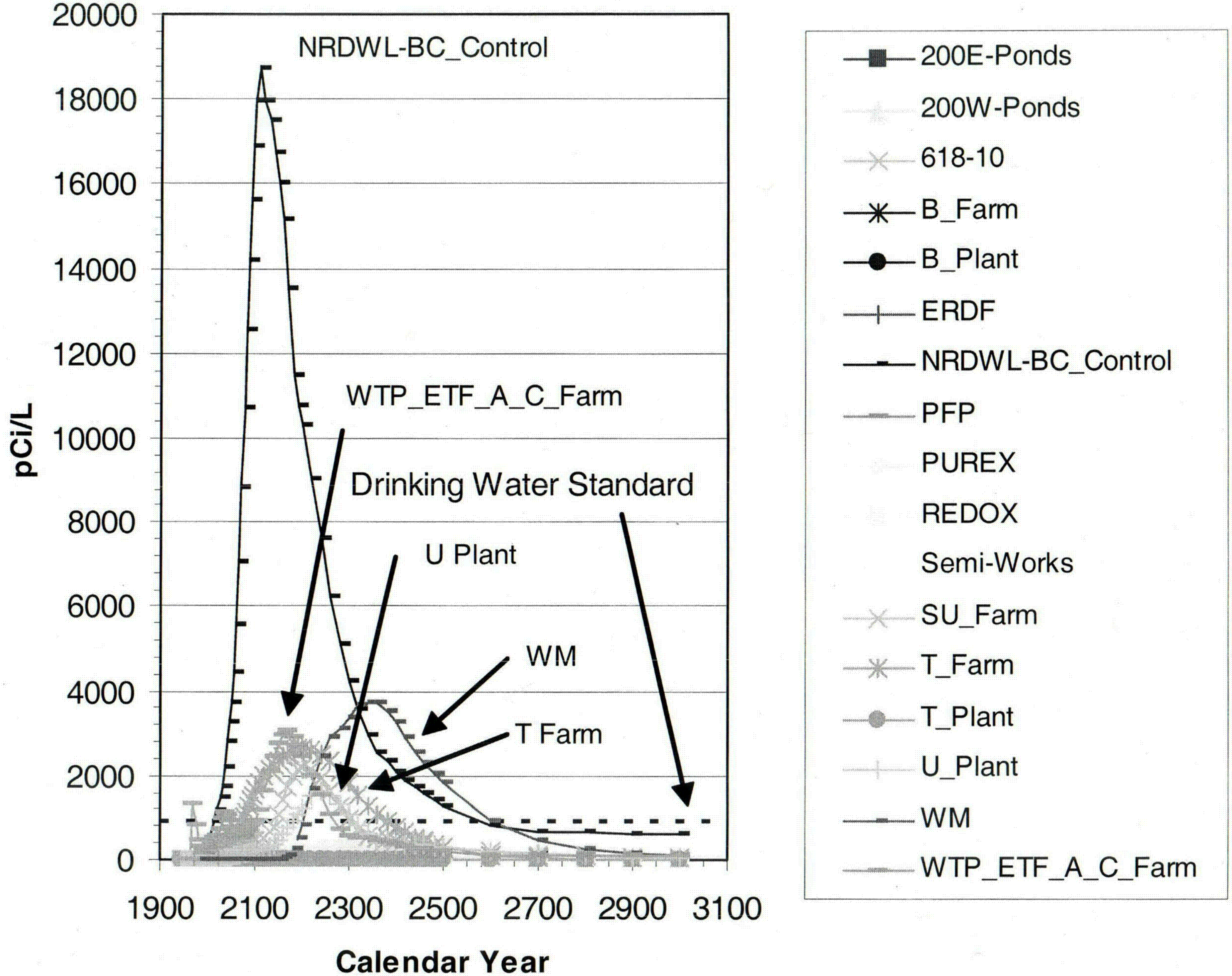
HANFORD SITE
200 WEST Waste Sites
Regional Closure Zones - DRAFT -
200-E Ponds Zone
WM Zone
T Farm Zone
T Plant
T Plant Zone
PFP
PFP Zone
ERDF Zone
U Plant
U Plant Zone
S/U Farm Zone
S Plant
REDOX
REDOX Zone
200-W Ponds Zone
Buildings and Mobiles
241-BY Tank Farm Names
U Plant Site Complex Names
Perimeter Fences
Security Fences
Hazardous Fences
Railroads
Major Roads
Service Roads
Steam Condensate/Cooling Water/Chemical Sewer Category
Tanks/Lines/Pits/Diversion Boxes Category
Chemical Waste Category
Miscellaneous Waste Category
Process Condensate/Process Waste Category
Septic Tank and Drain Fields Category
Landfills and Dumps Category
Unplanned Releases - Nonfacility Specific
Tank/Scavenged Waste Category
Tank Farms
Zone Boundary


HANFORD SITE
200 EAST Waste Sites
Regional Closure - DRAFT-
200-E Ponds Zone
B Farm Zone
Solid Waste Zone
ETF Zone
B Plant Zone
B Plant
CSB Zone
C Farm Zone
Semi-Works Zone
200-E Admin Zone
WTP/A Farm Zone
VIT Plant Construction Area
Purex Zone
PUREX
ILAW Zone
ERDF Zone
NRDWL/BC Control Zone
Buildings and Mobiles
241-BY Tank Farm Names
U Plant Site Complex Names
Perimeter Fences
Security Fences
Hazardous Fences
Railroads
Major Roads
Service Roads
Steam Condensate/Cooling Water/Chemical Sewer Category
Tanks\Lines\Pits\Diversion Boxes Category
Chemical Waste Category
Miscellaneous Waste Category
Process Condensate/Process Waste Category
Septic Tank and Drain Fields Category
Landfills and Dumps Category
Unplanned Releases - Nonfacility Specific
Tank\Scavenged Waste Category
Tank Farms
Zone Boundary
CMS

Preliminary Regional Closure Zone Priorities

CLOSURE ZONE See Figures 1-1 through 1-3)	Number of Locations Requiring Closure[1]	Future Groundwater Contamination Concerns	Intrusion Concerns (TRU Waste Residuals)	Radiological Cleanup Operations Concerns
Zone does not support Hanford cleanup operations				
U Plant Zone	103	^{99}Tc, U, ^{129}I	U	-
Non Radioactive Disposal Waste Landfill and BC Cribs (NRDWL/BC) Control Zone	37	^{99}Tc, ^{129}I	-	-
PUREX Zone	224	^{129}I, H_3	Pu	Pu, Cs, Sr
Plutonium Finishing Plant (PFP) Zone	133	Pu, CCl_4	Pu	Pu
C Farm Zone	53	^{99}Tc	Pu	Pu, Cs, Sr
B Farm Zone	119	^{99}Tc, U, ^{129}I	Pu	Pu, Cs, Sr
T Farm Zone	144	$^{3}H \cdot {}^{99}Tc$, ^{129}I	Pu	Pu, Cs, Sr
618-10 & 11 Zone	4	^{3}H	-	Pu, Cs, Sr
Fast Flux Test Facility Zone	90	-	-	-
Semi-Works Zone	48	-	Pu	Pu, Cs, Sr
200 West Ponds Zone	37	U	Pu	-
Zone supports Hanford cleanup operations & opportunities exist to alter plans and allow earlier cleanup				
B Plant Zone[4]	205	^{90}Sr, ^{137}Cs, Pu	-	Cs, Sr
East Ponds Zone[5]	72	^{99}Tc, ^{90}Sr, ^{129}I	-	-
Zone supports Hanford cleanup operations				
Reduction Oxidation (REDOX) Zone[6]	141	^{129}I, ^{3}H	Pu	Pu, Cs, Sr
T Plant Zone	184	^{3}H, CCl_4	Pu	Pu, Cs, Sr
Waste Management Zone	87	^{99}Tc, U	Pu	Pu
S/U Farms Zone[7]	155	^{99}Tc, U	Pu	Pu, Cs, Sr
Environmental Restoration Disposal Facility (ERDF)	64	-	-	-
Waste Treatment Plant and A Farm (WTP/A Farm) Zone	234	$^{3}H \cdot {}^{99}Tc$	Pu	Pu, Cs, Sr
Solid Waste Zone[8]	48	-	Pu	Pu
Immobilized Low Activity Waste (ILAW) Zone	3	^{99}Tc, U, ^{129}I	-	-
200 East Administrative Zone	145	-	-	-
200 Area Effluent Treatment Facility (ETF) Zone	11	-	-	-
Canister Storage Building (CSB) Zone	13	-	-	-

