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UNITED STATES NUCLEAR REGULATORY COMMISSION

ADVISORY COMMITTEE ON NUCLEAR WASTE

In the Matter of:)
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FIRST GENERAL MEETING)
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EVENING SESSION)

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FIRST GENERAL MEETING)

EVENING SESSION)

Tuesday,
June 28, 1988

Room 1046
1717 H Street, N.W.
Washington, D.C. 20555

The above-entitled matter came on for hearing, pursuant to notice, at 3:30 p.m.

BEFORE: DR. DADE W. MOELLER
Chairman
Professor of Engineering in Environmental Health and Associate Dean for Continuing Education, School of Public Health
Harvard University
Boston, Massachusetts

ACNW MEMBERS PRESENT:

DR. MARTIN J. STEINDLER
Director, Chemical Technology Division
Argonne National Laboratory
Argonne, Illinois

ACRS MEMBERS PRESENT:

DR. WILLIAM KERR
Professor of Nuclear Engineering and Director of the Office of Energy Research
University of Michigan
Ann Arbor, Michigan

DR. PAUL G. SHEWMON
Professor, Metallurgical Engineering Department
Ohio State University
Columbus, Ohio

CONSULTANTS:

D. Orth
M. Carter
J. Moody

INVITED GUEST:

DR. CLIFFORD V. SMITH

ACNW COGNIZANT STAFF MEMBER:

Richard Savio

NRC STAFF PRESENTERS:

John Greeves
Michael Tokar

MR. MOELLER: The meeting will resume. The next item on our agenda is Dr. Scott Sinnock, who will be talking about the translation of hydrologic setting to performance modeling applications.

DR. SINNOCK: Thank you.

My name is Scott Sinnock. I'm with Sandia Laboratories representing today the performance assessment activities that Sandia's been undertaking for quite a few years in support of the Nevada project.

As Max and Dwight mentioned, I'm going to try to put some perspective on the process of translating the concepts that Dwight talked about into numerical models that allow us to make quantitative predictions of site behavior for comparison with the regulatory requirements.

First, I will very briefly summarize some general overviews of the relations among data gathering that I'll refer to as data reduction modeling, and then finally, what we're at Sandia focusing on, performance assessment modeling.

That'll be fairly brief, and then I'll go to some length in showing selected examples of certain components we feel that all conceptual models must share, as Dwight talked about also.

MR. MOELLER: Excuse me. What do you mean by data reduction modeling?

DR. SINNOCK: Yes. In the next view graph or two, I hope to address that, spend some time drawing those distinctions.

(Slide)

DR. SINNOCK: I would first like to give some perspective on one way of cutting the pie in the physical world in a modeling sense, and it repeats using slightly different terminology what Dwight went through, that all conceptual models in some sense must share certain components.

Among these are some processes that describe the kinetics and kinematics of the situation, some energy and mass flux moving through some system of interest.

So we usually describe these first conceptually, narratively, and then eventually try to reduce these to some set of mathematical equations to describe the change in state of a system, either in space or time or both.

The physical domain we're referring to is we have to draw some domain physically in our perspective around the geometry, the volume of the earth that we're interested in. That defines a physical domain.

Within that, there's some geometry of light kinds of materials, and we have to define what the light kinds of materials are and how they're distributed through the particular physical domain.

Within any one of these units, there may be certain properties that influence the magnitudes, rates, directions of these processes. So these properties may be distributed statistically or with some trend within these individual units. So there are some properties and the processes have to work through those properties as they exist in space.

When you draw some boundary around your physical domain, you've automatically got some boundaries. You hope that these boundaries are not arbitrary, that in fact you may set them where there's no mass or energy flux. You try to make your boundary correspond to what may be a natural physical break.

But sometimes that's impossible. Sometimes you're boundary is arbitrarily drawn in space, and so you have to represent this physical process at that boundary through some mass or energy flux across it.

We have to specify some boundary on that domain.

And finally, for more perspective, and these basically are shared even at a conceptual level or narrative model, you can describe these.

Then as we turn these into numerical models, there are certain calculational constraints. We all wish we had more computing power and more computing time available, which always introduces some constraints on how finely we can resolve either all the physical processes that are occurring or this variability represented by the geometry within the system.

(Slide)

DR. SINNOCK: We look at this somewhat differently in space, hypothetically.

If for example, our physical domain and performance is defined by what we call a controlled area. The compliance boundary for the EPA compliance with the EPA standards as reflected in 10 CFR 60 occur at something called the accessible environment, which is defined as five kilometers maximum away from the implaced waste.

(Slide)

DR. SINNOCK: Earlier, Max showed a conceptual view of this in three dimensional space. This is the same thing. This is looking down on that cylinder, if you will.

There's some boundary that defines our physical domain for performance assessment. This particular physical domain of course sits within a regional setting and is part of that regional setting. We can't separate it from the effects of the regional setting.

This setting includes the effects of tectonics, climate, perhaps some sort of human activity outside the actual domain that can have effects of interest within this domain. It can affect the system geometry or material properties that occur within that or are part of this much larger sending. It may be a broad trend in properties, but to adequately see what the trend in properties is in the area of interest, we need to know the broader trend.

But perhaps of more immediate concern and of greater questions than what the effects are, this regional setting certainly sets the effects on these boundary conditions. We have to determine what the magnitudes and rates of those energy and mass fluxes in or out of this boundary are based on an understanding of the much broader regional setting in which the site might sit.

So the data collection then focuses on mapping the material properties within this domain to allow as detailed as possible and feasible a prediction of what those properties are, so we can map the process then into those properties throughout that physical domain.

We also need to make measurements in the regional setting in order to determine the effects on this. The site characterization modeling would be then in my the way I'm using it, is based on the measurements within this domain making predictions of how the properties vary.

There's modeling involved in that. I'll show some examples.

It will certainly also involve making predictions of the effects on the boundary conditions. I'm distinguishing that from the performance assessment modeling per se which is concerned with the movement of radionuclides to the edge of this particular domain. To do so, we will be requiring information from the site characterization programs to tell us what the likely ranges in the changes of those boundary conditions are so we can adequately accommodate the uncertainty represented by what may happen outside this in the regional setting.

Now, each of those items, the physical process, the system geometry, and boundary conditions -- I'll then go through very rapidly and show a few examples of what we're doing, as Dwight described, we're assuming Darcy Flow for hydrology through the system.

In the unsaturated zone in particular, as Dwight mentioned, the conductivity term of the standard Darcy equation is a function of the pressure, he expressed it as a function of the saturation we have characteristics curves that relate conductivity saturation and pressure.

Which basically is saying that this pressure is a function of the pore size distribution within the material of interest, basically based on what might be capillary bundle theory. You sort of think of the tension, the capillary bundle, you've got a series of little pipettes that vary in diameters, if you will. And how high would the water rise in those little pipettes in a bundle of those?

Well, it'll rise to different heights and those represent the different suction pressures.

Just to put things in perspective, we're looking at suctions on the order of 10 to the 4th centimeters, 10 squared meters, perhaps, of rise, so there you can see that those are very fine pores. Someone asked, we're looking at pores less than a micron in diameter in many of these units, which give a capillary suction to be able to rise water hundreds of meters.

This addresses the question, could you actually get water moving up, being drawn up by evaporation. Theoretically, yes. If you had interconnected pores small enough, you could draw water and evaporate it off the surface and brought up. It would be a very very slow process. But whether it can cross any of the fractures in the way, whether you can sustain a continuous pathway of those small pores is another question.

In our modeling, we're making an assumption that there's a pressure equilibrium perpendicular to the flow. Right now, that's sort of saying we're not accounting for antisotrophy (phonetic) plus, by doing this, we're able to come up with a composite relationship for the fractures in the matrix that accounts for the different pore size distributions within each.

It's sort of saying we're accounting for a, if you will, a bimodal pore size distribution which gives a shape to the conductivity curve as you draw the moisture out of the conductivity comes down sort of flat and as the fractures draw down, and it flattens and then draws down further as you get into the matrix pores, a double hump curve, we call that.

Sort of accounting for a bimodal distribution, not separating fractures of matrix but saying it's a bimodal porosity distribution.

We're calculating velocity, we're making the assumption right now that the so-called effective porosity, what we divide the flux by to get a velocity, is equal to the moisture content of the rock. We're currently assuming isothermal conditions. We have the capability to assume thermal conditions, but we have not yet, so far.

We can model in transient or steady state. Most of our solutions are actually run in steady state. And so far, we're only accounting for the single phase liquid flow although we're just starting to look at the effects of the vapor movement in the mountain as influencing the moisture balance for the hydrologic calculations also as a potential pathway directly to the surface for any gaseous radionuclides that may occur.

An example of using those processes in a two dimensional finite element sense is just shown here for where a schematic of the mountain, the non-welded paint brush unit, the offspring, and then the calico hill starts approximately here. It shows we can solve then the standard equations. In this case, we're plotting out saturations as a function of space.

Because of the depth, we do get some diversion of water and this diversion's actually occurring at the back of the arrow rather than at the point. This diversion's occurring right at this interface, and going down. This is for a simulation based on the assumption of a uniform infiltration of a tenth of a millimeter per year.

And the bottom just shows the velocity vectors. So we try to do solutions in this fashion because then these become testable hypotheses. You can go out in the field and see how closely we're mimicking the saturations we can observe in the field.

(Continued on following page.)

DR. SINNOCK: A little bit about the physical domain we are using.

The model you saw previously and other modelling have been based on a geometric description of the system on a computer-graphics model.

This accounts for the hydrostratigraphy, the various structures, the water tables, the water table elevation.

The hydrostratigraphy, these various units, are based on a sort of not very formal but a quasi-pattern recognition process.

We would look for units that have similar hydrostratigrapnic properties and classify those as the hydrogeologic units. Where we see a major change, that constitutes a new unit.

Then within each of these various units we are assuming that these properties are nonuniform but heterogeneous throughout the units and perhaps contributing to dispersion within the system.

We are currently looking very hard at geostatistics as a method for describing this variability within statistical populations defined by these various units.

(Viewgraph presented)

Geostatistics can, through kriging, remove some sort of trend. We can assume trends within the data. Get an idea on the spatial variability and the correlation length among the various parameters.

And then use the geostatistics. And I am showing an example of this.

(Viewgraph presented)

To simulate a distribution of properties throughout the mountain. It has some uncertainty associated with. In a Monte Carlo sense, we can account for uncertainty in that distribution of properties by sampling into the potential infinite distributions through some Monte Carlo sense.

We are not sure what the scaling effects are in terms of our predictability of material properties. We measure very small pores. Probably at a minimum something the size of this building will be our minimum volume of rock accounted for in a model.

So what is the relationship between sample measurements on a core or perhaps an in situ test that may sample something the size of this room at some level.

How do we scale this up to the modelling scale?

(Viewgraph presented)

Just a few examples of the current case. You have seen this figure several times before. Several questions have come up on how far the repository is above the water table.

This is a scaled representation off of the computer graphic system which represents the actual dimensions.

It is actually cut from southwest to northeast to maximize the variability including the variability from the repository to the water table.

This is the repository horizon. You can see it is approximately 200 meters; approximately 400 meters from the southwest dropping to somewhere around 200 meters in the northeast. That is approximate. That is almost at the minimum distance.

The same units, the welded units, the dark brown, and the nonwelded units, the light brown with the white showed, are used as hydrostratigraphic units.

These nonwelded units below the repository still have an overprint of zeolitization which, as Dwight pointed out, the zeolitic unit hydrologically behaves considerably differently.

So what we have are a series of wedges of all these various units underneath the repository. In fact, the Topopah Spring is the only unit that occurs underneath the entire repository.

No other unit does. Everything wedges out somewhere, either truncated by the water table or truncated by the facies changes based on the zeolitic facies beneath the repository horizon.

MR. MOELLER: Now is the fault shown there the Ghost Dance Fault?

DR. SINNOCK: That is the Ghost Dance Fault. You can see it offsets the units. We are showing it here as offsetting the zeolites. We are not sure about that. But it does not of course offset either the water table or the repository.

The repository goes right across the Ghost Dance Fault.

DR. MOODY: Where do you think the water, the fluid, came from making the zeolites at that particular height that is showing there because the water table now is considerably deeper than the zeolites are.

Where did that water come from?

DR. SINNOCK: Certainly I am not the expert to answer that. My understanding is that Los Alamos is tentatively suggesting that this represents an old level of the water table very shortly after deposition of the top units.

DR. MOODY: Which would have been how many years ago?

DR. SINNOCK: Eight to ten million years ago. And please don't quote me on that. I am not the expert. I believe that is what they are doing.

You note over here the zeolites start plunging. The densely welded units and the matrix appear to be nonzeolitized.

So this represents a somewhat quasi-parallel to the water table. There is some assumption there that it was related to some paleo water table.

There the thermal backing out of the temperatures of transitions I think are used to tentatively suggest that perhaps this occurred somewhat contemporaneously with the deposition or shortly thereafter when the temperatures were considerably higher.

DR. SHEWMON. Does the exchange characteristics of the retardation change dramatically when you go into the zeolitic material from the other rocks above?

DR. SINNOCK: As I look at the table in the EA and the SCP, I do not see a great distinction between any of these units in terms of their batch sorption.

DR. MOODY: That's probably something that is being looked at. The zeolites behave very much differently.

DR. SINNOCK: They certainly do. And for some nuclides, the zeolites have an order of magnitude greater batch sorption number associated with them.

DR. MOODY: Yes.

DR. SINNOCK: For many of the nuclides, there appears to be no difference.

There is an extremely high available surface area in the matrix of these rocks independent of the type of rock. Of course when you do batch sorption you grind it up anyway.

DR. SHEWMON. When you do batch sorption, does this tell you whether R is close to 1 or close to 100?

DR. SINNOCK: We hope so. And Los Alamos is certainly addressing that question through how reliable are batch sorption measurements to give you an estimator of the true sorption capacity.

DR. MOODY: That is a very touchy issue probably.

DR. SINNOCK: Yes. They are doing the kinematic modelling to try and determine whether or not the batch sorption which is of course much simpler to perform, to determine if it is a reliably estimator of the retarding capability of the rock.

And so yes, the zeolites behave definitely differently hydrologically. They are going to behave differently geochemically but it is going to be on a nuclide-specific basis.

But I do not think we should fall into the trap of thinking it is only the zeolitic layers that are sorbed. The densely welded layers through the batch sorption are showing very good affinities for most of the cationic species.

DR. SHEWMON. Is that factored into your model, also, or at least the capability to model that?

DR. SINNOCK: Yes. Currently we just calculate a retardation factor given a KD or what Los Alamos calls an RD, based on the porosity, and we calculate a retardation factor.

And they are quite high for most nuclides except a few, of course.

(Viewgraph presented)

Within each of those units, once we can quantify the actual distribution and space -- and of course being on a computer graphic system that allows us to the nearest thousandth of a foot if we want, to distinguish how thick a particular unit is or a particular space.

It gives us a quantitative way to characterize the geometry three-dimensionally in the mountain.

And we define those units and then look at the samples we have in these units to try and define what the property distributions might be.

This is an example of porosity, matrix porosity samples available for the various units: Topopah Spring, Calico Hills, Zeolitic.

For some units we have fairly large amounts of data. For others we are very low. Calico Hills Vitric, one of the important units, very little information.

Now this is an example of where we can use the actual data in a pattern recognition sense to determine the stratigraphy.

You will notice on this graph it looks like a distinctly bi-modal distribution. We think it probably is. We probably missed a unit.

This probably should be split into two distributions because we basically think the densely welded Bullfrog and this is the Vitric nonwelded, the partially welded Bullfrog, but they are distinctly different.

So we intend then to give measurements to help us assess whether we have got the proper unit distinction.

DR. SHEWMON. I have no idea what I am supposed to get out of that slide. You have some property and some measurements and you force fit a distribution to them and then draw some conclusion?

DR. SINNOCK: In this case, yes.

DR. SHEWMON. What is the property, the number?

DR. SINNOCK: This is matrix porosity.

DR. SHEWMON. Okay.

DR. SINNOCK: Zero to .6. So the densely welded units Dwight mentioned are about .12. That is an average of quite a few samples.

The actual histogram is shown here and yes, we just -- based on a mean and a standard deviation -- said there is the best fit normal distribution, just to get a graphical picture of the kind of variability we are seeing within these units.

(Viewgraph presented)

Now also -- this is now hydraulic conductivity. This is a map view showing the outline of what we call the perimeter drift of the repository. This is looking down on the repository area.

These properties also vary and have trends in space so this is a crude estimate using geostatistics of how normalized to zero -- the mean is zero in this case -- how hydraulic conductivity varies within -- in this case this is the Topopah Spring -- across the unit.

You can also use kriging to come up with an estimate of the variance associated with each point within the map of interest.

So using this trending mean and this variance for any given point then we have a value and a variance and an uncertainty associated with it. So for each point we can sample off the distribution represented by this mean and variance to get a particular value of conductivity .

And simulate, then, a pattern of any particular property within any given unit. The probability of this simulation being the real representation of zero. You go through it enough times and you will be able to capture the uncertainty in your output calculations.

Now whether this becomes a significant contributor to the uncertainty in your performance predictions has to be determined.

If it is not a significant contributor, maybe just use the mean. If the variation and uncertainty is significant, then we want to sample to try to pin down this variance as much as possible.

Not make the variance as little as possible, but describe it as we think it actually is.

(Viewgraph presented)

Moving along to some of our current assumptions about the boundary conditions. Again, repeating a lot of what Dwight said, the unsaturated zone, we treat the upper boundary as a flux variable.

So far we just assumed flux as spatially distributed to change the total volumes of flux across the whole side. Side boundaries, we can set a fixed pressure or a no flow boundary in the unsaturated zone.

Just stressing again, we have not yet included analyses of gas flow. Saturated zone -- the lower boundary in the saturated zone, we can treat that as a no flow boundary as we have or as a transient specified leakage flux.

In other words, we can assume a certain amount of water comes up along a particular fault and look at the potential consequences of that in terms of hydrology.

We have so far obtained the side boundary either obtaining a fixed pressure along the boundary from the regional model or by kriging the data we have available within he site area.

(Viewgraph presented)

And I think it is within these boundary conditions that we see treating a lot of the scenarios, the potential changes. This is something we call numerical experiments. We changed the boundaries to reflect some scenario such as injection of water or such as climatic changes that increases the infiltration flux above what we think it might be.

So we can modify the lower boundary in the saturated zone, the water table elevation, the flux across the boundary which we can do by changing it in particular ways.

Accommodating climatic influences primarily we think by modifying the surface flux. I think eventually we are going to need to do this both total magnitude and also look at what the effects are of distributing that flux across the site.

For these treatments of these boundary conditions, of course, we need to determine through our characterization programs what the magnitude, frequency and duration of these changes are likely to be. This is going to have to come out of the tectonic and climatic programs working in close conjunction with the hydrologic programs.

DR. STEINDLER: Before you leave that, when you say "numerical experiments", I assume that is a computer related exercise.

DR. SINNOCK: Yes.

DR. STEINDLER: Which no doubt has an infinite amount of variation and can be run as long as your account on the computer is still valid.

What relationship do you eventually try to establish between those numerical experiments and what you believe to be the real world?

DR. SINNOCK: That is what I am trying to get at in this very last item is yes, we could assume we have Hawaii out there in terms of infiltration. Right now we would saturate the mountain and the water would run off the surface, but we could push the system to that numerically and increase the filtration to 150 inches a year.

This is where the characterization programs have to focus on setting some sort of bounds on what the likelihood of the magnitude, the frequency and the duration of these changes might be.

And we have to work very closely with the site characterization program in an iterative fashion to try and determine what magnitudes of changes represent potential jeopardies to the site.

And if they do represent a jeopardy, are they indeed a reasonable possibility.

DR. STEINDLER: But I guess my problem is unless you have some way of doing a continuous rain dance for a long time out there, you are never going to turn that site into a Hawaii to determine whether or not your computer exercise has any relationship to the real world.

So if you are that far off in your ability to do experiments, how do you determine or what kind of processes do you go through to determine the data needs that will test your model or your composites or whatever?

DR. SINNOCK: In terms of the possible future scenarios, we can certainly look to analogues where we think information will tell us what conditions might be like at the mountain if they were to change.

But we can also perhaps to try to look for evidence of the system perhaps still responding to some former perturbation; saturation differences through the mountain that we know cannot be maintained under steady state conditions.

There may be some transient that is still being dissipated within the mountain.

Maybe the next slide will help a little bit.

(Viewgraph presented)

MR. MOELLER: We have another question.

DR. SHEWMON. Yes. Someplace in here you say you don't consider gases by which you mean up-drafts of air you haven't modelled yet?

DR. SINNOCK: Yes.

DR. SHEWMON. So what goes in, goes down?

DR. SINNOCK: Yes.

DR. SHEWMON. Since you are conserving water.

What is relevant to the question of licensing the site? Travel time or what?

DR. SINNOCK: The water movement, certainly, as downward and although theoretically it is possible to move water upward by evaporating it off the top. We are almost certain that would be a very long --

DR. SHEWMON. But it is also quite possible that most of what falls ont he surface does never make it to the bottom.

DR. SINNOCK: That is possible.

DR. SHEWMON. It depends on what your model is so far.

DR. SINNOCK: Yes.

DR. SHEWMON. So let's come back to -- so insofar as your model is limited currently to what goes in, goes through, you can get velocities out of it, is that right?

DR. SINNOCK: Yes.

DR. SHEWMON. And then the next thing is to try to model what fraction of what actually comes back up?

DR. SINNOCK: We do a moisture balance accounting for the vapor flux through the mountain to get at that question of given an assumption of what infiltrates to the surface, the upper few meters, how much of that is likely to propagate down to the repository horizon where it can contact the waste and become a transporting medium for the waste.

Certainly we hear talk throughout our hallways, et cetera, there is a possibility there is not water moving in that valve now. It is basically just held there by capillary forces.

DR. SHEWMON. And evaporation. Since something falls on it, something has to come out.

DR. SINNOCK: Well, the evaporative front may penetrate considerably 'eeper than the upper few meters is what we are findir~

So if we do a model that says net infiltration is anything below three meters, the agricultural science is that is certainly good enough. That is found in no man's land.

We may find we are getting some slight amount of evaporation deeper, perhaps hundreds of meters, with a net circulating system, air vapor.

Some of the preliminary modelling we have done does show some amount of natural circulation down to the repository depths of vapor. But we haven't coupled the two together.

(Viewgraph presented)

The next one is -- by doing one of these numerical experiments and for instance assuming considerably more infiltration, again it presents a testable prediction.

In this case, it shows that the entire mountain becomes saturated. Yes, we do instigate considerably more lateral flow. And this is in the matrix. And in fact, we saturate the fractures over on the eastern side of the mountain and sustain rapid fracture flow.

(Viewgraph presented)

But going back to the other slide, it is a testable type of prediction, so we want to cast the numerical experiments in a form that says okay, if this is to be the case, we should find very high saturation levels throughout the mountain.

Very briefly, I think I missed a slide in here somewhere.

(Pause)

Oh, there it is. Simply, our calculational approach uses standard solutions of the hydrologic equations for a pressure distribution that shows flow lines. We calculated velocity.

But we solved for pressure. Or come up with an approach that can just solve directly an algebraic equation.

The reason I bring that up is there are some trade-offs numerically. These are some numerical constraints we have to concern ourselves with related to the dimensionality of the code, the meshed time steps, treatment of spatial variability.

And we have to do this in the context of whether we are being conservative or not.

The full solutions, finite element solutions, very realistically we think treat the process. They account for pressure continuity, but boy do they crunch the computer time.

And they may not practically be able to account for spatial variability within the given units which may be a contributor to dispersion.

The algebraic approaches, on the other hand, can more realistically finally resolve the spatial variability but so far we are violating pressure continuity in the mountain by doing so.

So we think we are going to use the full solutions to give us representative -- on representative subdomains to help us constrain the boundary conditions from the simpler approaches throughout the full domain of the site.

Based on these, we have three major classes of information needs to support the model. One, what is out there right now? What can we measure to support our nominal case?

Secondly, particularly looking at the regional influences on the boundary conditions, how can this nominal case be disturbed. What are the bounds on that disturbance?

These then will be used to define scenarios for these numerical experiments and hopefully with very close cooperation with the people developing these scenarios.

The third major class of information is how do we come to some assessment of the models we have chosen as reasonable representation of the physical behavior of the system.

All of these have to be based on measurements of things that are out there today and we can make inferences in terms of what it means in the past.

We can also look at laboratory experiments and natural analogues particularly to help us bound the potential influence of scenarios.

Particularly the validation process, this meeting is one of the meetings where we are certainly expressing our ideas to a much larger audience.

And it is essential that we continue to do so.

Our parameter uncertainty, how does hydraulic conductivity vary, through using the input variables -- hydraulic conductivity, porosity, thickness as random variables -- we can then identify those variables as the variables that are the most influential on the travel time or the radionuclide releases to help us focus our characterization efforts on those sensitive areas.

Then we can put those back into a probabilistic prediction to see the source, given particularly those sensitive variables, how much they affect the prediction of performance.

And this in turn feeds back to how sensitive it is, not just if the travel time goes from a million years to ten million. It may be very sensitive to that parameter but we may not care.

However, if the travel time goes from 100 to 100,000 years, travel time sensitive to it, it is also of considerable significance.

(Viewgraph presented)

The basic conceptual concerns we have that are a little more difficult to deal with in getting a statistical basis of measurement have to do with the fracture flow.

Does it exist? If so, how much and where.

Something that has not been mentioned very much is matrix diffusion. Even if water were to flow in the fractures, and this occurs in the saturated zone we are pretty sure, and the contaminants are in the water in the fractures, they have concentration.

Out in the matrix, chemical concentration. So in the matrix pores where there is water, the chemical concentration is less.

So there is a chemical potential for diffusion of the contaminants from the fractures where the water is flowing into the matrix where the water may not be flowing.

How effective is that process? The physical process that will occur, will it occur in a sufficient enough rate or magnitude to be significant for the performance?

I will briefly mention the scalar relationships and vapor flux which are concerns we are dealing with currently.

(Viewgraph presented)

In terms of disruptive scenarios, I imagine we are interested in the magnitude, frequency, duration and spatial extent of potential changes.

And the material properties within our physical domain and the defining boundary conditions for our modelling domain.

Specifically the tectonic, climatic influences and perhaps some human influences such as water withdrawal in a desert, mining, et cetera.

(Viewgraph presented)

Sort of like validation, which comes back in here, these conceptual concerns are much less amenable to quantification than parametric uncertainty, which we can statistically describe and then account for.

We can address this conceptual uncertainty perhaps by waiting. We can do analyses based on one set of assumptions and analyses based on another. We have no way of knowing which is right.

We either have two sets of analyses or just through some sort of Delphi approach come up with some sort of estimate of their likelihood and roll them together.

Or we can use bounding calculations to see if they make any difference. If the uncertain represented by the conceptual alternatives we have to deal with does not influence the performance in a sense to jeopardize compliance, we may be able to, in a bounding sense, be able to say that we can live with the uncertainty represented by those alternatives.

It is all tied in again to this validation of our modelling approaches. So we can calibrate our predictions with respect to field observations to test them; is the saturation what we predict.

Or we can compare it to controlled field experiments or controlled laboratory experiments to see if we've got a handle on being able to mimic the process given a known set of material problems.

And of course, this process should be open to peri-dic formal peer review and continuing informal peer review.

(Viewgraph presented)

The summary summarizes what I said. We are running behind so I think I will not go over the last two viewgraphs.

DR. SHEWMON. Does the DOE program have any measurements in air flow through the mountain?

DR. SINNOCK: yes. There are some. Dwight. I think Ed Weeks has obtained some estimates in a bore hole. Right? Do you know?

MR. HOXIE: What?

DR. SINNOCK: The question is, is there any measurement of air flow through the maintain?

MR. HOXIE: Can I address that real quick?

DR. SINNOCK: Yes.

MR. HOXIE: I am Dwight Hoxie.

Ed Weeks also with USGS in Denver has discovered that we have one bore hole on the crest of Yucca Mountain and he has observed quantitatively air flow that will go in and out of the bore hole, a bore hole breeze essentially, as a result of barometric changes occurring at the surface of the mountain.

And so the whole idea is that there is a kind of chimney effect that the bore hole has induced within the fracture system at depth. And at depth I mean about 300 meters or so.

DR. SHEWMON. Well, in Arizona we visited a DOE program in which they were studying that sort of behavior in a mountain down there and my question is basically whether the same sorts of measurements will be made at Yucca Mountain that would be germane to the sort of movement of water up and down or to what extent what goes in comes back out instead of going through.

MR. MOELLER: Other questions.

MR. HOXIE: I was just going to respond to that for a second.

One thing we don't know for sure is whether or not the bore hole actually is responsible for the observed air flow.

It may have disturbed the system. Otherwise it may not be a natural cycle. We don't know.

DR. SHEWMON. Okay.

MR. MOELLER: Dr. Moody?

DR. MOODY: The question I have is we talked about validation of model approaches. It is sort of interesting. I am not sure that laboratory approaches will yield the kind of data that you need here.

Just explain why you are still interested in doing lab experiments.

DR. SINNOCK: Well, I certainly sympathize with your concern. We still want to build a warm fuzzy feeling that our way of treating the interaction between the matrix and the fractures is -- indeed the way we treat it mathematically and numerically -- is indeed a reflection of a real process.

I think within the lab we can control the material properties of the boundary conditions and specify them specifically enough that if we can mimic what we do perhaps see in a sandbox or its mimic with our codes, it will help give us a feeling that we are doing something right.

The control on the boundary conditions and the material property distribution in field experiments I think is going to be a continuing source of uncertainty in the interpretation of the results from those experiments.

So only in the lab do I see where we can get down our uncertainty about our material property and boundary conditions sufficiently to know that our inability to match it perfectly isn't due to our uncertainty and what it is we are observing in the field.

DR. MOODY: I know. But there is the classic question that you also probably know and that is especially the determination of physical properties, that when you talk about a laboratory experiment in a 3 cm core of rock and compared to what actually goes on in the field when you see the rock in place --

DR. SINNOCK: Even for the laboratory experiments we are going to rely on some of those small core samples to characterize the material properties within whatever volume of rock in the field it is we are testing, pulsing with energy or mass or whatever.

DR. MOODY: I know. But what I am trying to say is I question how you make that interface between laboratory experiments that you do and what you observe in the field. That is sometimes not easy, as you know.

DR. SINNOCK: I think another area of the laboratory can help us by measuring small samples, getting controls, and seeing how we can use small samples to mimic a behavior of a property on a larger scale.

One of the issues we have, especially the densely welded tufts, is the response time even in the laboratory, looking at the conductivity. It is a half millimeter per year. That is water moving that far in a year under natural conditions.

So we've got some problems of mimicking the actual behavior. We suspect in the site -- we can't do it in a real time basis.

So we have to pulse the system very hard with some sort of water which may be creating situations that are not analogous to the type of behavior we expect in the sites.

The response time of our system in the densely welded tufts is another issue we have to confront in designing and experimental program.

MR. MOELLER: Dr. Kerr?

DR. KERR: Is someone attempting to develop a meth^d of deciding when your model is good enough?

DR. SINNOCK: (Pause)

Well, yes, and we are in the process again of developing these position papers. And I think through this process of defining what goes into a position paper is going to be part of that process.

When do we think we've got enough in terms of model development? The other aspect, we have through our quality assurance program, done sufficient things to be able to demonstrate we think the development of that model numerically as adequate.

DR. KERR: Well, it seems to me those are two separate issues. Criteria for decision simply going to be based on somebody's judgment as to what's enough, and the other, it seems to me, is another question.

DR. SINNOCK: We are certainly continuing the development work in the model area at this time. Whether we are buying a 2 per cent improvement or a 50 per cent improvement I think is going to depend on some of the results we see from the experimental program and how well again we are able to match what we can observe.

DR. KERR: In using these to predict the behavior of a depository, the assumption is made that the material's properties do not change over the 10,000-year period?

DR. SINNOCK: That can be handled either way. One of the little arrows on my first one is that material properties can change.

DR. KERR: Which assumption is going to be made? That they do?

DR. SINNOCK: Either one can be made and we have currently made the assumption that material properties are constant.

DR. KERR: No, but eventually in determining whether you meet whatever criteria that have been set, you are going to have to decide, it seems to me, which of these assumptions you make.

DR. SINNOCK: We are assuming that something like porosity remains a constant. I think as we consider some of these tectonics scenarios where they are actually modelled, say fracture porosity chains are treated as a change in a boundary condition on flux, depends on what the sensitivity of those various treatments are in terms of performance of the system. And if they make a difference.

MR. MOELLER: Dr. Orth?

MR. FRAZIER: Excuse me. Let me follow up the last question. My name is Jerry Frazier.

In the tectonics section of the SCP, we address the subject you were asking and we say that we will attempt to identify whether properties will change by more than a factor of 2 is the number we use.

DR. KERR: Thank you.

DR. ORTH: Do you have your proverbial warm fuzzy feeling that you really have identified all of the material and properties that might be important in the overall characterization?

For example, considering your earlier remarks about zeolitic strata and vitric strata and plum puddings versus layer cakes, those kind of differences can make tremendous differences in the retardation and the way things move.

And so again, just using that as an example, do you really think you have identified all the material properties now to put them into your model and to put them into your experimental programs?

DR. SINNOCK: My personal opinion?

DR. ORTH: Personal opinion.

DR. SINNOCK: Yes. At least those parameters that will have what I will say will be a first order effect on the performance and behavior of the system.

MR. MOELLER: Other questions?

(No response)

MR. MOELLER: Well, thank you, Dr. Sinnock.

DR. SINNOCK: Thank you.

MR. MOELLER: We will go back to Carl Gertz.

I suppose the question at this point will be what is the remaining program and what sort of a schedule can we anticipate. I know Dr. Syzmanski is next.

MR. GERTZ: Yes. I am going to take about three or four minutes to introduce Dr. Syzmanski and then I will leave it to Ed to discuss with you what you would like to do after that.

MR. MOELLER: Okay.

MR. WEEKS: We have about an hour's presentation scheduled by Jerry Syzmanski followed by about a 30-minute summary presentation by two other presenters.

And we also have about another 15-minute presentation in there. So that we have approximately an hour and 45 minutes of presentation time which we are prepared for.

MR. MOELLER: All right. Well, we will plan on that. And if we can stick to that schedule, then we will be through by 6:00.