Tc-99 at Zone Boundary with no Covers

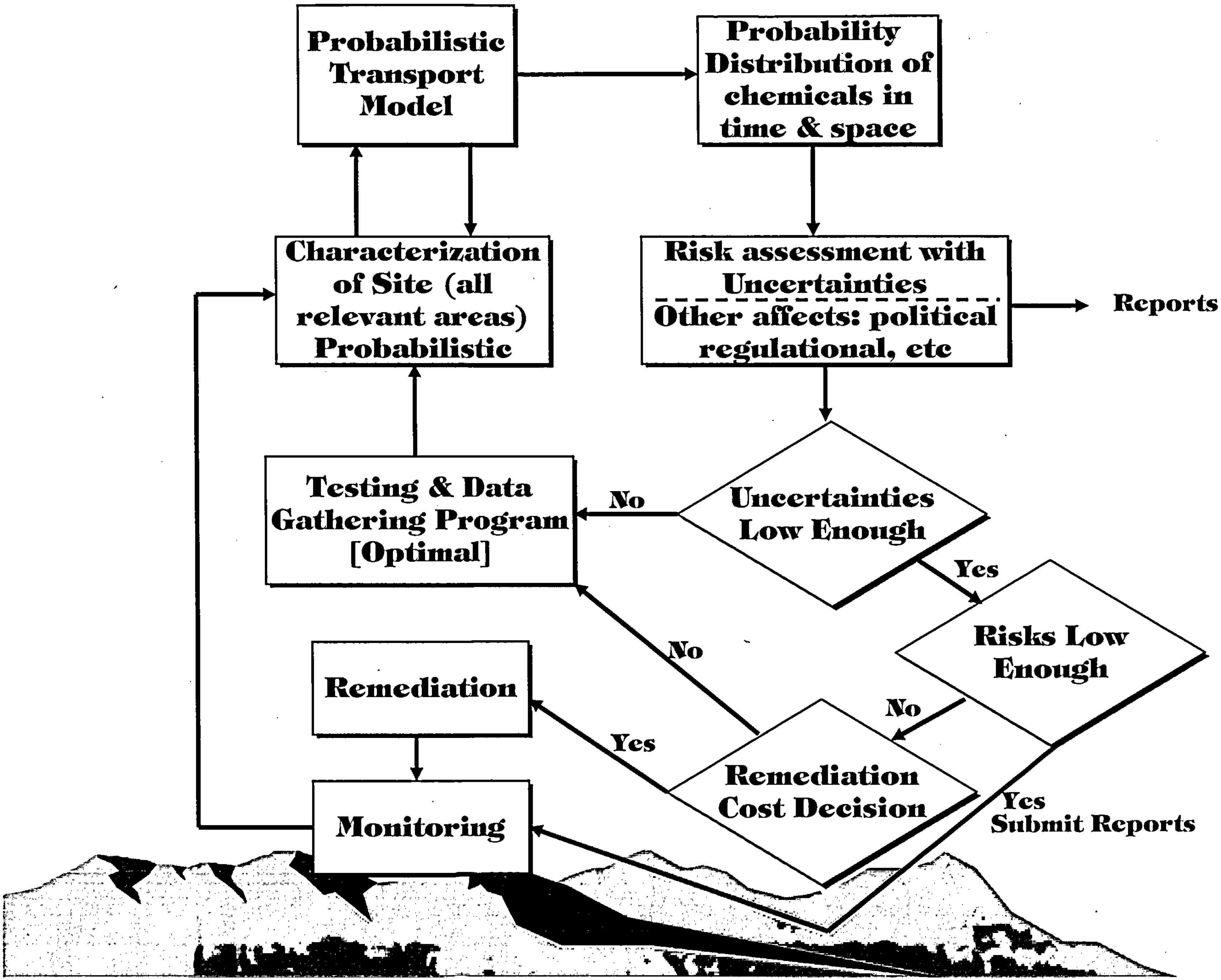


Future Remediation technologies (integrated point of view)

- Removal and disposal actions
  - Moving contaminated material
    - Phyto-remediation of strontium-90
  - Vitrification of wastes
  - Grouting of wastes
  - Excavation of waste and removal of materials to WIPP
  - Pump and treat groundwater
    - Increase capacity with EC Soil vapor extraction
    - Six-phase heating Enhanced volitalization of chlorinated hydrocarbons

Remediation technologies (integrated point of view)

- Immobilization of contaminants left in place
  - Sequestration of contaminants through a chemically reactive zone
    - ISRM
    - Near shore strontium-90 infiltration barrier
    - Micron-sized elemental iron injection
  - direct application of reacting chemicals
    - Calcium polysulfide injection
    - Bio-reduction of chromium
    - Polyphosphate injection for uranium
    - Bio-degradation of carbon tetrachloride
  - Reduce or eliminate water flux to groundwater
    - Caps on landfills (enhanced design capabilities)
    - Desiccation


Probabilistic Transport Model
Probability Distribution of chemicals in time & space
Characterization of Site (all relevant areas) Probabilistic
Risk assessment with Uncertainties
Other affects: political regulational, etc
Reports
Testing & Data Gathering Program [Optimal]
No
Uncertainties Low Enough
Yes
Risks Low Enough
No
No
Remediation
Yes
Remediation Cost Decision
Yes
Submit Reports
Monitoring

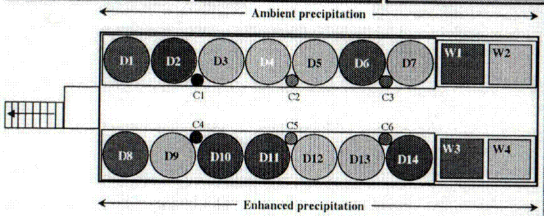
Types of Conditions Needing VZ Instrumentation for Characterization & Monitoring

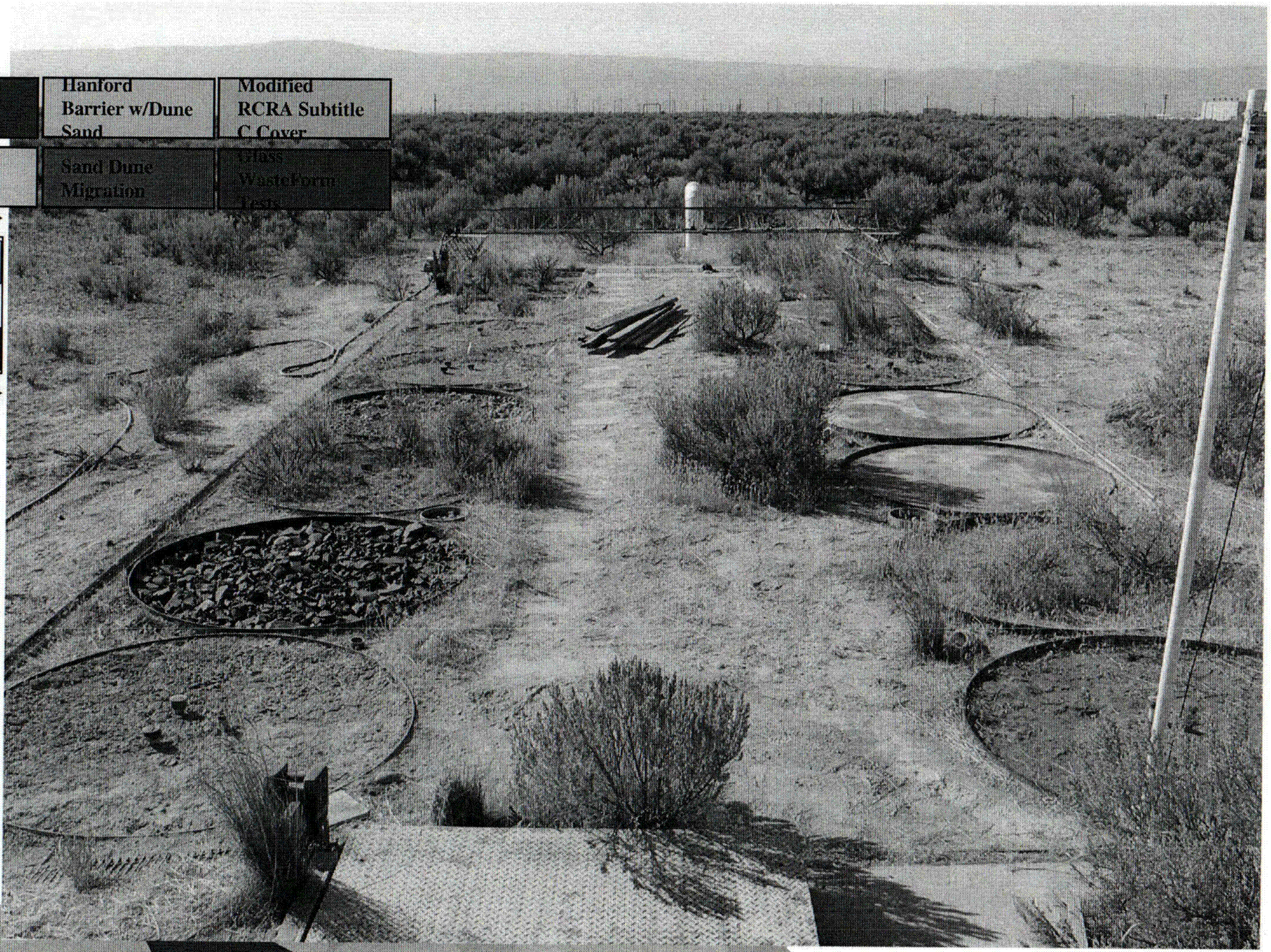
- Waste Sites (Cribs and Trenches)
- Tank Farm Sites
- Canyon Buildings (Reactor buildings)
- Disposal Facilities (ERDF and IDF)
- Liquid Effluent Retention Facilities
- Low-Level Burial Grounds

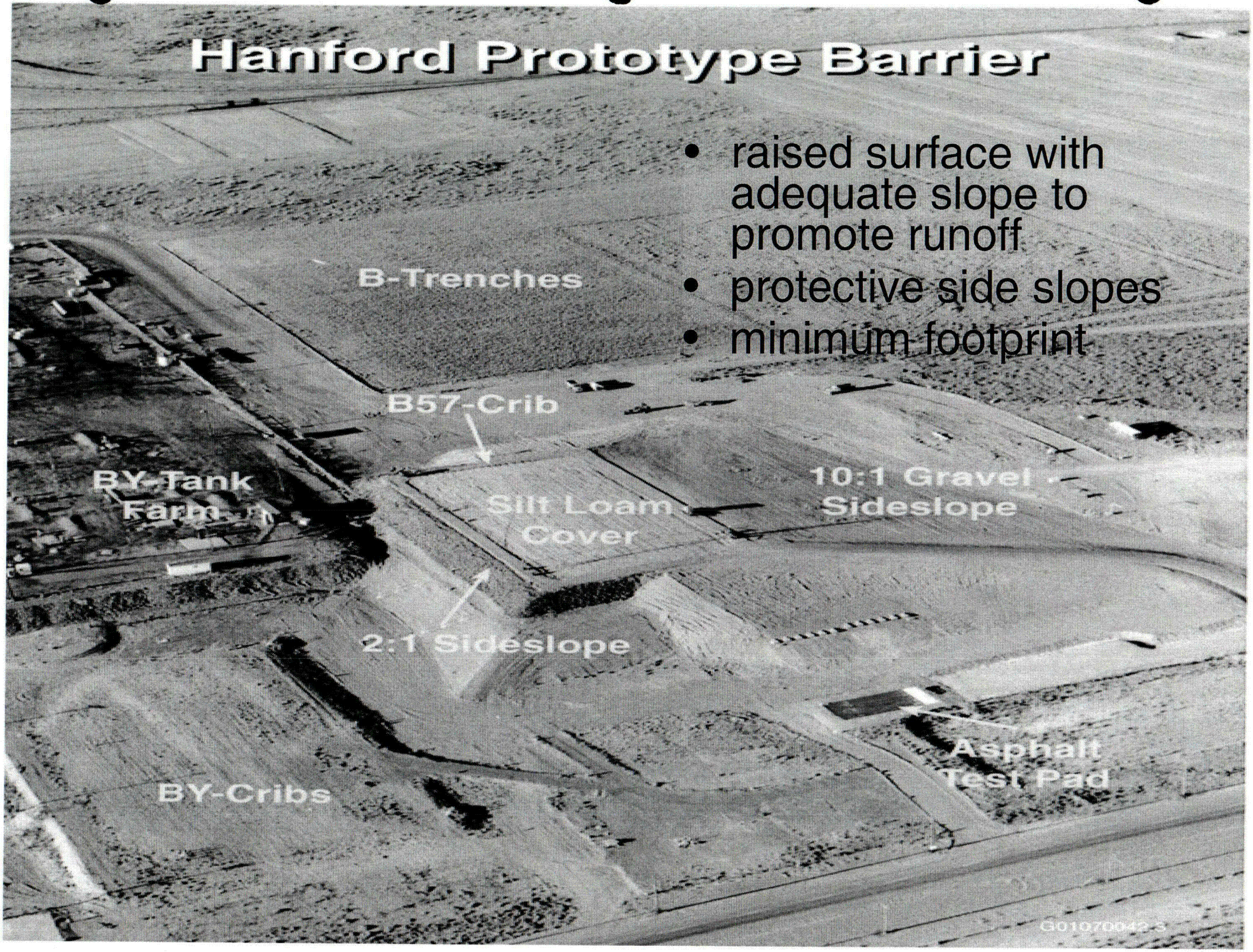
Field Lysimeter Test Facility (October 2003)