MR. GERTZ: I didn't state for the record what my background is. And I am a civil engineer from Michigan State University, and there are some people from Michigan around here, so I wanted to get in Michigan State University.

I have a Masters Degree in Systems Management from the University of Southern California, and some post-graduate nuclear engineering work. But I didn't want to miss an opportunity to talk about Michigan State.

Let me first state before I introduce Jerry's subject is that DOE Management is committed to a comprehensive site investigation program. We're absolutely committed to get on with the job. We recognize that it's important to the power industry and society that this project is a success, success being we build a repository if the place is right, or we don't build it if Yucca Mountain doesn't meet the safety requirements.

However, if you believe in keeping the nuclear option open, finding solution to nuclear waste is essential. We also believe and we heard a discussion today, and I hear wherever we go, there's many technical requirements that are unprecedented. Ten thousand year models, unsaturated zone activities, and therefore our perceptions and our approaches will constantly be evolving. We're going to be changing them all the time we think through site characterization.

And therefore we do welcome input for ways to refine current approaches and we'll respond as appropriate to clarify or modify programmatic plans. In fact, one of the things that has caused us to change our thinking on the project is the next subject. And that's going to be Jerry Szymanski's report.

Let me talk about it a little bit. It deserves some introduction, I believe. The background is that it is a conceptual model for thermal tectonic interactions. Jerry's going to talk a lot more about it when he gets up here.

The origin of the report, a couple years ago Jerry had some ideas about what was happening at the mountain. He discussed these verbally although he didn't put anything in writing at the time. And then last November, Max Planck, the supervisor and myself said, gee, some of these things may make sense. Why don't we get them in writing so that we can have a review of it, so we can see what the facts represent, what the report would be like.

And he did that. In fact, he provided the report officially to me on December 22nd, about five months ago. About a month later though, that same report, which was certainly an early and an unreviewed draft, was released to the public so to speak by the Governor of Nevada.

And because of some of the conclusions drawn, and some of the paraphrases that were made by the media, it did create some confusion. While the conclusions had qualifications to them, when you have a media and a United States Senate race, it created some confusion about out of context.

So we got a lot of interest, 29 media contacts the day it was released in my office, 29 media contacts. We did initiate a review process at the time it was received and it's on-going now. It's a standard QA review process, it's comments and resolutions documented. Each piece of paper, we're going to evaluate any possible impacts to the project approach, being incorporated right now, and we will produce a peer review report.

What is the status of that peer review report? Well, we've had a lot of reviewers, 17 to 20 reviewers, diverse expertise because it certainly crosses many technical boundaries. We've had some other reviewers. We've talked to the National Academy of Sciences. We've discussed it in the alternate conceptual model workshop and the State of Nevada has some comments on it, comments that I've not received yet, and I've asked for them, so it could be factored into our peer review process. Perhaps they'll be coming with us in the SCP comments.

We've gone through the comment resolution process, we've talked about it. And I'll name them because they're important: hydrology, flow processes, thermal convection, vulcanism, tectonics, rock mechanics, geochemistry, and under ground nuclear explosions at NTS, all those things are part of Jerry's report.

The resolution process has been interdisciplinary with scientific interactions and the status is we've looked at the majority of the major topics at this time. We've resolved, achieved about a hundred percent resolution. And let me tell you what that means, though.

Resolution means that perhaps the report needed clarification and the author, Jerry, has agreed to clarify the report. Maybe the comments needed clarification and the commenters agreed to do that.

Commenters and the authors recognize there have been alternate interpretations possible that perhaps one initially stated, so that's being stated. And the significance has been qualified and not just given without qualification.

What are our plans, though? Well, we do want to resolve all the comments that these reviewers have, and we want to develop our peer review report, and that's about a month or two in the future. But more importantly, we want to co-author a synthesis, because Jerry's report is pretty thick, and we'd like to co-author a 20-page synthesis, Jerry and some of the key reviewers, and then we would present that to people so that we can clarify technical issues, and provide a better peer review so to speak quote unquote of it, outside evaluation.

And as part of today's presentation, we hope to talk about 15 minutes, after Jerry's done, about what the peer reviewers have to say about it. And I think it will be very important, if you'd bear with us through that. Jerry's going to -- endorses it totally and wants to have it happen today. So we're going to have that happen.

And certainly we want to evaluate our adequacy of site characterization plan. Our bottom line is, project's perception of the environment is evolving. There is a management commitment to integrate all evolving hypotheses into the project, concepts that stress and temperature, inner components of behavior are now being integrated at the working level.

One of the things I think the report did was cause the scientists to think about this, that perhaps they weren't thinking about it before, they were focused maybe too narrow. There has been healthy technical disagreements about magnitudes and frequencies of hydrologic events. They're being expressed by various scientists. As project manager, I endorse that scientific debate.

During the re-review process, it's been beneficial to the scientific community. Some of the disagreements about significance, this significance, hydrologic significance, may be resolved during the review process; others we're going to have to wait until testing to resolve.

And in summary, that's where we stand. And I'll just turn it over to Jerry now to talk about his report for you all.

MR. MCELLER: Thank you, Carl.

(Continued on following page.)

DR. SYZMANSKI: What I will be talking about is the key player in the repository performance which I believe is the hydrologic system.

And of course in order to formulate such a thing, we have to have something which I call the conceptual model. So that is basically what we will be talking about.

(Viewgraph presented)

I would like to present this thing in four parts, this introduction which will be broken actually in two parts. We will be talking about conceptual models of a hydrologic system in general, which I think requires some clarification.

And the second part I will be talking about specifically the Yucca Mountain as seen in the data base which exists already at this point in time.

There is an integral part of this whole thing which is essentially somehow to conceptualize the tectonics environment of this site and try to obtain what is important in terms of hydrology.

Finally, I will put this whole thing together to develop the conceptual model of the whole system. And finally I would like to go to the technical issues.

MR. MOELLER: Your handout says on the cover that you are a physicist.

Could you tell us what your background is?

DR. SYZMANSKI: Well, my background essentially is in geology and geohydrology, but I guess the Government doesn't have such a title so they slapped this physical scientist on me, which is fine with me.

(Laughter)

The system that I will be talking about essentially is the one whereby -- I think it is the best viewgraph to synthesize this thing.

(Viewgraph presented)

In my perception, that system changes cyclically. There are two parameters which vary. The one is the hydrolic potential and the other one is the temperature of the rock which is another form of a potential.

What is important is that there is a decay in time in coming back to its normal position.

Actually I think that Yucca Mountain right now is somewhere at this point in time. And that is essentially the main point, that there is a cyclic change which involves two potentials: temperature and hydraulic potential.

DR. SHEWMON. Are you going to tell us what you think the return time is in that model?

DR. SYZMANSKI: Yes. I believe that these conceptual models are quite important things. They are important because they provide the foundation for all aspects of our activity; formulating mathematical models, development of compliance strategies, development of the data collection, and finally demonstration of the regulatory confines.

What is important from that viewgraph is that the conceptual model is a foundation. If the foundation is wrong, the building is likely to be functionally wrong.

(Viewgraph presented)

Well, before we get any further I would like to concentrate on the word "conceptual model" of a geological system. What is it?

For my purposes I am defining this as a set of thoughts or concepts which has three characteristics. One is that it pertains to a system. The second one is it must be useful or organized and somehow reduced to a readily digestible form.

And finally, such a thing has to recognize and express either from the nature of the system under question or the circumstances under which this system operates.

I would like to spend a bit more time on the word "system", what is "organized" and "circumstances".

(Viewgraph presented)

So essentially as a geological system, I have used a part of the earth's crust as a body which is composed of interacting and interdependent parts. The strengths can be variable.

Now what is important in this second bullet is that "subsystem" cannot be treated in isolation of the overall system. The subsystem is only a part. In some places, the interaction is very weak and justifiably so.

We can view the subsystem as not really related to the overall system.

DR. MOODY: Jerry, do you think in the system we are going to be talking about, the repository at Yucca Mountain, do you think the crust is the only portion of the earth you have to be concerned about?

DR. SYZMANSKI: I don't think so. I think we have to be concerned with the mantle as well because that is where the energy will be coming from.

But I would like to see this connection in terms of boundary conditions. Later I will have a viewgraph which will tell you exactly where I see the connection.

Somehow we have to break it. We cannot really look at the 30 km or so. So somehow we have to cheat nature a bit.

There is a third bullet which is likewise important in my judgment which essentially says what Judith was asking. We cannot really expect to know everything that is to be known about the system.

However, we must know what is important, of course for purposes of our activities, which is the waste system interaction.

(Viewgraph presented)

I think this is a very important viewgraph. What we are really interested in is this one, the subsystem. There is some linkage between the vadose zone hydrology and the overall system, which consists of both saturated and unsaturated.

Now this hydrological system is somehow related to this one. And again one can view a conceptual model as specifying what these relationships might be, specifying how strong this relationship might be.

And finally evaluate how important these relationships are. Well I view that quite strongly what we are talking about in terms of a saturated zone is a sub-subsystem. Its basic nature is related to these two things.

Now I also feel that this concept must be useful. And again I see them as useful when they are organized. It is quite difficult to organize geological observations or geological descriptions.

However, we can try to do this more kind of in a mathematical physicist language. In other words, what we want to focus upon is the information which will help us to set the governing equation.

For example, we have to ask ourselves the question of whether or not the governing equation should concern all these three things or maybe there is only one important thing.

But again a thought here is that that decision must be conscious. It cannot be a decision by default. ·ne is interested in the state of the system.

Well, it is quite easy to solve the equation when it is a steady system and it is more difficult when it is a transient.

But the convenience again should not be the one who guides us to which state we use for our evaluations.

Well, there is another important parameter which is very often ignored because it is very difficult to probe in, which is boundary conditions.

And again I see this as a mass and/or energy input into the system. There is some description of it. It is quite easy to say that the boundaries are really of no importance and that there are no flow boundaries.

Well, our problem is completely different. Finally, we have to know what our initial conditions are and there is a fourth aspect which is quite important, I think, which is essentially space and time dependence of constants which relate work and energy.

In our case, the biggest important is a constant which we call hydrolic conductivity. There is another one which is called thermal conductivity.

Now my thought would focus on possible time dependence. And I think that is a unique thing in the hydrological thinking that I have seen thus far because most hydrologists say that these constants are the function of space but very few of them think about them as being a function of time.

Again, the temporal aspects of the behavior of such a system are completely different.

(Viewgraph presented)

Well, the third part of our requirements in defining conceptual models is this concept will recognize in a tectonics setting which is active in terms of strain energy and one which includes alkaline volcanism, that the strain energy in such rocks vary in time, and it is very likely that the terrestrial heat flow coming from the deep parts of the earth is substantial.

By putting this together, after my talk -- I hope -- it will become quite obvious that there are three things which are important. The first is time dependence of the constants I was talking about.

There is another possibility that there is a convective nature of the flow process. Thermal energy drives the system.

And finally recognize in the convection in fracture we could be talking about transient convection.

DR. SYZMANSKI: The integral point of my introduction would be to put some very basic and very selected information pertaining to local geology, in situ stress, slug test and in situ temperatures which I have selected for the purposes of illustrating that some of the concerns which I am expressing have some roots in terms of the information which we already have.

So first the very brief overview of Yucca Mountain, the repository somewhere in this area, there are two features which strike any geologist visiting this place.

The one is the presence of numerous cones. They are volcanic cones, those here.

(Viewgraph presented)

There are about 11 of them. They are all of quaternary age. And there is one bugger right here which can be as young as about 20,000 years old.

The rocks which form these cones are alkaline -- kind of rocks which are similar to what they are in Hawaii.

The second feature which is of interest is the presence of basically five faults. There are five of them.

Now these faults have a history of quaternary movement. This one, Windy Wash Fault, is known to have about five movements in the last about 200,00 years.

The others, we don't have such precision yet but we know there is a late quaternary movement involved.

(Viewgraph displayed)

This is the east-west cross section of Yucca Mountain. Of interest are these five zones which correspond to the five faults I have shown on the photographs.

Now the rock which is composing these zones is very peculiar and I have brought you a piece to take a look at it.

(Passes rock out to audience)

What is peculiar about it is this is essentially matrix supported, the one which has a very substantial amount of volumetric strength.

Now I have done a very simple computation. The total length from here to there is somehwere on the order of 10 km. We have five zones about .5 km thick, each one. Together they form 2.5 km.

On the average, I judge the volumetric strength to be on the order of 10 per cent. So therefore a conclusion is that the width of that mountain has increased 250 meters since the deposition of the rock.

That is a very curious circumstance. And I started looking into this deeper. Now these breccias zones are quite old. There is no question about it.

However, in the center of this breccias occur materials which are obviously much younger.

Next viewgraph.

(Viewgraph presented)

There is a picture of it over here. And of interest is this group of veins. We only know them for about the first 15 feet of the surface.

Now this material consists of essentially intermixed and interlayered calcite and silica. What is peculiar here is that the water table is down 500 meters.

This is a close-up of the vein section

(Viewgraph presented)

We know that these things are late quaternary. They are somewhere on the order of 200,000 years old or so. So we do have these breccias. We do have these materials. I think they are suspicious looking things, myself.

So my next step was all right, let me imagine what kind of a system would be the one which allows this dramatic change in the water table.

Well, the next bunch of data which I have looked at were in situ stresses. And ag Yucca Mountain in terms of engineering project is quite unique.

We do have four deep bore holes whereby hydrofracture measurements were performed. So before we get into this, I think some unification between me and you is required. Therefore, let's examine this.

This is a typical Moore diagram which shows two things: the stress, in terms of the Moore circle, and presents also strengths of the rock.

Now if this distance between the circle and the line comes essentially nonexistent or zero, we will develop here failure.

If this distance, which I call e-2 becomes zero, we will have a hydraulic failure. And if a failure occurs in-between, it will be a hybrid. It will be a combination of the two.

Now let's take a look at the stress measurements at Yucca Mountain. This is essentially bore hole g-1. And now should the circle be substantial distance from a dashed line, it would mean that our e-1 value was substantial.

However, having these dots quite systematically right smack on this dashed line tells us that e-1 is very, very small.

That is the coefficient against -- friction stability coefficient against frictional sliding is very close to one.

I think it is a very important observation. Now of course this type of thing is recognized in terms of tectonics, stability of openings and other engineering purposes, but very seldom this thing is looked at in terms in hydrology.

I would like to spend a bit more time. And before we go, I would like to show you another measurement whi h is an interesting situation here. Again we do have these three dots right smack on the line but somewhere down in depths that thing wants to depart.

In other words, what we begin to see is that the deeper we go -- somewhere around the order of 1500 meters -- that coefficient becomes bigger than one.

but it is not so in this area.

Next viewgraph.

(Viewgraph presented)

Now let's probe a bit more in terms of the potential hydrologic significance. And there are two drawings here which really are after this one, but we cannot get results understanding this thing.

This one is the standard shear stress, shear displacement diagram which essentially consists of two parts.

If our coefficient against friction or sliding is one, then the displacement is either here or somewhere there.

In other words, we would not know which one the case pertained to on the basis of stress measurement alone.

However, what is significant to understand is that once that rock is stressed in such a manner that we go to this limit, the rock begins to be dilated in shear.

In other words, the space of the joints begins to increase. Now common sense tells us if we have a rock in this situation, the conductivity of such a rock is much different than over here.

So this is essentially a concept of how shear displacement translates in terms of shear dilation.

Next one.

(Viewgraph presented)

This is a very interesting graph as well. This is the increasing full pressure or it could be a decreasing effective stress.

In other words, if we stress rock in such a manner that the coefficient against frictional sliding is much greater than one, the conductivity is constant and stress independent.

However, when we take it to the limit, our rock seems to have very small increases of poor pressure or decreases in the effective stress and causing enhancements in conductivity.

Now that enhancement is extreme at this point where our e-2 will go to zero. In other words, our rock opens up and conductivity is as high as you want.

Now what is interesting, I think, is to examine some selective data. And we have them from about 25 holes. Let's do a slug test. And I selected a few results. I hope everybody knows what a slug test is.

What happens is we are taking an interval of rock, say 50 or 100 meters, sometimes we use 200 meters, and we isolate that interval with two pockets, one at the bottom, one at the top.

There is a pipe which goes all the way to the surface with the mouth at the bottom.

We will fill the pipe with water, usually 500 meters of air. We will open our valve and we will be watching how fast the slug moves in the pipe.

And this essentially is the result.

Now obviously in this case our slug travels quite slow. And there is 10,000 seconds required to reduce the head by about 20 per cent.

So the interpretation here is that of course with 500 meters of head we do not have an enhancement of conductivity induced by hydraulics.

But let's take a look at another plot which is slightly different.

(Viewgraph presented)

See, there are two intervals here. And we have two distinctive parts of the graph, this one and that one.

This one and that one.

(Points to two areas on graph)

Now fortunately not far from that bore hole we have measured that the stress, the confining stress, which allows e-2 to go to zero is somewhere on the order of 220 meters.

So therefore the interpretation is that the break essentially establishes a point at which the rock fails in the Griffiths mode; that is, opens up hydraulically.

And of course over here we are measuring rock which is dilated in shear. However, you can compare the first plot and this one in terms of how fast the slug disappears and you will see quite a significant difference.