► New Test Matrix

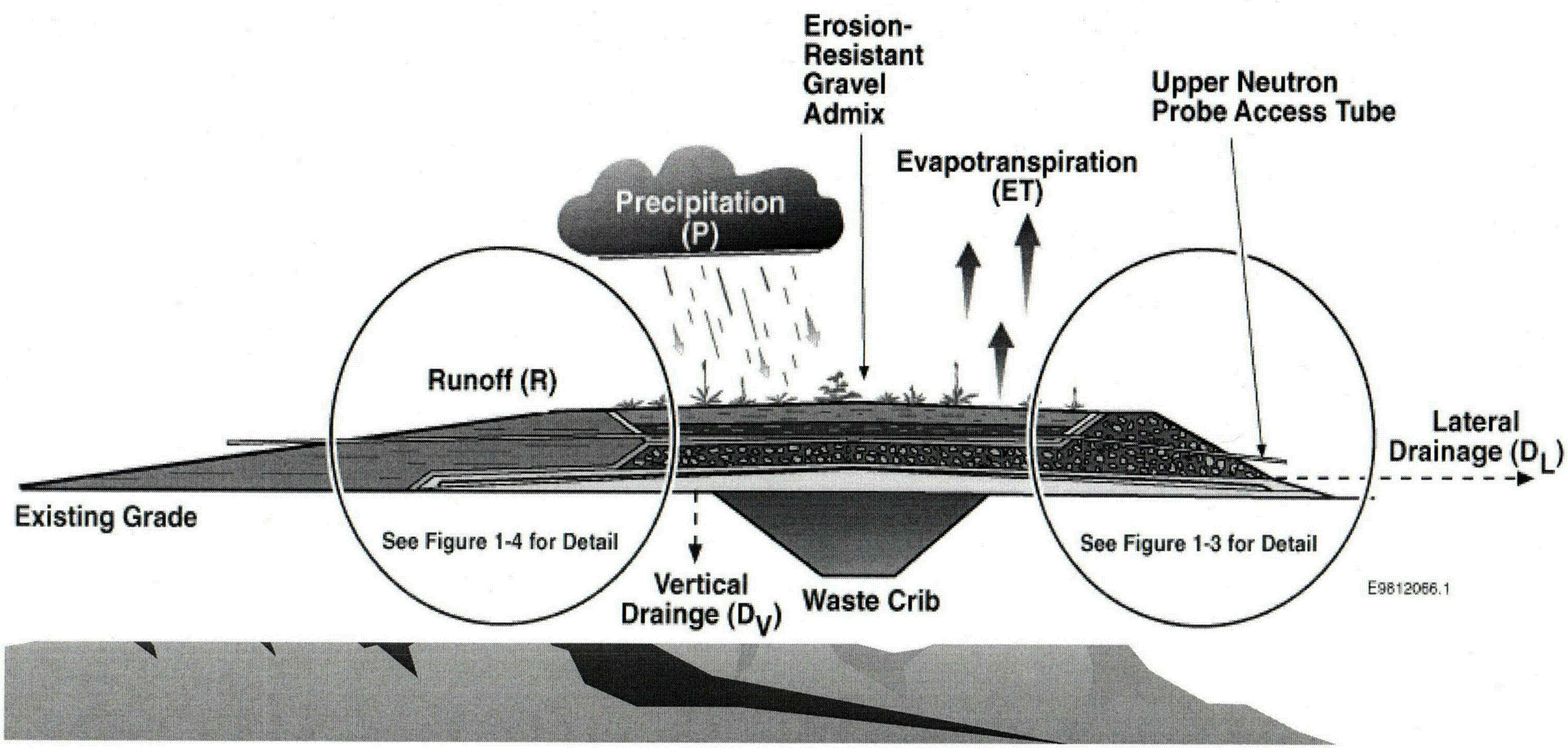
Hanford Barrier		Basalt Sideslope	Hanford Barrier w/Dune Sand	Modified RCRA Subtitle C Cover
Eroded Hanford Barrier	Pitrun Gravel	Sandy Gravel Sideslope	Sand Dune Migration	Glass Wasteform Tests





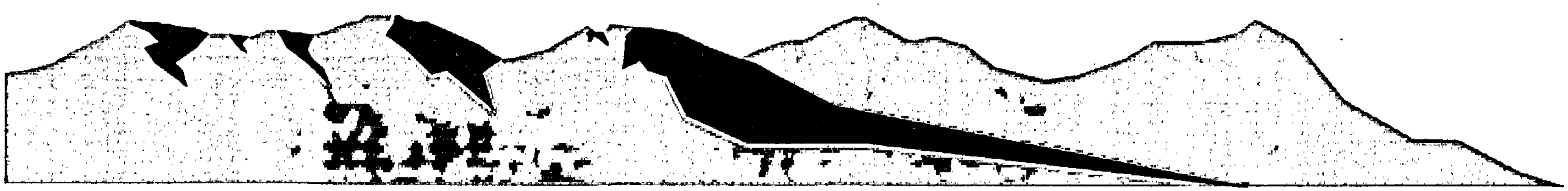

Hanford Prototype Barrier
• raised surface with adequate slope to promote runoff
• protective side slopes
• minimum footprint
B-Trenches
B57-Crib
BY-Tank Farm
Silt Loam Cover
10:1 Gravel Sideslope
2:1 Sideslope
BY-Cribs
Asphalt Test Pad
G01070042-3

Prototype Surface Barrier
(vertical cross-section)