There is finally another one which I think is the most important one. Essentially we are seeing here that the slug travels very fast. About 2 minutes or so are required to get rid of 500 meter column of water.

I don't think I can swim that fast and I am a good swimmer. And the curve doesn't have any breaks. Very important to stand what it is an interpretation of. Let's put this one up.

(Viewgraph presented)

Now I think that one is that essentially at that point, that rock is stressed in such a manner that at that point it is very low. In other words, we are observing this part of the curve.

If you put the two together, I think it becomes quite obvious that this is a reasonable expectation. In other words, what I think we are seeing is combined slug test and in situ stresses.

In situ stresses are telling us that the rock is stressed at limit in places. Small increases of either poor pressure or either decreases of a stress by extension must be introducing the permanent slip.

But we do not know whether there is certain permanent displacement on the basis of stress measurement alone.

However, when we introduce the slug test, I think they are telling us that that rock is not only stressed at limit but is quite dilated in shear.

DR. SHEWMON. You are setting up this head of water out there on the mesa some place and watching it come out the bottom somehow?

What is this column of rock? How is it defined that you are talking about it?

DR. SYZMANSKI: Well, it is defined arbitrarily. Usually it is --

DR. SHEWMON. This is experimental data, is it not?

DR. SYZMANSKI: Yes.

DR. SHEWMON. Okay. So there is a column of rock. How long is it and where is it?

DR. SYZMANSKI: Well, this one --

DR. SHEWMON. Yes.

DR. SYZMANSKI: -- is at depths 911 through 972 meters. There is about 60 meters of rock isolated about a kilometer from the surface.

DR. SHEWMON. So you put a pressure on one end. And as the pressure falls, after the stress goes down, it opens up?

DR. SYZMANSKI: When the stress is high, the rock opens up. And remains open until it reaches that point. At that point, the rock begins to close because what happens is that the hydraulic head decreased.

DR. SHEWMON. Okay. And then it opens up again?

DR. SYZMANSKI: Yes. But you see there are two types of openings. Maybe we can come back to our Moore diagram.

(Viewgraph presented)

There are two types of openings. In this particular case we've got them both.

You see, this tail opening marks where that distance becomes greater than zero. The first break, corresponding to about 220 meters, that one is zero.

The difference is this is what we call a normal dilation of hydraulic. In other words, there is an opening like that.

Where that one is a shear dilation. There is a kinking of that rock.

DR. SHEWMON. Okay. Fine.

DR. SYZMANSKI: So, you see, what I think the three types of curves are telling us that replaces that circle is more than 500 metes equivalent stress away of the rupture. That is our first example.

There is another one whereby that circle is very close to the rupture. This is where we have these two humps on the curve. And finally there is a third one whereby that stress, that circle, is very small in size and shifted all the way here.

In other words, we are not seeing the tail that we are seeing on the second one. But I just wanted to show this as an example. There is some basis that probing this data can be a very profitable undertaking.

Now we also are just simply imagining what is happening. The rock is stressed. There is an opening. The response of such a rock to stressing as a dynamic effect is completely different then when the rock is unstressed.

And again it is a very good example of it, the response of the water table to pore pressure. This record is about six or seven days after the detonation.

And the bore holing which we are observing has built up some pore pressure is about 3 to 4 km from the detonation site.

Now of interest is this very erratic behavior of the pore pressure. The interpretation of it, in my judgment, is quite straightforward. What we are seeing is a situation whereby detonation, the system becomes unbalanced and is searching for an equilibrium point.

And that is why such a dramatic drop of water table. Increasing the pore pressure was sufficient to open the fracture.

But in a system, mechanical system, this type of behavior is quite important and to be expected. We are talking about 15 inches of water.

The second part which I would like to talk about.

DR. MOODY: I have a question of time. Okay. We've got a time period there, 1200 hours. Does that change as a function of a month, a year, five years later? Does it come back to what it was before that detonation occurred?

DR. SYZMANSKI: Some places I understand it does; in some places, it doesn't.

Now later we will get into this because there are two various settings which are justified, and one is permanent but in some it is transient.

In this case, we are talking about a transient effect. What we are essentially seeing is the time changes in the hydraulic storativity in the rock.

It is two components, like husband an wife. The wife dies or the husband dies and she is kind of out of balance. This is a very similar situation.

There is a second aspect which I think is quite important, which is the temperature. And again I would like to focus your attention on the data we have obtained from WT-10 or WT-1. We have about two of those.

WT stands for water table. In other words, we drill the hole to know how deep is the water. And after that we will measure temperature in this rock.

Now this is the result. This is the depths. Of importance I think is the difference in the temperature from one point to another.

I was actually impressed about this number. It is 15 degree C. And if you take a look at the map between hole No. 10 and No. 1, all we have is about two miles.

In one spot, the rock is warmer about 15 degrees C than the other. Well, one would ask why is it. I think that it is very reasonable to suspect that there is a nonhomogeneous heat flux through the base of this thing and that is why these rocks are warmer, since more heat is flowing over here; and over here it is less.

It is not difficult to imagine what in reality we are seeing is a system which convects in the saturated zone.

MR. MOELLER: These depths are from a fixed level, not the depth from the surface?

DR. SYZMANSKI: It is from the surface.

MR. MOELLER: It is from the surface. Well, is the surface flat?

DR. SYZMANSKI: Of course not.

But we can quite safely assume that for the elevations involved, that zero is really isothermal surface. Or a fe' [illegible] below, I would say 10 or you could argue 15, you will have a temperature which is equal to average annual temperature.

MR. MOELLER: Yes.

DR. SYZMANSKI: However, as we go deeper and deeper you can see that the gradients are changing.

MR. MOELLER: Right.

DR. SYZMANSKI: And that is what is important.

Now our second graph is telling us a bit more about the temperature in the saturated zone.

(Viewgraph presented)

Again, at some depth we are seeing the fluctuations. The water on the north and west side seem to be a bit more warmer than the waters in the repository.

Now you can actually, by looking at the map where the cross sections are, you will see that this step occurs in parallel to the step in the water table.

But I brought these examples, and they are just selective examples, to demonstrate I think the point that it is not such an abstract thing to initiate a bit more interest in the temperature and the stressing of these rocks and what do they mean in terms of hydrology.

I think we have real data. We have good examples. And all we have to do is to understand it.

So that is essentially my problem. What I am really interested in is the post-closure performance objective, all of them. There is a very important player, which is hydrology.

So I would kind of like to zero in, the tectonics, hydrogeological system, how they are related and see what it means in terms of our performance assessment.

In other words, a conceptual understanding of tectonics environment would be a useful thing to know, to understand what that connection might be. And finally one could speculate on the nature of that.

Once some logical scheme of things is developed which is justified by first principles, I think we can start looking into that.

So in terms of developing my perception, I had this general approach. I was focusing upon the question is it possible rather than is it true.

I am not an experimenter. I have to live with the data which are available to me. And some of these data was not obtained surgically. Therefore, it is rather difficult for me to get that point. Is it true?

Now for the second one I said to myself well, it is reasonable assurance that is required here and does not mean absolute assurance that either the site or the site characterization logic contains a fatal flaw.

And finally I think the fatal flaw is very important and I think we have to know explicitly what are we looking for.

The question has to be explicit. Otherwise, we can bury them in terms of the bureaucratic language meaning of which is not known anyone, least of all to people like myself.

The second part I would like to get the conceptual understanding of tectonics environment. That is our first understanding of the system.

DR. SYZMANSKI: Finally, I would like to synthesize these things and say well what is all this information telling me in a manner which is simple and useful and I can use this thing to establish what my governing equations are, what are the states and so on.

(Viewgraph presented)

So the first viewgraph is the location of the site. I am interested in the overall hydrologic system situated in the Great Basin.

The Great Basin is quite anomolous in structure in the United States which has very well defined characteristics which are readily available. They are known.

The first one is an isostatic anomoly map, gravity measurements. Our place is somewhere here.

(Points to spot on map)

And as you read the label, you will see that this means mass deficiency. In other words, that the gravitational attraction over this area is less than in the standard area.

Now there are two ways to explain such a thing. On one hand, we can assume that the crust is thin and the mantle is of decreased viscosity. Therefore, that is why we get the less mass.

Or, we can assume that the crust is thick there.

There are two various compensation mechanisms.

In order to distinguish which one is the case, we have to know or we have to obtain some measurements of the thickness of the crust.

And there it is. It is a recent seismic reflection survey. And again it is seen that in our region the thickness of the crust is low.

Therefore, on these two observations we can expect that our mass deficiency, the origin of it, is in the mantle.

Now in order to confirm such a thing, it would be nice for us to know what is the velocity of seismic waves in the mantle.

(Viewgraph presented)

Well, we've got it over here. This is based on deep seismic soundings, nuclear detonations and earthquakes

This region is of interest to us. And again the mantle velocity is reduced from normal 8.2 or 8.3 to somewhere on the order of 7.8. Just to give you a comparison, the mantle underneath Japan would have a velocity somewhere of the order of 7.7 km/second.

There is another characteristic of this area. It is a surface heat flow. We know the area is quite increased. It is 2.5 heat flow units.

Now putting these four characteristics -- that is, mass deficiency, thin crust, low seismic velocity in the mantle, high heat flow -- it is easy to guess what is the raw picture of the geological system.

And such a thing was developed by Scholz and represented here.

(Viewgraph presented)

The mystery is readily explainable by assuming that the mantle is partially melted. Well, if it is so, I have performed an analysis or computation of the stability of such a thing.

The critical number for such analysis is the viscosity.

(Viewgraph presented)

Now I have assumed that it varies somewhere between 10 to the twentieth to 10 to the twenty-first poise. That is a very important assumption. I think it can be justified.

Now we also know on the basis of various computations that the critical rating number for the mantle is somewhere on the order of 1700.

From that it becomes quite easy for us to compute what are the requirements for the convection in the mantle to be initiated.

And again for various viscosities which we will be talking about later, which is about 100 km thick, 10 to the twenty-first poise, all we really need to initiate this thermal instability is 200 degrees C difference between upper/top and the bottom, 100 km.

That is a pretty darn reasonable number, I think. Now this computation is telling us that an assumption of convection, thermal convection in the mantle, is reasonable.

It would be a miracle if that thing wouldn't be convecting. So the next step is what does it mean for us, for the hydrologists, which I think is Judith's question.

Heat flux, which is heterogenous there, and there is a continuous introduction of strain energy.

(Viewgraph presented)

I would like to examine the local characteristics of our area as we know them, oh, in the shallow depths of a few kilometers. I would like analyze what is the history of strain accumulation and there are information which pertain to long-term, geological, short-term, which is years, and very short-term, which is weeks.

And I think it is quite constructive to review this information.

It is interesting to see that the very long-term, like this one, is essentially the strain rate was derived on the basis of geological records. It is not terribly dissimilar to what we get from the second one, which is on the basis of geodetic measurements, a few years.

And it is quite comparable to what we get from earthquakes. Now there is another interesting aspect to this one which is the shear strain in the horizontal plane.

Unfortunately, it is quite difficult to measure it and all we can really do is paleomagnetic studies. It was surprising to me, this 30 degree rotation. I think it is a very substantial number. It is not trivial by any means.

There is another rotation which occurs about the horizontal axis and it is a tilting of the area. It is quite obvious that the area is strained, that it is being strained.

It is an interesting diagram or strain measurement which was achieved through measurements with strain meters. The occasion here was an event in 1970 at the Nevada Test Site and someone was very wise and decided to keep the strain meters operating.

(Viewgraph presented)

Of interest is this record that essentially indicates a very substantial straining which occurs on all of them in a very short period of time.

MR. MOELLER: Is there a reason to use this particular year or two months?

DR. SYZMANSKI: No. These measurements are quite difficult to make.

MR. MOELLER: I see.

DR. SYZMANSKI: It is unique. I think that there may be only one other place on earth which has more than one.

MR. MOELLER: Okay. I see.

DR. SYZMANSKI: They are quite, quite sophisticated measurements.

This just happens to be when these instruments were operating.

MR. MOELLER: Okay.

DR. MOODY: So again, Jerry, you are saying there isn't anything more recent since that two-month time period which you are showing up there?

DR. SYZMANSKI: Right.

DR. MOODY: Have they stopped measurements after that?

DR. SYZMANSKI: What I am trying to show here is that it is reasonable to assume that this area is being strained on a continuous basis.

We have enough information to say that.

MR. MOELLER: Okay.

DR. SYZMANSKI: How it happens is not so terribly important. But if one verifies that statement in light of geological observation, a few years geodetical measurements, very short-terms, all are telling you it is being strained.

Well, the second characteristic is essentially all things related to heat flow.

(Viewgraph presented)

And of course we know that Yucca Mountain is a place which is unique because it is located in the area which is known as a eureka low in terms of heat flow.

The eureka low means there is near-surface hydrological disturbance. In other words, a picture of the heat flow which we would obtain on a basis of very near surface measurements is likely to be misleading.

Therefore, I look at other aspects of it. The first one is the volcanic. And of course of interest to me is this area here.

Now if anyone would care to make these two maps in the same scale, I don't have anything to make it in the same scale. But one would like to correlate where these volcanos are with that.

Now what that thing is, at the Nevada Test Site we do operate about 53 or 54 seismic stations essentially distributed through this large area and they are shown here as triangles.

(Viewgraph presented)

On this particular map which we had is a plot of seismic delays in a seismic velocity of teleseismic waves. Now the earthquakes are coming from far away like Chili, China, whatever.

At that place, they have already very low frequency. So we can measure them quite precisely. The objective is here to know what is the velocity between these two points, these two points, and so on.

And you compute the average velocity and see which ones are higher or which ones are lower and so on. But of interest I think is this feature here plus two features like that. It is kind of circular areas.

I don't think it is unreasonable to interpret that these things could be magma bodies where the rock is molten, for one. And there is another aspect of it that in general the rocks at the depths of about 50 km in this area are a bit warmer than outside.

Now of course in order to be certain -- it is a very important conclusion -- one would like to confirm that with electrical measurement. We don't have these things yet.

So therefore I will be assuming that this anomaly here in the QA velocity is caused by temperature. It doesn't have to be.

DR. STEINDLER: If you are correct, should you be able to calculate your electrical measurement results on a contour?

And if you do that, can you provide some way in which that can be relatively easily tested?

DR. SYZMANSKI: Yes. It is kind of a standard technique. All you have to do is you have to go deep, 15-20 km. And what you will see if indeed this is high temperature, the electrical resistivity will just suddenly drop.

Well, we don't have them so I have to assume them. But I have assumed there are two things. The area is being strained continuously and there is a local, localized small dimension heat source.

It is a relative heat source. The two conclusions become important. The conclusion 1, it is being deformed. It is deforming. And the second one, about the heat.

Diagrammatically, I think we are getting a connection over here that Judith was talking about.

(Viewgraph presented)

And that can be viewed as a conceptual model of a system. There are two boundary conditions. There is one which is expressed as shearing on a horizontal plane here. What I am saying is that shear stress is variable in space.

And there is also the flux of heat which is not equal from one point to another. Having this shear stress acting and being complied, we can conclude that the deforming fractured medium is involved.

Therefore, we would like to start thinking in terms of time dependence or stress gradients. By putting more strain energy we will be straining this thing more and we will be changing the stress picture as a function of time.

But the second feature we would like to talk about is time dependence of geothermal gradients. And that takes us to essentially the third part of my presentation, which is a conceptual model.

It is kind of common sense putting these two assumptions together. So flow system, we are talking about conceptual understanding of it. And I would like to get into two topics.

Ones are assumptions, and I would like to state them explicitly so everybody can argue with them. And after this I would like to present the synthesis, what does that mean.

That is, I will present the conceptual model in terms of the behavior of this fluid here.

Now I have assumed there are three factors. Conceivably there are four but I am not a chemist so I don't know much about chemistry.

But there is geohydrologic, which I will be calling H. There is a heat, which I will call T. And there is strain energy, which is mechanical (M).

Obviously they are interactive. Now I have assumed that there is two-way interaction. That is, geohydrologic can affec' ᵗ ᵗt flow. Heat flow can affect geohydrology.

I want to simplify my problem and for strain energy I have assumed that the relationship is one-sided. There is no feedback relationship.

Of course, that is a fallacy but I am not a computer. I just work with my drawings. It is much easier to draft them that way. However, the point is made.

I also make three other assumptions; that the changes in the temperat ıre distribution at some depths, say 20 kms, as a function of time are insignificant.

In other words, I have a steady state geological process which operates continuously. And for my purposes, that operation is a steady state. Nothing changes there.

Such a convection mantle would provide that unchanging situation. I have assumed that the amount of water contained and flowing through the system is not related to time.

What I have done here really is I have assumed there is no change. And finally I have assumed there is a very controlling factor here, the stress.

There is the mechanism that is known as seismic pumping. In other words, when our stresses were increasing or our gradients were getting more curved, what we were actually doing was reaching shear stress on the fault, the actual curves, analyzing and drawing the conclusion that a large expulsion of fluid must take place.

And the mechanism is known as seismic pumping. For my purposes, the seismic pumping by itself is not important.

I is important only in the sense that it will be responsible for the large- scale change in stress. So let's probe into how this thing looks like.

(Viewgraph presented)

And I have developed a few block diagrams.

The fracture consists of two components. One is a residual fracture. And a definition of that is that that aperture is independent of stress. It doesn't really matter what happens to the stress. It remains at some constant value.