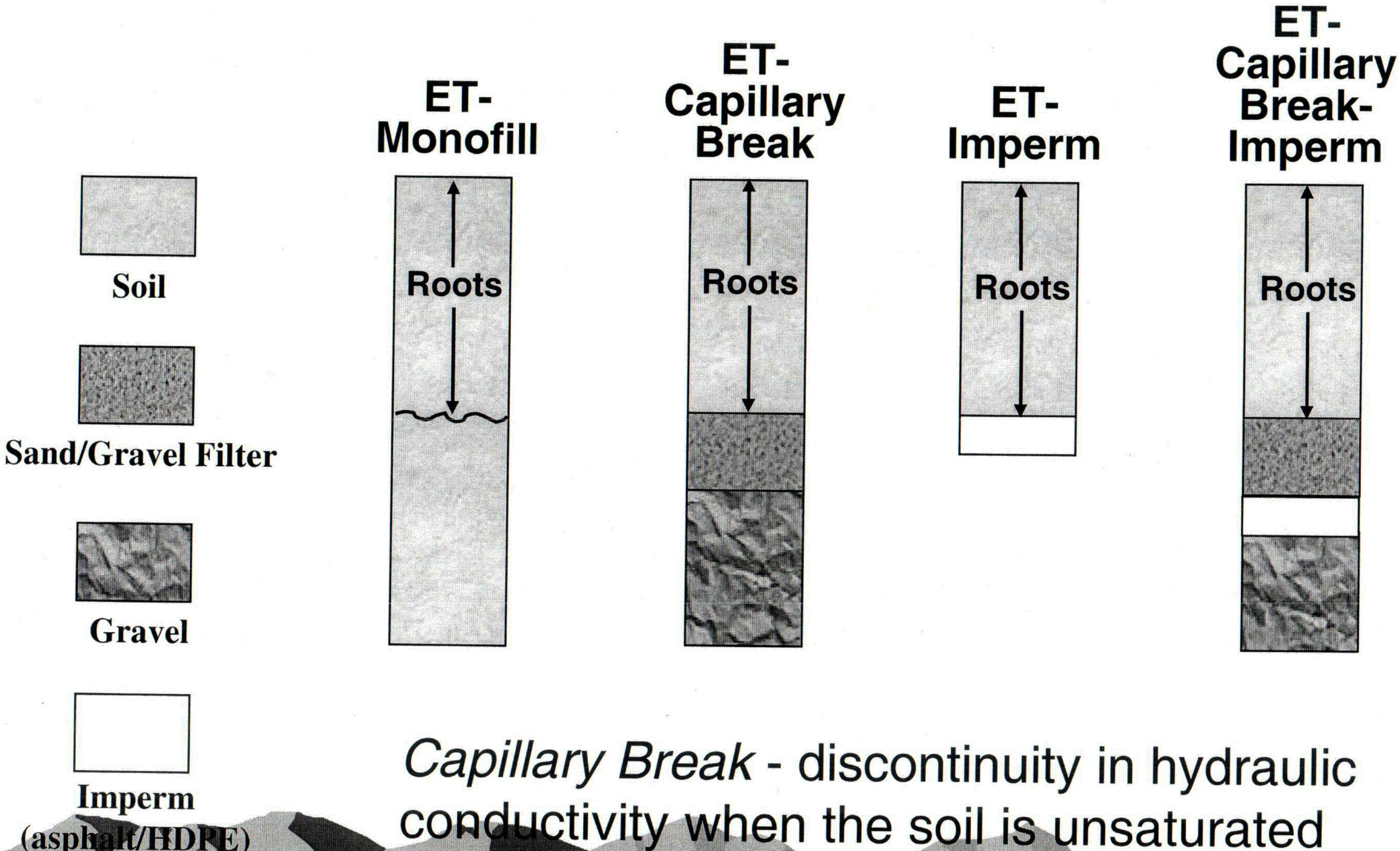


Current Monitoring Scope

- Water balance monitoring
- Vegetation and animal use surveys
- Stability surveys
  - settlement
  - surface topography
  - riprap side slope stability

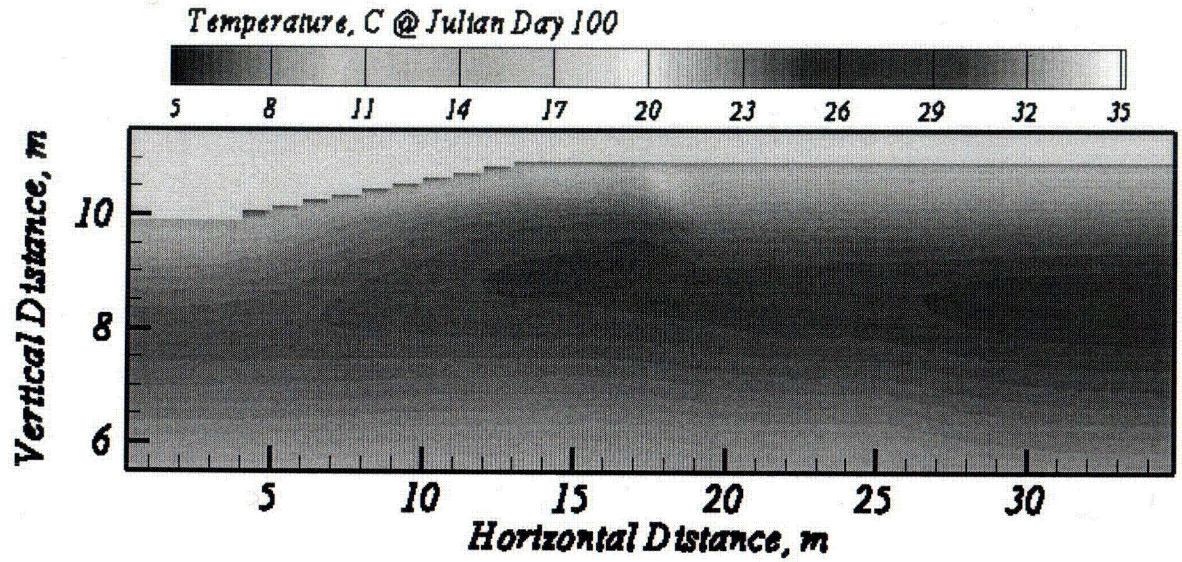


Example Designs for ET Covers

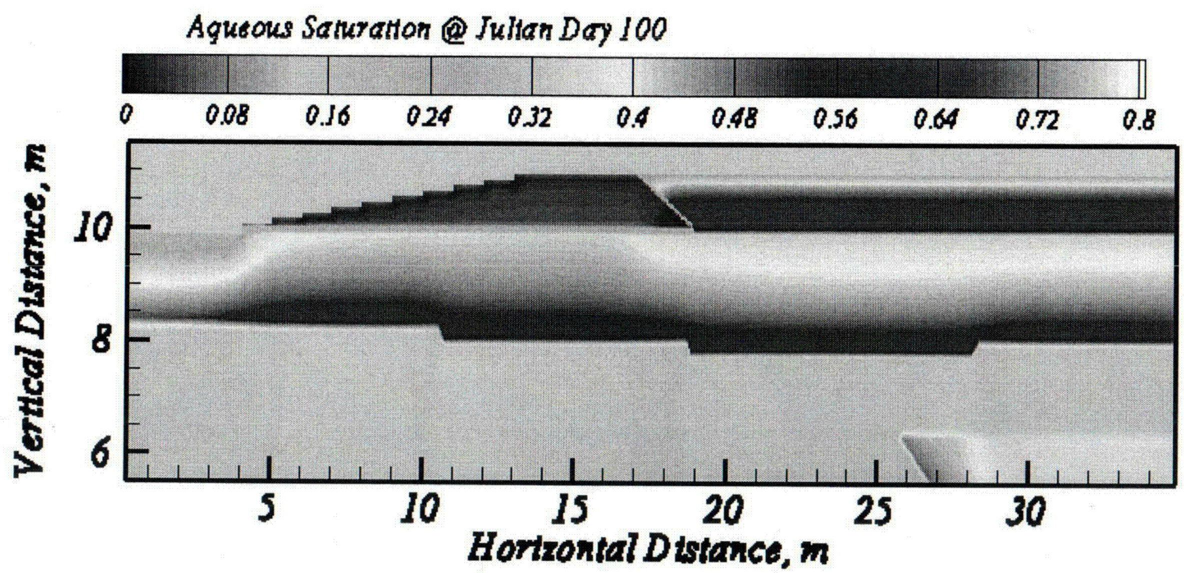


Capillary Break - discontinuity in hydraulic conductivity when the soil is unsaturated

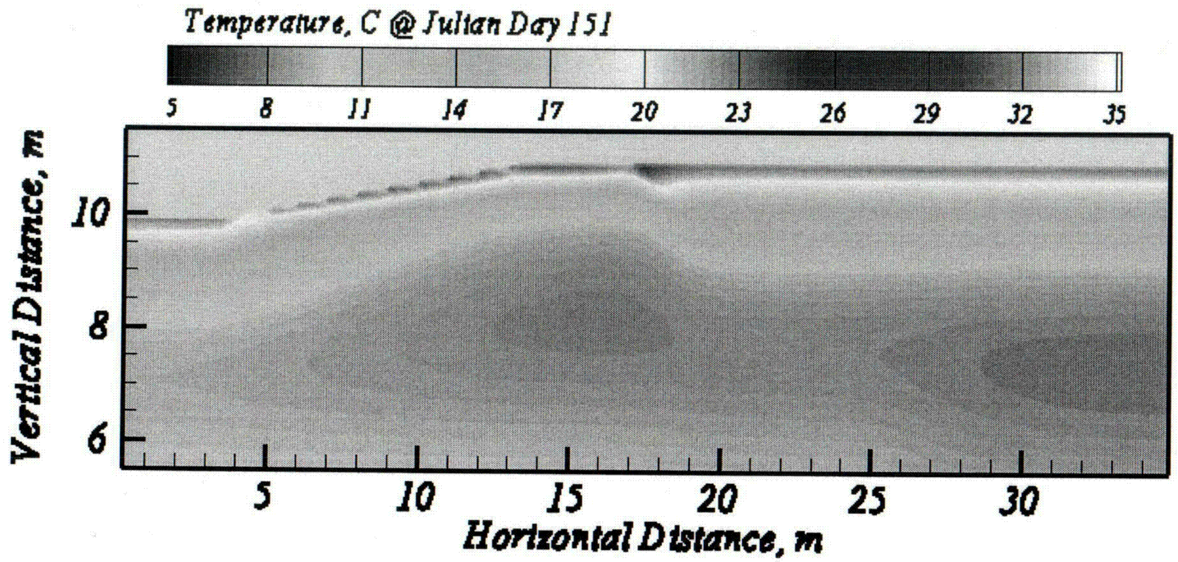
- e.g., Silt loam/ sand; Sand/gravel; Gravel/silt loam



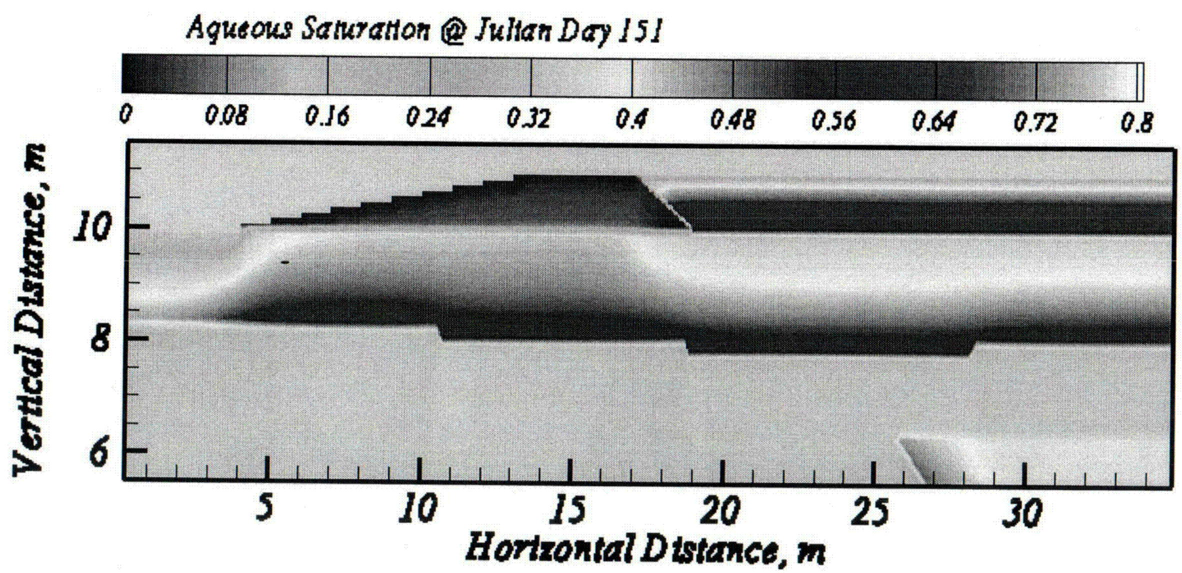
Temperature, C @ Julian Day 100
5 8 11 14 17 20 23 26 29 32 35
Vertical Distance, m
6 8 10
5 10 15 20 25 30
Horizontal Distance, m



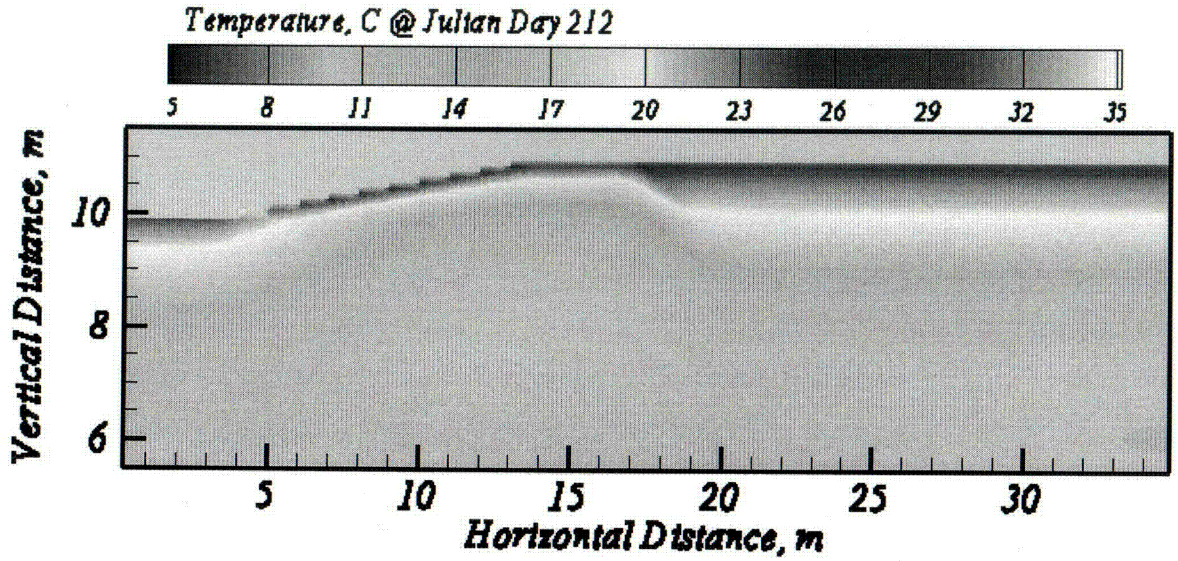
Aqueous Saturation @ Julian Day 100
0 0.08 0.16 0.24 0.32 0.4 0.48 0.56 0.64 0.72 0.8
Vertical Distance, m
6 8 10
5 10 15 20 25 30
Horizontal Distance, m