But this of course holds only true to a given level which we call the closure pressure. If we still decrease the effective stress, the aperture starts increasing and we are getting a normal dilation component of the aperture.

There is another part here which is shear dilation. Now --

DR. STEINDLER: Now does that model assume a homogenous medium?

DR. SYZMANSKI: Not necessarily. Not necessarily.

This is essentially kind of a conceptual model to see in a qualitative sense how these things might be changing.

It is also important to know what is the coupling between hydrolic and the temperature. And of course the candidate here is the buoyancy, a really straight-forward thing.

And as we increase the temperature of water, its density decreases and there is some tendency toward upward component of flow, thermally driven.

It is interesting, I think, for some hydrologists to take a look quite easy, at how easy it is to convect fluids.

There are two parts to it. Very small temperature gradients are required to initiate the convection. There is another point which is very important. That is, understanding that the convection, the process of convection in fractures is completely different than in a porous medium.

The difference is essentially that a porous medium can be a steady state process; convection in fractures is transient.

And in the way this transiency expresses itself is the gross rate of convection is a function of two things. One, it is a heat transfer function; how much heat is taken out from the convecting water and introduced into the rock.

But there is a second important aspect, which is our aperture. In other words, by increasing aperture, we are increasing rate.

Now just imagine what will happen when our pore pressure comes, a separation develops. Obviously we have changed quite a bit the aperture of a single fracture, which is the fault.

And by doing so we have dramatically affected the gross rate of this convection's stability. Putting things together, this essentially conceptual model of flow --

(Viewgraph presented)

--it is two dimensions, there are two features here. One are these things, which are essentially the boundary conditions along the horizontal plane. And I will be putting variably distributed heat flux to the base and variably distributed fluid flux to the base.

What is important is that that boundary condition in a system like ours, it is a very strong likelihood that such a boundary is a flow boundary with respect to both fluid and heat.

Another important aspect of it is the dashed line in this drawing. The dashed line is the depths which is dependent on space and time.

Now what that thing represents is a division of our flow domain into two parts. The upper parts are hydrolic and thermal parameters and are dependent on stress and the pore pressure which together form the effective stress.

But below they are now. Now during a tectonic deformation, one can imagine that these depths migrate from some shallow position at the top early in the straining cycle to some maximum and comes back to its previous position.

What I wanted to illustrate what is happening to the hydrologic system, such a thing, so I assume we have a well.

(Viewgraph presented)

This is a distribution of pore pressure as a function of depths. And I have assumed that there is a horizontal flow only. And there is a water table at this level.

And my depth is z-sub-x-of-t, somewhere very shallow. And then start the deformation at the time of t-sub-0. The second part is essentially the same drawing.

(Viewgraph presented)

The difference is that I introduced this deeper. But still about the water table. If you compare these two plots you will see that the water table remains in the same position.

And the third step, I have migrated these steps all the way down. This dashed line over here is telling us where the water table was. And that one outside, where it is.

In other words, what we have done is taken that potential and reduced it by that amount and we have changed the shape of this fault, this curve, from a line to this S-shaped curve.

In other words, a system like ours -- I mean a deforming system, should have two characteristics. The one, the distribution of the pore pressure as a function of depth should show this as curving.

And if anyone would be observing this point in time, one would detect changes in it. Again, it is a very easy way to distinguish whether such a system existed at Yucca Mountain.

Now we do have information from three holes which can be fed into this S-shape and they are telling us that that delta P here is at the minimum 68 meters.

Recently I am analyzing the data which pertains to changes in this point in time and they seem to be quite distinctive changes. There is a lowering of the water table.

Now at the end when our depths come back, the formation now is very shallow. Our S-shaped curve is transformed to this curve, plus there is some addition of the water released from the start.

In other words, we have temporary distribution of the pore pressure like that. Now if you would be observing this thing in time, this would be a system like that.

Of course, of importance becomes is it a system like that, No. 1, and what is this in terms of years. And what is this amount in terms of meters.

Now there are other characteristics which are thermal which likewise can be deduced from following this reasoning. And it is essentially temperature. This temperature should do the same thing as our hydrolic potential.

That is when the rocks are unstrained and should be high. However, when they are strained, the potential should be reduced.

Well, the fourth part are technical issues. Again I see three points.

(Viewgraph presented)

Is tectonic rise possible? What is the magnitude of this rise? And what is the frequency of occurrence, which is the bottom line question here.

And again the answer to the question "is it possible" is it is purely a matter of conceptual model of the flow system.

If we envisage this as a purely gravitational system like most hydrologists do, of course not. That by definition won't do anything.

However, if we increase the amounts of components which play a role or increase the coupling, the answer of course is yes, yes and yes. The more elements, the more sensitive such a system is.

Now what is the magnitude of it? I think that there are three components for a system which is composed of three elements.

(Viewgraph presented)

There is this overpressure that is S-shaped, the distribution of the pore pressure. There is this one which is the water released from the storage. And there is a convective component thermally-driven.

Now we know the one at Yucca Mountain is 68 meters or more. We know that 68 meters for sure exists but the question is did we go deep enough to know the maximum.

Two other holes have this thing. One is about 42 meters and the other one is 22 meters. Now water that is released from storage is essentially a dynamic effect.

The third aspect of it is the frequency, and of course this is related to the conceptual model of that system. And in my case the main player is the aperture. And that is related to stress.

Therefore, the frequency is a function of faulting frequency with this range in terms of an earthquake. The duration is a function of another parameter. It won't be a day. I think it can be measured in terms of hundreds of years.

But that is essentially all I had to say.

MR. SMITH: Jerry, in your report issued in November of 1987, in the conclusion you made the statement that the conceptual model of the flow field indicated by the currently available data from the Yucca Mountain site points towards serious limitations of this site to effectively isolate radionuclides.

I wonder if you still feel that way. I am looking for a relationship between everything that you have said and the feasibility of deep geologic depositories storing nuclear waste.

DR. SYZMANSKI: Yes, I understand that.

DR. SYZMANSKI: Right. If this model is correct, it offers very serious limitations. Because essentially it removes our main attribute which is the very limited amount of water.

DR. STEINDLER: Can I follow that?

At one time there were three repositories, one of which was effectively underwater. That was a viable candidate up to relatively recently, not perhaps the best but certainly a viable candidate.

I have trouble with that giant step that you take between saying that we have lost an important attribute, namely unsaturation, and your conclusion that there is serious question.

Can you give that connection?

DR. SYZMANSKI: Sure. It can be done on the basis of number of performance objectives. Probably the most meaningful would be travel time.

As you probably know, the site which was being investigated had a very long travel time in the saturated zone.

At Yucca Mountain, the travel time today is certainly not measured in thousands of years. Perhaps in tenths of years.

MR. MOELLER: This is the water?

DR. SYZMANSKI: For water. For water.

DR. STEINDLER: In the saturated zone?

DR. SYZMANSKI: Yes, in the saturated zone.

But you see the most sticky aspect of this situation as I have envisaged would be expulsions of water on the surface because of the convective aspect of the total flow system.

In other words, we are talking about very short flow paths somewhere on the order of 300 meters. And these waters would convect and intersect the earth's surface.

There is another aspect of it which was in my mind: how do you handle mathematically such a system? In other words, whether the mathematical models can be developed with sufficient certainty to be used in licensing. That in my mind was a serious question.

Fractures is a subject which is very poorly known and mathematics is quite difficult.

MR. MOELLER: Other comments or questions?

Dr. Moody?

DR. MOODY: I was just going to ask you to talk a bit more about that. One of the things that is exceedingly important, of course, is the structural tectonic region that Yucca Mountain is.

And just articulated the way you said it, on and off, but articulate what you also think the structural peak is not only in terms of earthquakes but movements along faults, the major impact that that will have in terms of water movement.

DR. SYZMANSKI: Well, I think I did enough talking. You see, the movement by itself, I don't think it will be of any consequence in terms of fluid field. What is very important, however, is that the movement on the fault at Yucca Mountain will be a trigger to changing the conductivity structure of the rocks.

In other words, an earthquake is an indirect cause of the rise of the water table. Think in terms of conductivity in these apertures. It is indirect. It is not direct.

DR. MOODY: That is what I was heading at.

MR. MOELLER: All right. Well, thank you for your presentation.

And I am pleased that the staff could be here and hear it. Because certainly from my standpoint I have read about it but not heard it.

Ed, why don't we turn back to you and hear your suggestions for the rest of the day.

MR. WEEKS: In view of the lateness of the hour, we have been throwing less than completely essential viewgraphs in the waste basket.

I believe that we could complete the remainder of our presentation in about 25 minutes. Jerry Frazier would have about a 10-minute presentation.

That would be followed by about a 10-minute presentation by Don Alexander discussing how we are using scenarios and summarizing our activities on alternative conceptual models.

And a very short presentation by Steve Brocoum which will summarize precisely what it is we will be doing in the SCP to accommodate these.

I think they would be quite useful presentations. I would hope you will be able to hear them.

MR. MOELLER: Let's go ahead with them.

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MR. MOELLER: And you are going to give us a preliminary look-see at what the peer review has said, is that it?

MR. FRAZIER: I am going to give you a little bit of insight into the peer review. I am actually focusing on a little tiny piece of it. I am trying to synthesize many of the physical factors that Jerry has got, and get it down and we will get our arms around it to see how to deal with it.

MR. MOELLER: Okay. Thank you.

MR. FRAZIER: I have travelled with the peer group. We have had several meetings of a half a dozen to a dozen scientists in the room. We have done this for three weeks time now, in which Jerry and the reviewers have interacted with comments. So we have multi-discipline science talking going on.

And let me just comment, and it is a subjective statement on my part, that this has been very useful. It has helped to get this scientific communications going and so forth.

(Viewgraph.)

MR. FRAZIER: I am going to shortcut what I was preparing. This is a little synopsis of some of the issues that have come up where we have agreements and disagreements. Basically, we have agreements down the left side here. Let me just point out a couple of highlights here. There is agreement that there is tectonic hydraulic interactions. There is agreement on that subject, and we are working on it. It is ASCP.

The questions that we are dealing with is what is the significance of this. There is also relatively good agreement that the SCP is pretty comprehensive. Now you know, I can fiddle around or anyone can fiddle around and find something missing in the document, but you are not going to find very much missing. It is fairly comprehensive. The questions that we are dealing with here are strategy priorities and things like that.

That is also a little bit of a brief synopsis of what it would be that I was going to present here. What I have done is drawn some sketches. I actually did this on the airplane coming out here last night.

This is roughly a north-south cross-section. Here is the ground rise to the north elevation. It decreases to the south, and drainage to the south. Here is the present groundwater table. The repository is setting up above it some 200 to 400 meters. At about three kilometers to the north, there is an elevation rise that brings the groundwater up two to three kilometers about at the repository level.

Now one scenario that would be of concern where tectonics might interact with groundwater and cause us some disturbance would be if somehow whatever is causing this groundwater rise would migrate down there to the site.

And what I have commented on this is that it certainly appears at this time, and there is general agreement on this, that to have that sort of thing happen is that you would have to stop the conductivity here at the site somehow. It would require major and widespread reduction in the hydraulic conductivity parameters. You have got to build a dam down here somewhere around in the center of the Yucca Mountain to get the water to back up in that area. If the conductivity is low, the thing is going to keep flowing.

The flatness of this water table. This water only loses about tens of meters down at the southern end of Armagosa Valley some thirty or forty kilometers away. That low elevation change in the water table indicates that it is generally taken to be that there is high conductivity here. The fact that this rises says that there is low conductivity. So somehow, you have got to get low conductivity in here.

Jerry's model is one way that one might drop the conductivity. I think that there are mechanical ways to get at how widespread could that drop be. But there is one scenario there that we are looking at.

Now the next in the handout that I gave you is a summary. The top part is roughly what I just went through with you, and the bottom part of this is some parameters about the tectonics.

Regional strain rates, Jerry went through. There is general agreement on this, the faults. I think that this is important. Jerry was kind of dealing with this at the end. What it looks like in the local faults is that we are seeing stuff up to on the order of tens of centimeters on the order of tens of thousands of years. There is just some data here to help you understand what we are dealing with, because I am sure that a lot of you are not familiar with it.

The thought is that we are seeing something like magnitudes of six and a half approximately, or I think that it is a little bit less than six and a half on the order of tens of thousands of years, something on that order. Probably, we were looking at something up around seven or a little bit bigger by looking at the local faults.

The volcanic rates in the area. If you take an area about this size of the control area, we are getting a return period on vulcanism. The volcanics are on the order of a million years or more. And that is sort of a dimension. These are just some rough estimates of looking at the tectonic processes.

Now I have sketched out what I think is an interesting way to think your way through this. You see, you can think it through in several different ways. The reason that I appreciate this way is that what I have done is that I have divided the system into two parts, and it seems like a complete set to me.

On the left is what I call an inverted tree structure in conductivity. On the right, I call it a no inverted tree structure. What is significant about dividing it this way is that with the tree structure system, when you squeeze the earth by an earthquake, some sort of squeezing mechanism, you amplify the groundwater movement. Because you have got a lot of available volume here, and you are squirting it up through a fault like that.

So if you have an inverted tree structure system in the conductivity, which appears like we do at the site, you have an opportunity to squeeze it to cause the water to go up. But on the other hand, you have a mitigating circumstance. Down below our water table, it looks like we have high conductivity. So that means that indeed that things are probably connected pretty well. But on the other hand if they are connected and you squeeze it, it looks like you have got a drainage system.

So the more conductivity that you have down in there area, you might be able to squeeze it and cause something to squirt up here, but then it has got a way to drain back off again.

So at least in my mind, that is the way that I think about this kind of a system. When you have got that kind of inverted tree structure, you have got a mitigating circumstance to go with it.

What concerns me personally that I think that we need to look into a little bit more -- and when I say that it concerns me, I cannot totally mitigate all aspects of it -- and that is what happens if we have situation with a fault that penetrates to great depth. Now we have got a circumstance where if it goes deep enough. I am saying here that it is going to have to go, and I think that I can argue this fairly strongly, that it is going to have to go to depths greater than ten times the amount that you are going to rise.

So if we are trying to make that groundwater rise up on the order of 300 meters, we are going to be down there at three kilometers or greater. And seismologists and geophysicists are not accustomed to thinking about water connected fractures running down to those depths. We are not sure that there is water down there in the area of the Great Basin and at what depth, five kilometers or ten kilometers. It is a little speculative about how deep it goes.

But if there is no conduit down there to five or ten kilometers somehow, then I think that you have got a way in which you could have an earthquake, perturbed local systems. And I outlined them briefly in the lower left-hand corner here, how I would envision what could happen.

One is that you could squeeze the rock. And if you squeezed it enough and had enough crack here, you could get it to poke up the crack. The other one is that when the earthquake occurs and you have got large heats down here, and you might have some trapped fluids down here at a high temperature, and the earthquake could break loose, the conductivity due to the heat imbalance and the density differences. You could enter a conduction cell and bring up water that way. And the same thing roughly with hydrochemical.

If you have got materials down here where the chemistry is different than it is above, you could get density imbalances. And when you open the conductivity, the density imbalance can cause a buoyancy effect, and up comes the water.

So this is a very quick talking outline of some of the ways, sort of a synopsis I think of the sort of things that Jerry is talking about in his report. I have summarized it here rather cleanly I think. I have broken it into three parts. Let me jump rather quickly.

The first says that we have got high conductivity that looks like a mitigating circumstance at this site. The outstanding thing, as Jerry points out, is that it is possible that there are ways that the tectonics might reduce that high conductivity under a site. If that were to happen, then all bets are off are our high conductivity mitigation.

The second factor here is this idea that you could get this local rise to come up a crack, up a fault of some kind, if that fault were to reach deep enough into the earth. On the order of three kilometers or more in my judgment for conservation of mass considerations. Coming at it in a couple of different ways, I could come up with this. So you are going to have to have cracks pretty deep in the earth, and then you can have localized water coming up a fault.

And finally, I summarized once again these factors, the mechanical squeezing, the hydrothermal confections and the hydrochemical convections. And just sitting there thinking, all right, how do we constrain these where we have not seen mechanical squeezing with ground water hundreds of meters before. It has not been observed to my knowledge. About the largest numbers that we have ever seen historically is on the order of fifty meters.

Now the data that we have are mighty poor. When an earthquake goes off, we see seismic waves all over the earth, but we do not have monitoring devices for groundwater all over the earth. We have those in very selected locations. So our data are sketchy here. They are not conclusive at this time.

We can get a handle on the strains that are generated by earthquakes. And from this, we can get some mechanical constraints on how many cracks can you close and how much can you close them. And so we can constrain this mechanical squeezing by those kinds of things.

Hydrothermal convection. It looks to me, and I am not expert in this business on how to do this, but it seems to me that you go dig around in the faults and you find out what are the mineralization characteristics, and what are the alteration characteristics, and try to get an estimate.

Obviously, the veins in the faults were generated by hydro processes of some kind. What were the temperatures that they were generated at. We still do not have a tight grip on that subject it seems, but we are making progress. And we need to get busy, and look harder at those is my judgment.

And I think probably that with enough experts that I think that there are things around that we can look at, and try to identify those factors and find out.

It is the same with hydrochemical. I mean I do not know that business, but it seems to me that there is going to have to be some foreign material in those faults. And if something down there, if a density imbalance occurs, you are going to find some foreign compositions there. I think that we ought to check that out carefully.

This is just a final thing. And it a little bit addresses the question that you are asking. An approach to evaluating site suitability. I tried to outline some thoughts. We are doing it. I would like to see us focus on it a little bit personally.

This is just my impressions. And these are hand done. They have not even been project reviewed. I showed them to the people this morning. What it looks like to me is that what we are doing and what we need to do is to focus our investigations. And I really trigger on the word understanding. You see, it makes me nervous focusing everything on regulations. I think that we need to focus on understanding. And of the geologic and hydrologic environments related to repository performance.

Let that drive us. Find out what is hanging out, what is more relevant to those uncertainties, and then bear down on those subjects. Begin with judgment. I think that just by judgment. What Jerry has done is that he has pulled out things that he thinks creates reasonable suspicion.

So use our judgment, find out what those are, and follow it up with some quantitative assessment, so that we can get very solid about what are our uncertainties and what is the range of uncertainties. And then when we find that out, we characterize. I think that you do not just jump from knowing the uncertainties to a result. I have been scratching my head to how do we deal with some of the problems that Jerry had brought up. I think that we have to characterize, and we have to get them out in black and white, Option A and Option B, what is creating these uncertainties, and refine our strategy for going after it.

It seems to me that that is an interaction among scientists. We need to get scientists together to do that. And one of the way to form strategies, it seems to me, is to ask questions. If you ask the right questions and get them ordered properly, I think that that helps us a lot.

So we need to get the strategy together, and then we need to get on with the investigations. Or we will sit here and talk forever, and we will not know the answers.

And I also have a thought on this last item here. I am suggesting that it seems to me that there may be a need to increase priority for conducting relevant scientific inquiries.

Now that is just my opinion, and I am not certain that is the case. But I find that for some reason that scientists are not resolving these issues. I have been aboard this project for almost two years now, and I have not seen a lot of progress. So something is impeding trying to resolve these very complicated subjects. You know, if it is not QA, it is some sort of procedures, writing a site characterization plan, I mean something has happened. I think that we may need to pump up the priorities a little bit. That is my opinion. There is a brief summary.

MR. MOELLER: That was very well done.

Are there any questions or comments for Mr. Frazier?

DR. STEINDLER: I have one comment. Let me just comment that I think that that last viewgraph may well lead you to a 300 man-year exercise in experimental work in order to get a handle at the level that you are calling for. And one of the additional bullets that I would add to that pile is to recognize that with constraints of time and perhaps even resources that the adjudication of order of priorities probably needs to recognize that ultimately you are going to end up with some empirical models rather than that full understanding that you keep looking for. And that unless you focus in on that, you are not going to meet the year 2010 deadline.

MR. FRAZIER: I totally agree. And I really am surprised that we might have any disagreement here.

Hopefully, we are on the same wavelength. What I am looking at is those processes relevant to repository performance. And I am advocating, it seems to me, that we ought to actually use performance assessment, this quantitative assessment of performance, to tell us what are our outstanding items, so that we can bear down on those.

(Continued on next page.)

endT7

endrct

MR. MOELLER: Thank you again.

MR. FRAZIER: So next we're going on with Don Alexander, whom you met earlier.

MR. MOELLER: Fine. Thank you.

MR. FRAZIER: Dr. Alexander.

DR. ALEXANDER: I think there are several key points, in fact I know there are several key points that we need to cover in order to bring our thinking more closely together.

Where I'd like to start is I'd like to back up for a moment before I talk about scenarios and talk about conceptual models.

(Viewgraph displayed)

DR. ALEXANDER: A conceptual model is a representation of a system that includes descriptions of processes and events affecting that system.

I want to emphasize that the conceptual model includes working hypotheses, and where the data are insufficient, in particular where the data are insufficient to make a single interpretation that's definitive, then alternative conceptual models should be proposed to describe the system and the processes and events under consideration.

A scenario, on the other hand, is a sequences of processes and events as we use this terminology that may affect the release or radionuclides.

And a scenario describes the effects of characteristics important to waste isolation for safety. The scenario is based upon a particular conceptual model of the system, and for the processes and events postulated to occur o that particular rendition of the system.

A complete set of scenarios considered should address all alternative conceptual models appropriate for the system.

Jumping ahead through my package, and you might want to go back and look at some of the slides I'm omitted, one of the key points that I want to make is that the scenarios flow down from conceptual models. And if you look carefully at the SCP you will find that there is more than one conceptual model that's posed in the document.

(Viewgraph displayed)

DR. ALEXANDER: There are many conceptual models. And I want to talk about that in the next few minutes.

For the testing program, I think the point that we're all trying to get to is that for the testing program we want to make sure that all of the processes and events, the information that we need in order to understand any potential conceptual model that we might come to in the end, and the set of scenarios that go with that, are covered, and that we have the data in order to evaluate that particular conceptual model.

Next slide.

(Viewgraph displayed)

DR. ALEXANDER: Now, I'm taking you back to my talk this morning, and I want to point out a little bit about this nominal case.

If you read the SCP on issue 11, you read about this nominal case which may have appeared to some as being a single conceptual model within a series of scenario classes being evaluated that were operative on that particular single conceptual model. But if you look carefully you'll find that that conceptual model envelops numerous, or I should say this nominal case envelops numerous conceptual models.

And there are a number of examples in the text that I can talk with you about later, but I want to assure you that we were not trying to restrict ourselves to a single conceptual model.

DR. ALEXANDER: Now, what this mean in terms of the testing program? The SCP/CD treatment of the total system performance was structured around a set of scenarios. The testing program in the SCP is intended to address the full range of site characteristics relevant to those scenarios and we feel that based on the discussions we've had on this topic today that the SCP being revised should clarify the relationship between the site characteristics and the alternative conceptual models that serve as the basis for the scenarios. We're in the process of doing just that.

(Viewgraph displayed)

DR. ALEXANDER: As a part of this summation that we've been doing, if you look at a scenario the way we do, and assume that it's a set of processes or events which are important for waste isolation or safety, then you come up with a set of classes or scenarios. The exxes indicate scenarios that we're looking at. Specifically in the SCP there are about 53 sets of scenarios.

Within a scenario class as I refer to them you will find that there are a number of variations on that particular theme within that set of scenarios.

Next slide.

(Viewgraph displayed)

DR. ALEXANDER: This is a cartoon to try to drive home the point. This is the conceptual model of the Yucca Mountain site. We could put a lot more information on it. But basically what it represents, should represent to you, is an image of the site as it's known today with all the variation that's possible and all the interpretive variation that's possible based on the existing data.

Next slide.

(Viewgraph displayed)

DR. ALEXANDER: Now, that set of conceptual models, if you think about the variation in the information that's available which allows you to come up with a range of concepts for that particular geologic setting, there are a number of scenarios that can operate on that particular conceptual model.

This is a cartoon that I've put together which shows fluctuation in the groundwater table assuming a maximum wetting event. And as you've heard today, based on information we currently have in hand, the maximum wetting event would probably only affect tens of meters in the upper part of the system.

Now, of course that needs to be evaluated and investigated through time and as I've indicated, we recognize that the flux through, along a fracture would likely be much greater, of course, than the flux within the matrix. And we don't know what the petitioning coefficient is for the flux in the fracture versus the flux in the matrix. That needs to be determined through site characterization.

Next slide.

(Viewgraph displayed)

DR. ALEXANDER: Now, one of the scenarios that one might consider, one of the many that comes off this matrix that I showed you a moment ago, would be a maximum wetting event due to an extreme climatic event.

And this is just another rendition of that kind of thing. All these scenarios need to be evaluated as a part of the process.

Next slide.

(Viewgraph displayed)

DR. ALEXANDER: Therefore, in my opinion, there need to be some changes for purposes of clarify in the SCP. The first is that the text needs to be added to relate the testing program to the alternate conceptual models, as I've just defined them.

Scenarios that will be tested will be more clearly explained. Scenarios that have been screened out -- and this is an important point that the staff has made, the NRC staff has made -- scenarios that have been screened out and will not be tested will be explicitly discussed, and a rationale for why they've been screened out will be presented.

The text will be added to clarify the relationship between the testing program for processes and events to the scenarios. And then no changes to the structure of the SCP described earlier is required. That was a question that came to us from the staff. I wanted to tell you that the sections of Chapter 8, 8.1, 8.2 through 8.7, need not change in order to make this clarification.

Next slide.

(Viewgraph displayed)

DR. ALEXANDER: Therefore, in conclusion, because of the focus on performance objectives and design criteria, the emphasis on waste isolation and safety, site characterization is structured to address release scenarios.

Our focus is on release scenarios.

The site investigations also need to consider legitimate alternate conceptual models. We recognize that.

If you look at some of the slides that I've used myself today you'll find in the current CD that there's discussion about alternative hypotheses and scenarios and some have been screened out and will not be tested and those will be discussed in the SCP.

Information obtained during site characterization will be used to ascertain whether particular models can be confirmed or removed from consideration.

That's my talk in a nutshell.

DR. STEINDLER: The implication of the third bullet is that any rational hypothesis or scenario that somebody else could think of should be covered somewhere in the SCP?

DR. ALEXANDER: Go back to that set of scenario classes. Yes. We believe that, Dr. Steindler, and what we have been soliciting, trying to solicit, are holes in our current program, areas where testing would be absent, areas where scenarios are left unidentified, et cetera.

What we have put together here is our first cut at a resolution where this part of the ACM problem, and we have identified areas where we think there are credible classes of scenarios that need to be evaluated.

What Steve Brocoum is going to talk about for the next several minutes are tables that will go in the back of the document which will correlate with the testing in Section 8.3 and will go into detail on alternatives that we're going to consider, beyond the scenarios that we could consider.

MR. MOELLER: Thank you.

DR. ALEXANDER: You're welcome.

(Continued on the next page.)

DR. BROCOUM: I'm just going to briefly go over the treatment of alternate hypotheses in the SCP.

(Viewgraph displayed)

DR. BROCOUM: My first viewgraph is just a summary of the objection -- I won't go over it, since we know what that is -- on alternate conceptual models. It's a summation of it.

(Viewgraph displayed)

DR. BROCOUM: The second viewgraph was just a history of the meetings we had, which were mentioned earlier, the meetings in March on the point papers, the meetings in April on the alternate conceptual models.

The basic agreement that came from the alternate conceptual model meeting was that the DOE agreed to provide tables that more clearly describe alternate conceptual models in the SCP.

(Viewgraph displayed)

DR. BROCOUM: In response to that, in our SCP completion, we had created a working group which is responsible for addressing these concerns of the NRC. And the modifications to the SCP will include in Chapters 1 through 5 to clarify DOE's consideration of alternate conceptual models.

In Section 831, the section described in testing, it will be expanded to include DOE's philosophy about consideration of alternate conceptual models. It will have a road map to explain the manner in which alternate conceptual models are presented in the site programs. It will provide linkages between the alternate conceptual models in the site program and numerical models used in the performance, assessment and design portions, and it will provide alternate conceptual model tables in Sections 831 through 817, and these tables will be comprehensive for the geohydrology, the geochemistry, the climate and tectonics, and there will be additional tables in some of the other sections.

And some of the overview sections will also be expanded to include the DOE's philosophy on alternate conceptual models.

Now, I had hoped, when we were planning this meeting, to have an actual table for you. But as of today, we haven't closed on the exact format of our table.

(Viewgraph displayed)

DR. BROCOUM: So I have a viewgraph that describes what the table will address but it's not an example of a table. And the exact number of columns and exactly what the headings will be has not been finalized yet.

So this is really an outline rather than a table. For each element, it will describe our current understanding or representation and for each element it will identify and evaluate the significance of the uncertainties in the assumptions underlying that element and for each uncertainty, it will identify alternate interpretations or assumptions that are consistent with our present understanding of the data, and for each of these alternatives, it will identify, it will list or identify the activities that are planned to be undertaken to discriminate among the alternatives.

So that for each alternative, we should have a study or an activity. And in completing these tables, we will reach an understanding as to whether we have all the activities needed to understand and discriminate among all the possible alternatives. These tables are being constructed or created right now.

Also, the activities will be prioritized in two ways. And first is to resolve a major concern. And this will be done in, I think it's Section 85 -- is that right, Don, where we have the networks -- and also in Section 84, where possible interferences among tests or activities will be considered, to make sure we don't preclude the ability to characterize the site by an earlier activity.

So, the last bullet just again repeats what was on the previous viewgraph where the major tables which include geohydrology, geochemistry, climate and tectonics, will be included in the SCP.

Additional tables will also be present, but they will probably, to a large measure, reference back to these tables.

So that is the status of the tables for the SCP on alternative sectional models.

Any questions?

MR. MOELLER: That sounds to me like it will be very helpful.

Any comments?

(No response)

MR. REIGNER: In closing, I would simply like to emphasize that we are committed to conduct a thorough investigation of the site which will enable us to evaluate if these are conceivable conceptual models which could influence the licensability and effective function of the site, and to evaluate the other questions which have been raised, and emphasize that we will be responding to all of the objections and concerns raised in the NRC point papers.

Let me say that we certainly appreciate that critique we've gotten today.

If you have any follow-up questions, or additional information, please feel free to contact me.

And I would say in closing that we anticipate that today's discussions will be the initial part of a continuing interaction which will be very constructive.

I believe that this type of process will be beneficial in ensuring that a safe -- let me emphasize that -- safe repository is put into operation.

Thank you.

MR. MOELLER: Well, thank you. And certainly on behalf of the Advisory Committee on Nuclear Waste, I want to thank you and the members of your DOE staff and its contractors for coming here and making the presentations for us today.

I know that such presentations do not just jump up out of the ground. They reflected a lot of hard work on your part and good organization, and certainly very good audiovisuals, which are very helpful. We appreciate them and also appreciate having the copies provided to us.

So we look forward also to continuing interaction with you.

Thank you again.

MR. REGNIER: You are certainly welcome. Thank you.

MR. MOELLER: I believe with that I also should thank the NRC staff for staying with us once again and seeing it through.

Let me thank our Reporter for her hard work this afternoon.

And with that, I will declare today's session adjourned.

(Whereupon, at 6:31 p.m., the meeting was adjourned.)

REPORTER'S CERTIFICATE

DOCKET NO.:

CASE TITLE: FIRST GENERAL MEETING

HEARING DATE: June 28, 1988

LOCATION: Washington, D.C.

I hereby certify that the proceedings and evidence are contained fully and accurately on the tapes and notes reported by me at the hearing in the above case before the UNITED STATES NUCLEAR REGULATORY COMMISSION.

Date: June 28, 1988

Donna L. Cole

Official Reporter

HERITAGE REPORTING CORPORATION
1220 L Street, N.W.
Washington, DC 20005

DOE BRIEFING TO THE ADVISORY COMMITTEE ON NUCLEAR WASTE

SUBJECT: Translation of Hydrologic Setting to Performance Modeling Application

DATE: June 28, 1988

PRESENTERS: Dr. Scott Sinnock

PRESENTERS' TITLE/ORGANIZATION: Supervisor: NNWSI Program Interface Division, Sandia National Laboratories

PRESENTER'S TEL. NO: 1. (505)846-0081

PRESENTATION TOPICS

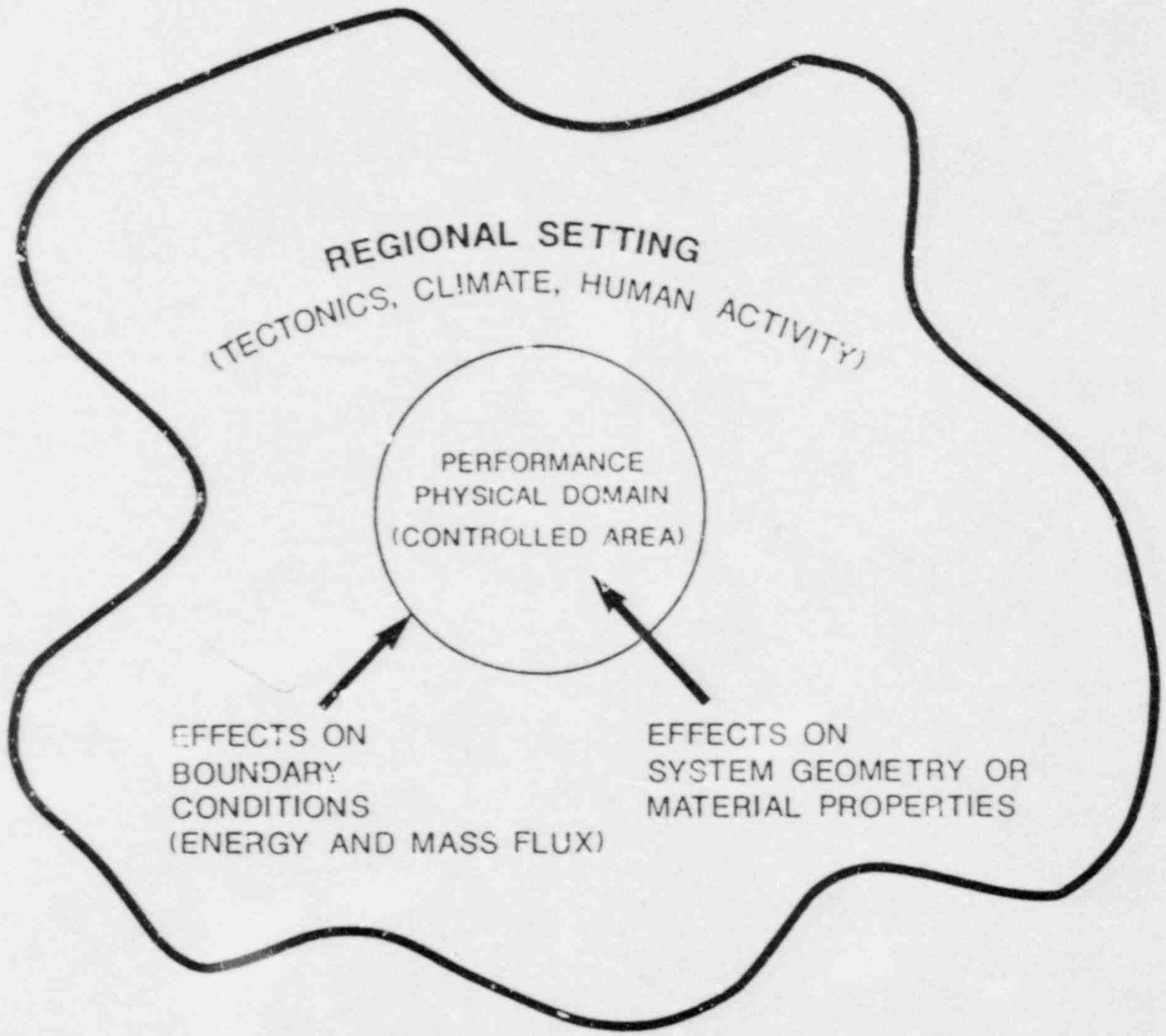
- Summarize General Relations Among
  - Data Gathering
  - Data Reduction Modeling and
    Performance Assessment Modeling