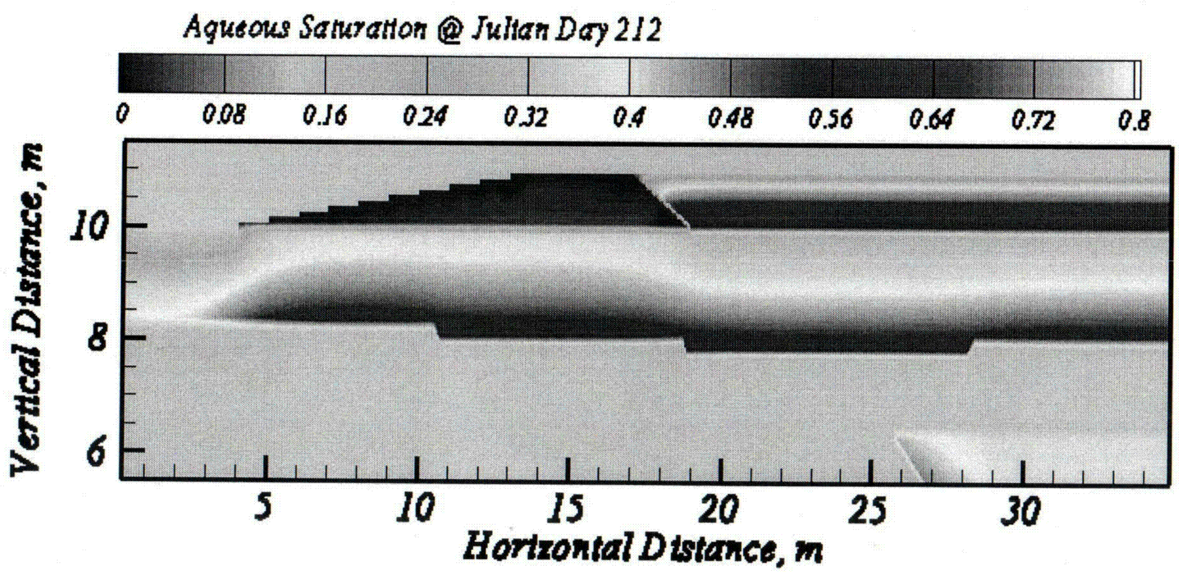


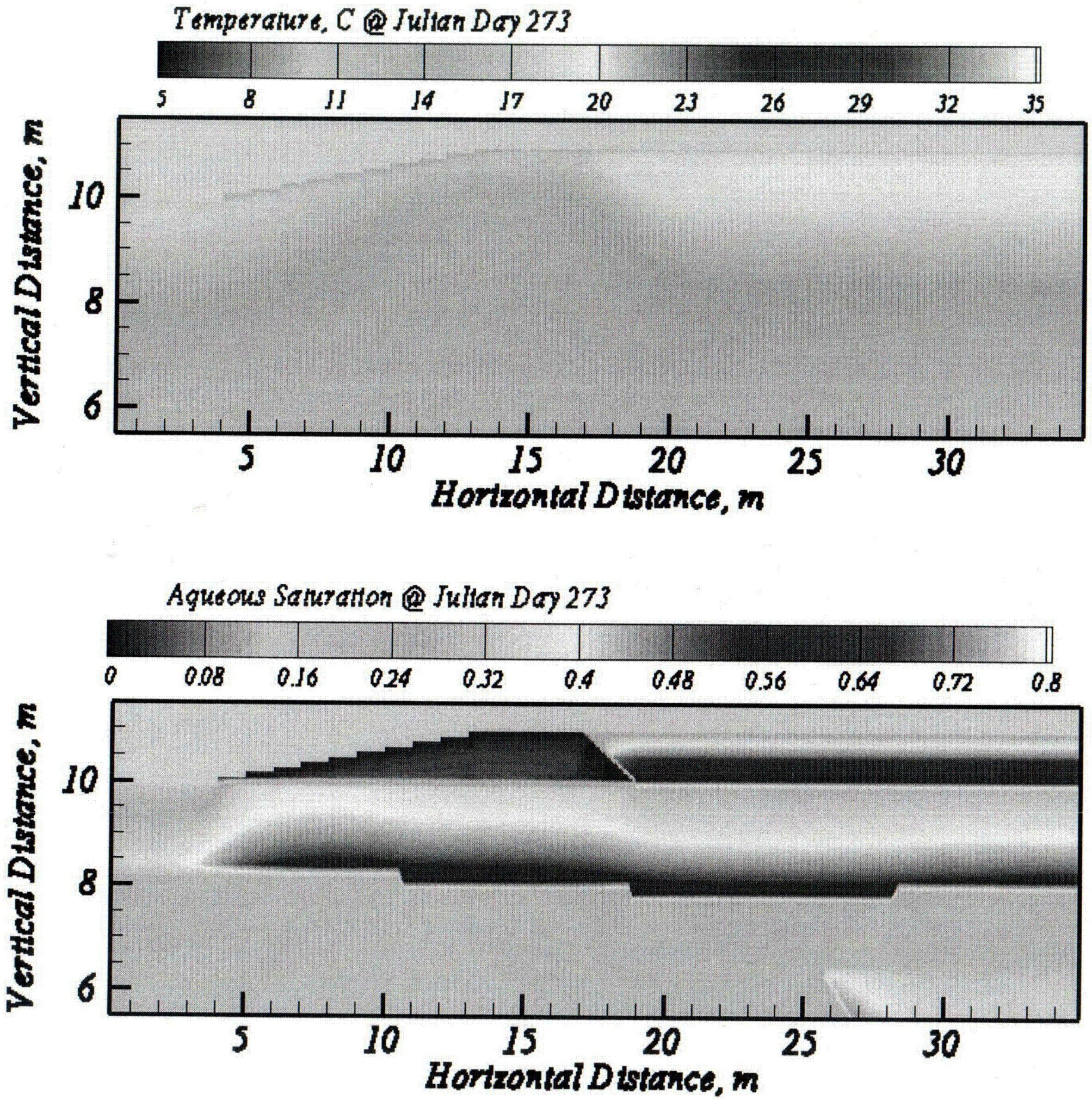
Temperature, C @ Julian Day 151
5
8
11
14
17
20
23
26
29
32
35
Vertical Distance, m
10
8
6
5
10
15
20
25
30
Horizontal Distance, m



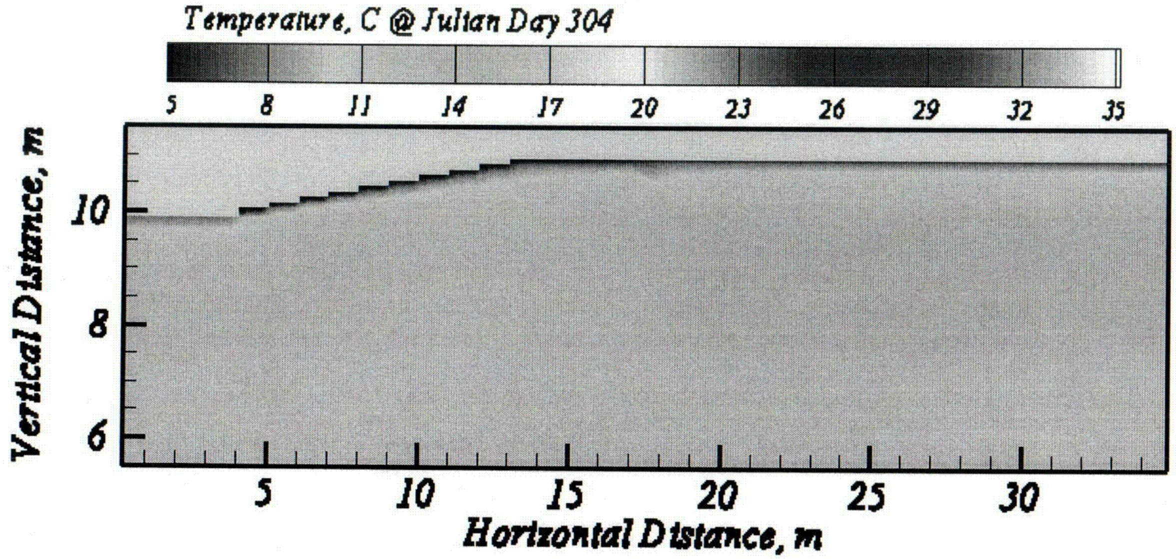
Aqueous Saturation @ Julian Day 151
0
0.08
0.16
0.24
0.32
0.4
0.48
0.56
0.64
0.72
0.8
Vertical Distance, m
10
8
6
5
10
15
20
25
30
Horizontal Distance, m


Temperature, C @ Julian Day 212
5
8
11
14
17
20
23
26
29
32
35
Vertical Distance, m
10
8
6
5
10
15
20
25
30
Horizontal Distance, m