- Describe and Show Selected Examples of the Component Conceptual Elements of Performance Assessment Models

Components of Conceptual Models Requiring Definition

- Physical Processes
- Physical Domain
    - Geometry of Units (including faults)
    - Property Distributions within Units
- Initial and Boundary Conditions
- Calculational (Numerical) Constraints

GEOGRAPHIC ACCOMMODATION OF EVENTS AND PROCESSES



(4)

CURRENT ASSUMPTIONS
(PHYSICAL PROCESSES)

DARCY FLOW

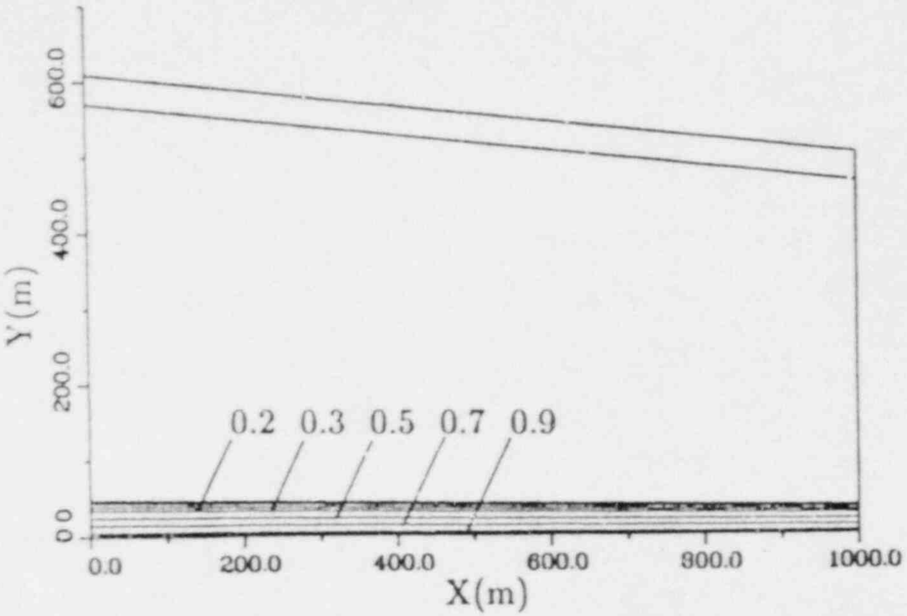
- RICHARD'S EQUATION IN UNSATURATED ZONE
- $K(\psi)$, ψ(PORE SIZE) "CAPILLARY BUNDLE"
- * - PRESSURE EQUILIBRIUM PERPENDICULAR TO FLOW (FRACTURE-MATRIX INTERACTIONS)
- * - "EFFECTIVE POROSITY" = MOISTURE CONTENT
- * - ISOTHERMAL, TRANSIENT OR STEADY STATE, SINGLE PHASE (LIQUID)

---

* POTENTIALLY OVERCONSTRAINING

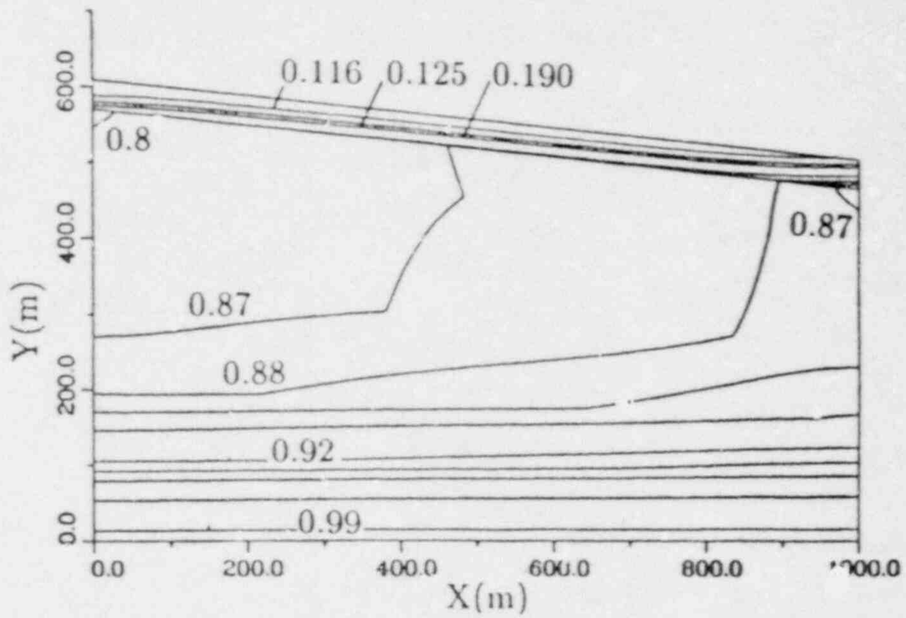
FRACTURE SATURATION CONTOURS

(Q=0.1 mm/yr)



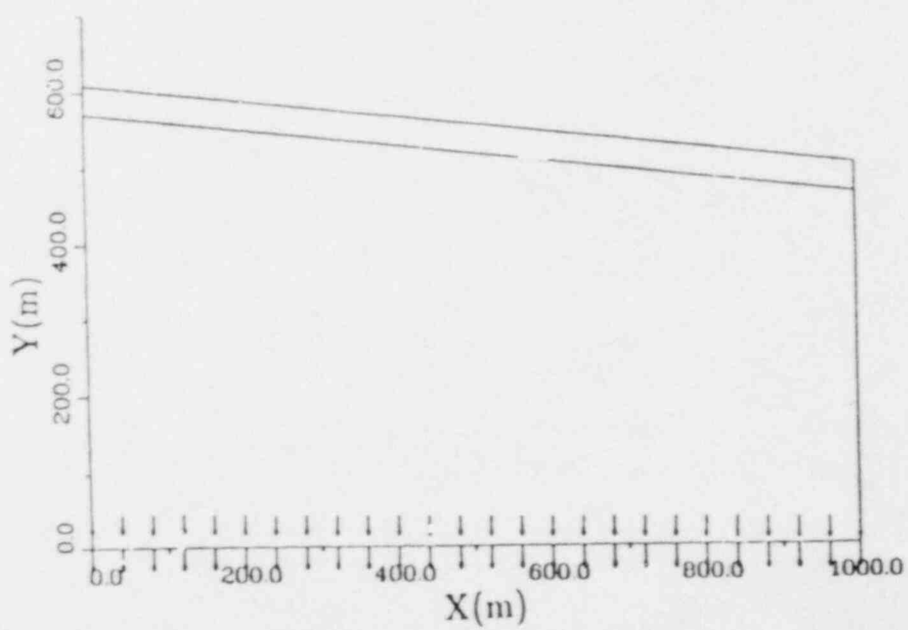
MATRIX SATURATION CONTOURS

(Q=0.1 mm/yr)



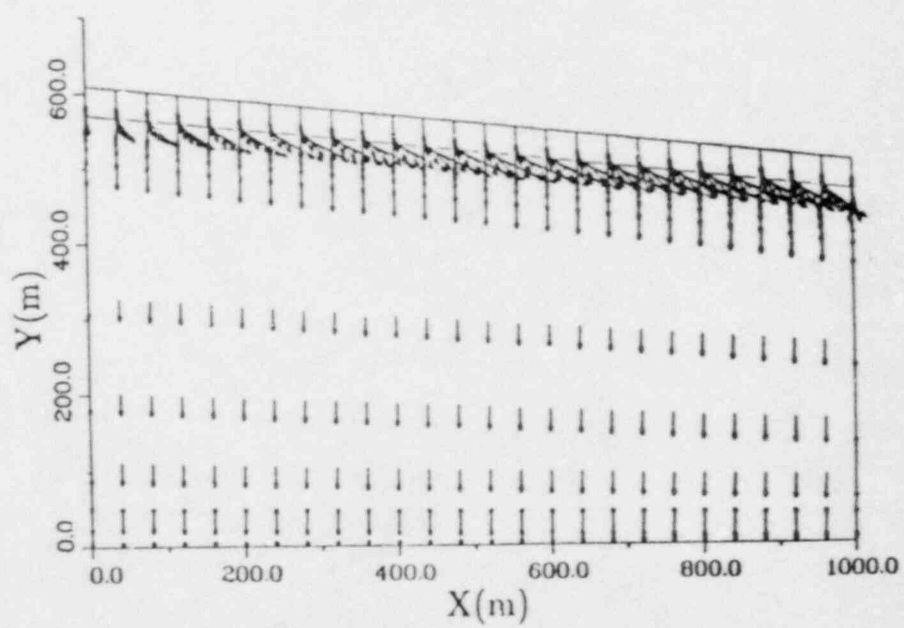
FRACTURE MASS FLUX

(Q=0.1 mm/yr)



MATRIX MASS FLUX

(Q=0.1 mm/yr)



Tape 7

PRELIMINARY SYNTHESIS OF DRAFT REPORT

"CONCEPTUAL CONSIDERATIONS OF THE DEATH VALLEY GROUNDWATER..."

AUTHOR - JERRY SZYMANSKI (DOE)

PRESENTED TO

ADVISORY COMMITEE ON NUCLEAR WASTE

PRESENTED BY

GERALD A. FRAZIER

SEISMOLOGIST, SAIC

(702-794-7824)

JUNE 27, 1988

1.

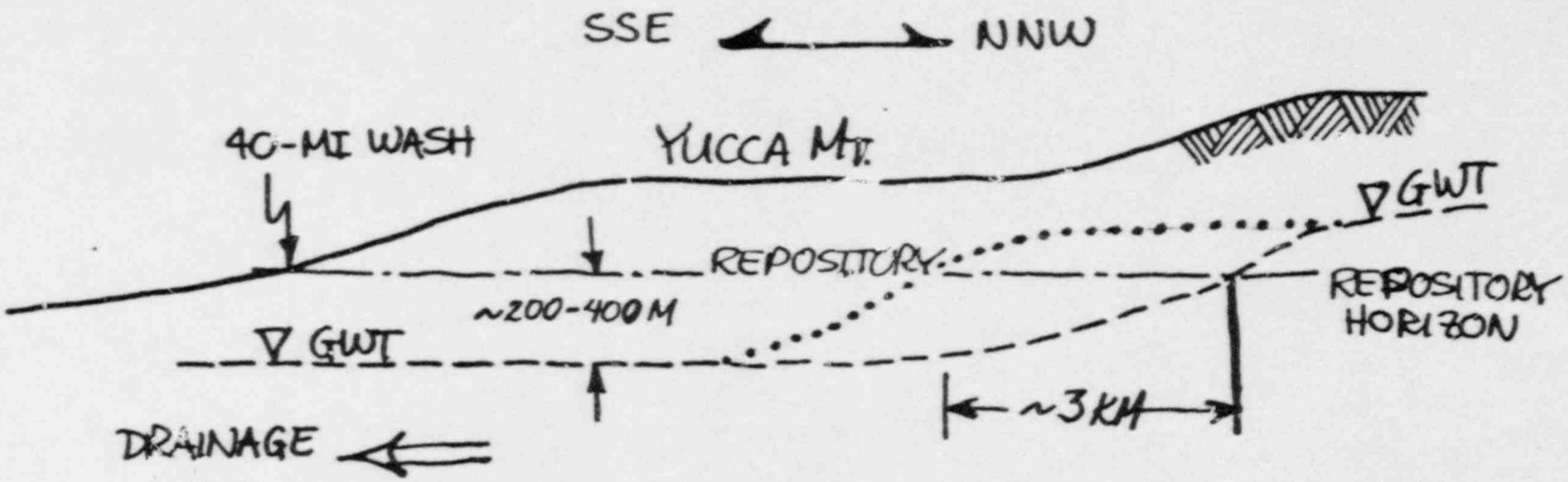
CURRENT SCIENTIFIC UNDERSTANDING

~ PRESENT CONDITIONS	UNCERTAINTIES
■ TECTONICS ACTIVE AT YUCCA Mt.	■ POTENTIAL EFFECTS
■ RELEVANT DATA ARE AVAILABLE	■ INTERPRETATIONS
■ DIRECT THREAT OF VOLCANOS $<1\% / 10^4$ yrs.	■ SIG OF GEOTHERM. ENVIRON.
■ RECURRENCE OF LOCAL EARTHQUAKES	■ IMPACTS TO HYDROLOGY
■ TECTONIC-HYDROLOGIC INTERACTIONS	■ SIGNIFICANCE
■ PLANNED INVEST → COMPREHENSIVE	■ STRATEGY & PRIORITIES

2

POTENTIAL TECTONIC DISTURBANCES TO GROUND WATER:

DOWNGRADIENT MIGRATION OF ELEVATED GROUND WATER TABLE



------ PRESENT GROUND WATER TABLE

.... POTENTIALLY DISRUPTIVE GROUND WATER TABLE

■ REQUIRES MAJOR, PERVASIVE REDUCTION IN HYDRAULIC CONDUCTIVITY BENEATH YUCCA MT.; REQUIRES FURTHER EVALUATION

p. 3

APPROX. PRESENT CONDITIONS: HYDROLOGY & TECTONICS

- GROUND WATER TABLE (RELATIVE CONDUCTIVITY)
  - 200-400M BELOW REPOSITORY HORIZON
  - LOW GRADIENT TO SOUTHERN DRAINAGE (HIGH CONDUCTIVITY)
  - STEEP GRADIENTS TO NORTH & N-WEST (LOW CONDUCTIVITY); REACHES REPOSITORY ELEV. AT CLOSEST DISTANCE ~ 3 KM

- LOCALLY ACTIVE TECTONICS

PROCESSES/EVENTS	RATES/RECURRENCE TIMES
REGIONAL STRAINS	$<\sim 10^{-7}$/yr.; E-W EXTENSION; N-S COMPRESSION
FAULTS	~ TENS CM/ 10^{4+} yr. $<\sim$ 0.1 MM/yr.
EARTHQUAKES	~ M 6½ / 10^{4+} yr. < M 7^{+}/ QUATERNARY
VOLCANOS	$<\sim 10^{-6}$/yr PER AREA ~ CONTROLLED SITE