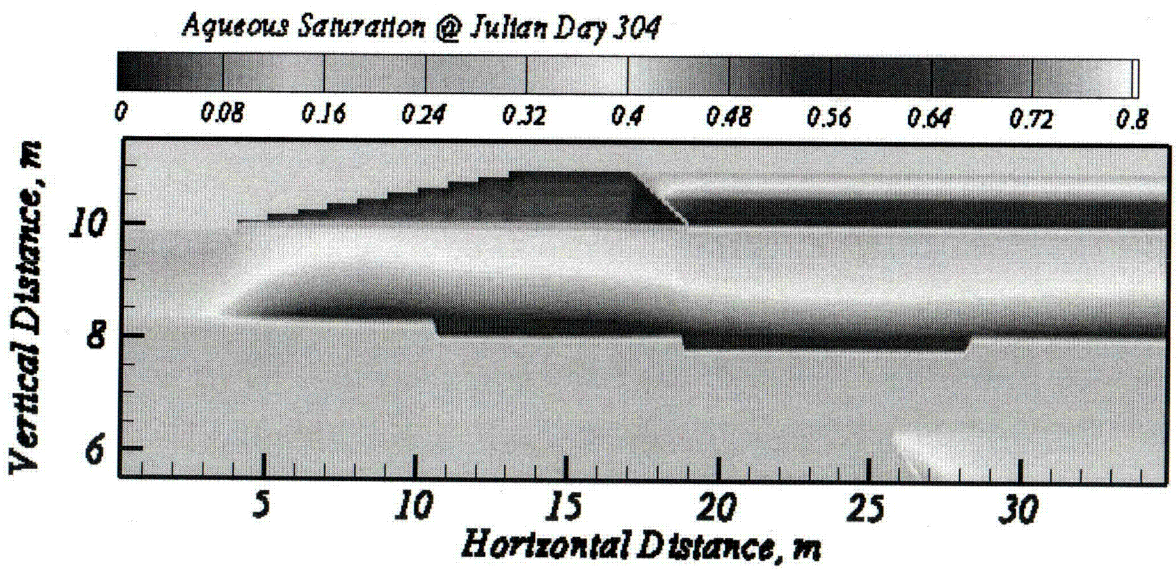

Aqueous Saturation @ Julian Day 212
0
0.08
0.16
0.24
0.32
0.4
0.48
0.56
0.64
0.72
0.8
Vertical Distance, m
10
8
6
5
10
15
20
25
30
Horizontal Distance, m



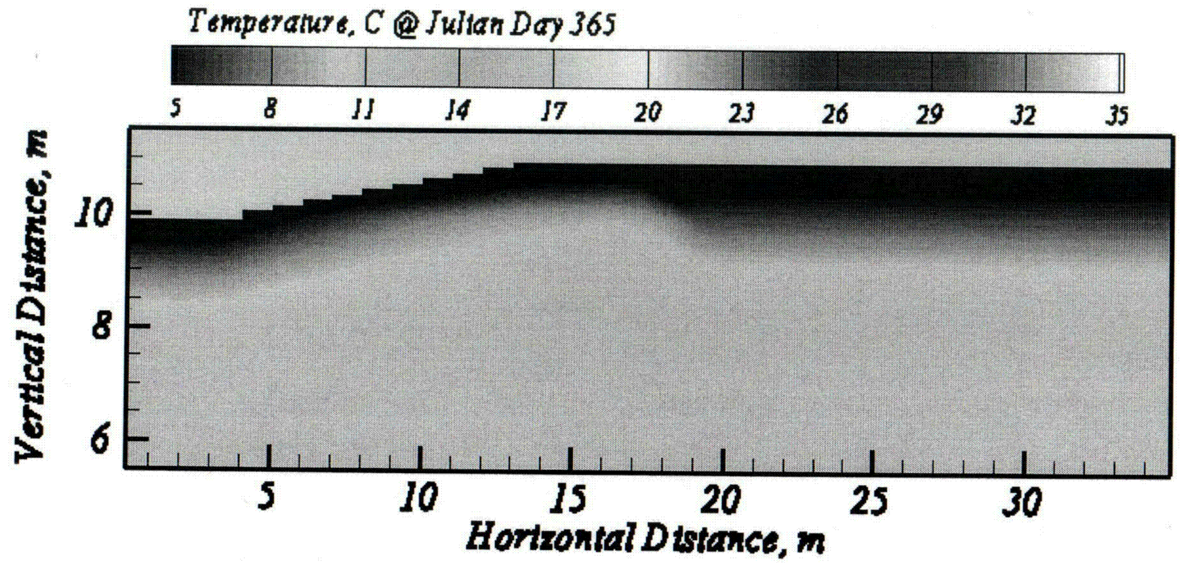
Temperature, C @ Julian Day 273
5
8
11
14
17
20
23
26
29
32
35
Vertical Distance, m
10
8
6
5
10
15
20
25
30
Horizontal Distance, m
Aqueous Saturation @ Julian Day 273
0
0.08
0.16
0.24
0.32
0.4
0.48
0.56
0.64
0.72
0.8
Vertical Distance, m
10
8
6
5
10
15
20
25
30
Horizontal Distance, m



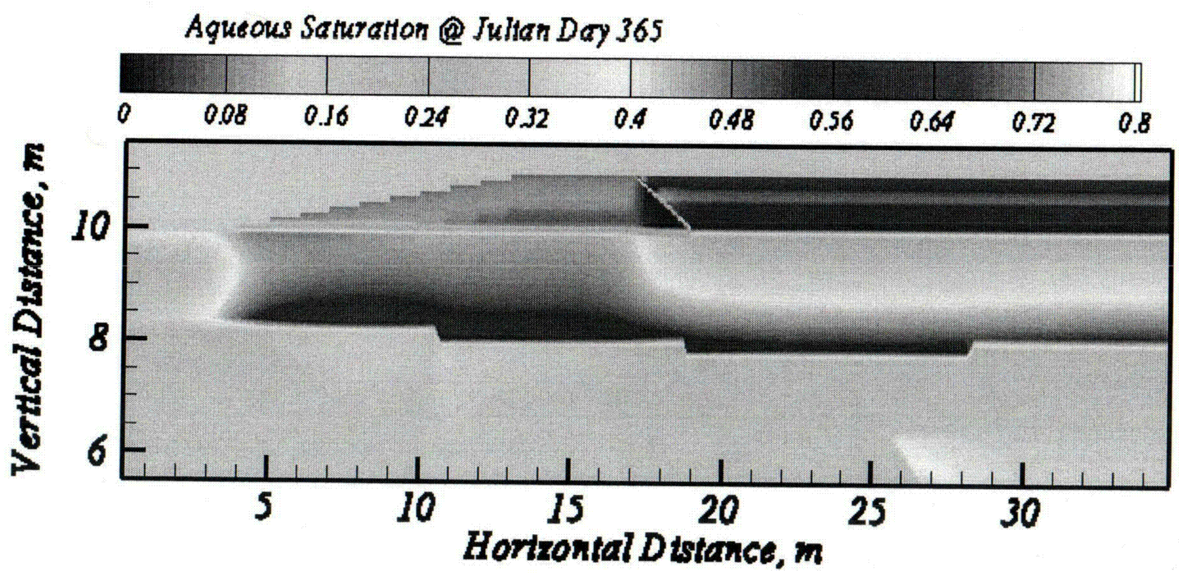
Temperature, C @ Julian Day 304
5
8
11
14
17
20
23
26
29
32
35
Vertical Distance, m
10
8
6
5
10
15
20
25
30
Horizontal Distance, m



Aqueous Saturation @ Julian Day 304
0
0.08
0.16
0.24
0.32
0.4
0.48
0.56
0.64
0.72
0.8
Vertical Distance, m
10
8
6
5
10
15
20
25
30
Horizontal Distance, m



Temperature, C @ Julian Day 365
5
8
11
14
17
20
23
26
29
32
35
Vertical Distance, m
10
8
6
5
10
15
20
25
30
Horizontal Distance, m



Aqueous Saturation @ Julian Day 365
0
0.08
0.16
0.24
0.32
0.4
0.48
0.56
0.64
0.72
0.8
Vertical Distance, m
10
8
6
5
10
15
20
25
30
Horizontal Distance, m


Environmental Restoration Disposal Facility
E0009040.1