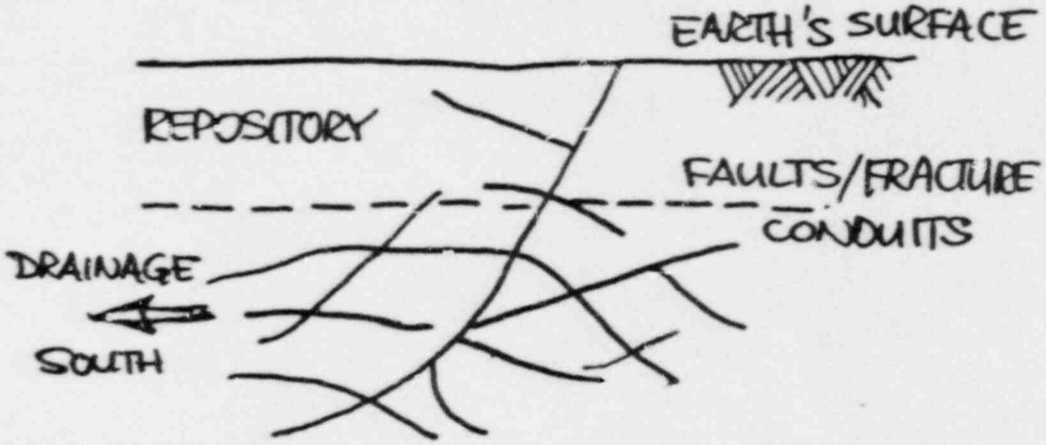
p. 4

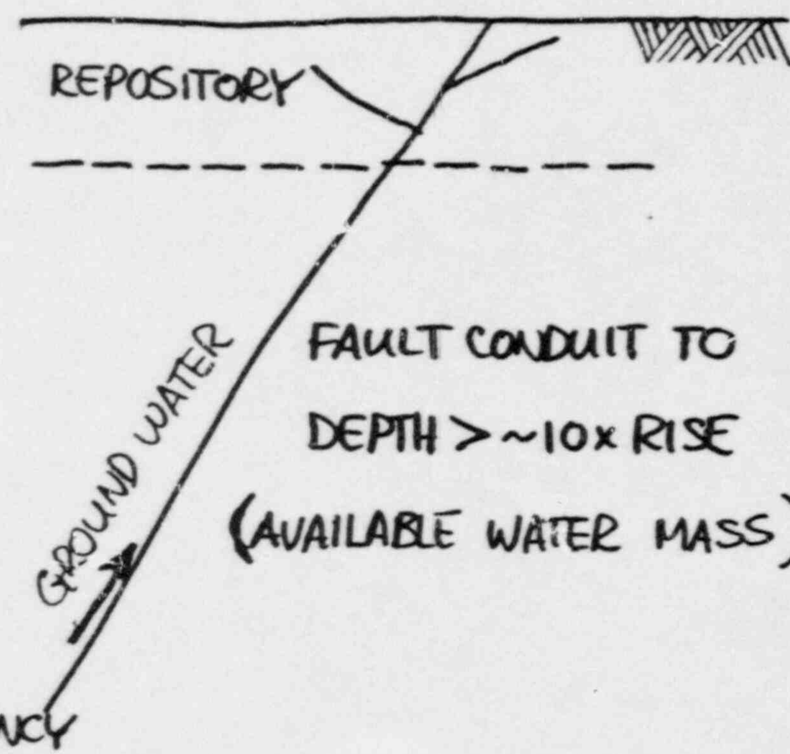
POTENTIAL TECTONIC DISTURBANCES TO GROUND WATER:
EARTHQUAKE INDUCED PROCESSES

POSSIBLE GROUND WATER CONDUIT GEOMETRIES

INVERTED TREE (ALLOWS SHALLOW PENETRATION)

NO INVERTED TREE (REQUIRES DEEP PENETRATION)





EARTHQUAKE - HYDROLOGY INTERACTIONS

- MECHANICAL ROCK COMPRESSION
- HYDROTHERMAL CONVECTION
- HYDROCHEMICAL CONVECTION

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POTENTIAL TECTONIC DISTURBANCES TO GROUND WATER:

— SUMMARY —

- APPARENT HIGH CONDUCTIVITY BENEATH REPOSITORY MITIGATES WIDESPREAD RISE IN GROUND WATER; POSSIBLE TECTONIC REDUCTION IN LOCAL CONDUCTIVITY NEEDS FURTHER EVALUATION

- LOCALIZED RISE IN GROUND WATER ALONG FAULT CONDUITS APPEARS TO REQUIRE HYDROLOGIC CONNECTIONS TO DEPTH > ~10 x RISE (ie, DEPTH > 3 KM TO REACH REPOSITORY HORIZEN)

- A SIG. EARTHQUAKE COULD ACTIVATE GROUND WATER RISE ALONG DEEP CONNECTED CONDUITS

POTENTIAL PROCESSES	POSSIBLE CONSTRAINTS
MECHANICAL SQUEEZING	NOT PREV. OBSERVED; STRAIN ~ 10^{-4}
HYDROTHERMAL CONVECTION	EPITHERMAL MINERALIZATION/ALTERATION
HYDROCHEMICAL CONVECTION	FOREIGN FAULT COMPOSITIONS

6

4-152

APPROACH TO EVALUATING SITE SUITABILITY

- FOCUS INVESTIGATIONS TO GAIN BETTER UNDERSTANDING OF GEOLOGIC ENVIRONMENT AND PROCESSES RELEVANT TO REPOSITORY PERFORMANCE
  - IDENTIFY MOST RELEVANT UNCERTAINTIES: BEGIN WITH ANALYSES & JUDGEMENT, FOLLOW WITH QUANTITATIVE ASSESMENTS (PROBABILITIES FOR UNCERTAINTIES)
  - CHARACTERIZE NATURE OF RELEVANT UNCERTAINTIES
  - REFINE STRATEGY FOR RESOLVING UNCERTAINTIES
  - START INVESTIGATIONS
- INCREASE PRIORITY FOR RELEVANT SCIENTIFIC INQUIRIES

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Tape 8A

RELEASE SCENARIOS USED IN DEFINITION OF TESTING NEEDS

ACNW MEETING
JUNE 28, 1988

DR. DONALD H. ALEXANDER

CONCEPTUAL MODEL
FOR THE TOTAL SYSTEM

- A CONCEPTUAL MODEL IS A REPRESENTATION OF A SYSTEM AND INCLUDES DESCRIPTIONS OF PROCESSESSS AND EVENTS AFFECTING THAT SYSTEM
- A CONCEPTUAL MODEL INCLUDES A SET OF WORKING HYPOTHESES
- WHERE DATA ARE INSUFFICIENT TO PROVIDE UNAMBIGUOUS INTERPRETATIONS, ALTERNATE CONCEPTUAL MODELS (ACMs) MAY BE PROPOSED TO DESCRIBE THE SYSTEM AND THE PROCESSES AND EVENTS UNDER CONSIDERATION

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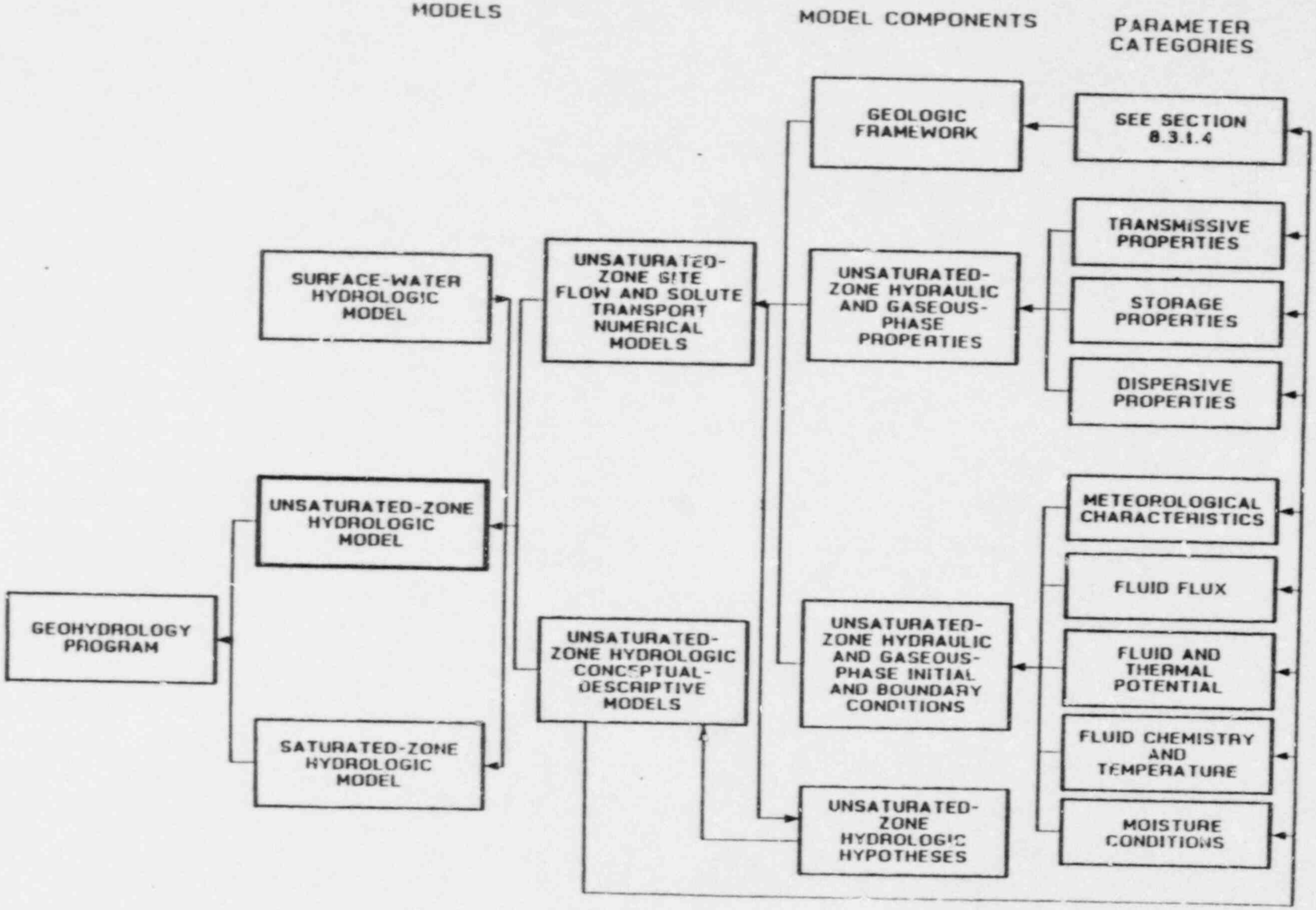
UNSATURATED-ZONE HYDROLOGY COMPONENT OF THE GEOHYDROLOGY PROGRAM



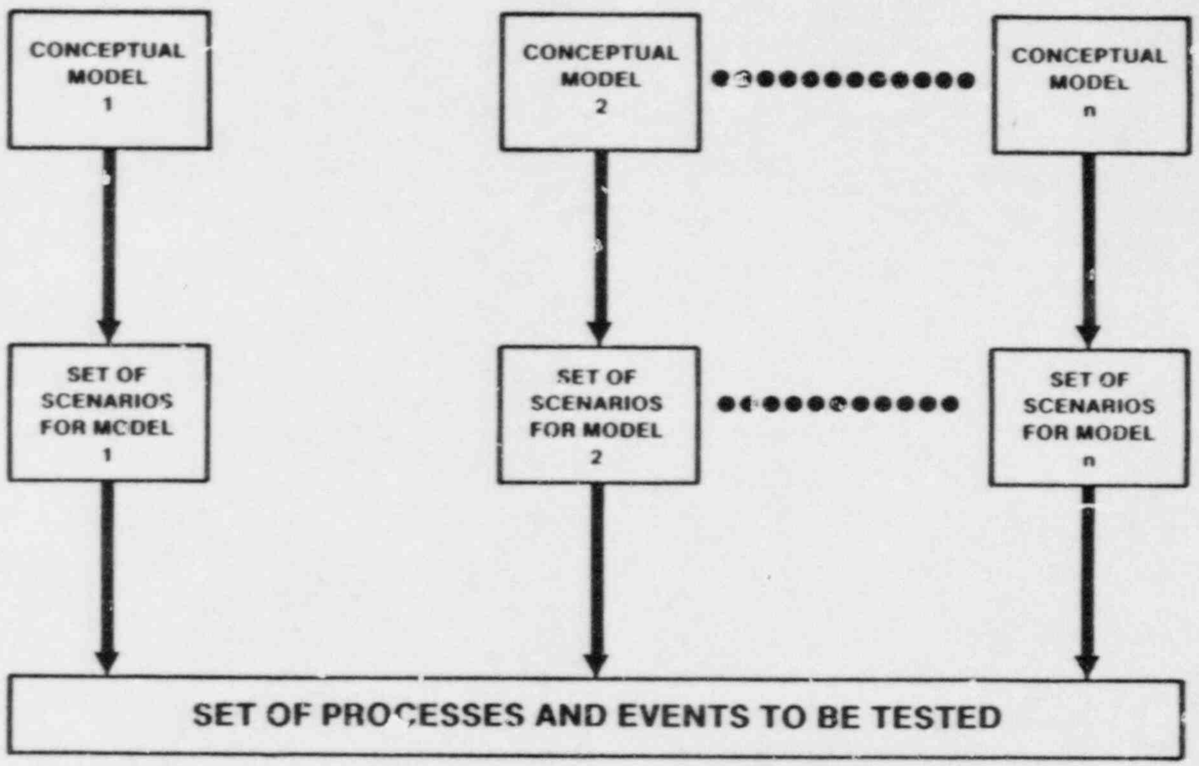
8.3.1.2-3

3

SCENARIOS

- A SCENARIO IS A SEQUENCE OF PROCESSESS AND EVENTS THAT MAY AFFECT THE RELEASE OF RADIONUCLIDES. A SCENARIO DESCRIBES EFFECTS ON CHARACTERISTICS IMPORTANT TO WASTE ISOLATION OR SAFETY
- A SCENARIO IS BASED UPON A PARTICULAR CONCEPTUAL MODEL FOR THE SYSTEM AND FOR THE PROCESSES AND EVENTS POSTULATED TO OCCUR
- THE COMPLETE SET OF SCENARIOS CONSIDERED SHOULD ADDRESS ALL ALTERNATIVE CONCEPTUAL MODELS APPROPRIATE FOR THE SYSTEM

RELATION BETWEEN SCENARIOS AND ALTERNATIVE CONCEPTUAL MODELS



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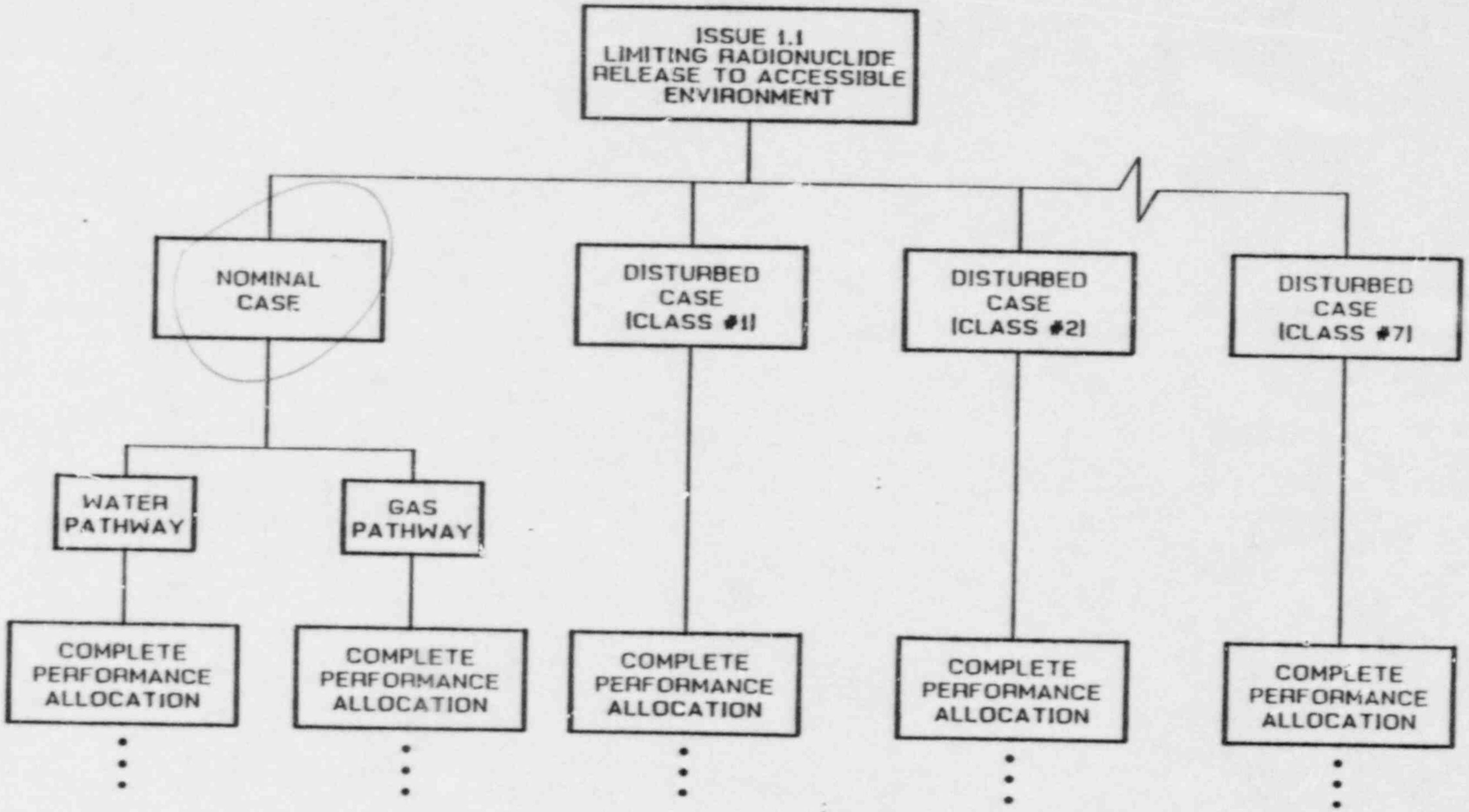
PERFORMANCE ALLOCATION FOR "NOMINAL" AND "DISTURBED" CASES



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FOCUS OF THE TESTING PROGRAM

- THE SCP/CD TREATMENT OF TOTAL SYSTEM PERFORMANCE WAS STRUCTURED AROUND A SET OF SCENARIOS
- THE TESTING PROGRAM IN THE SCP/CD IS INTENDED TO ADDRESS THE FULL RANGE OF SITE CHARACTERISTICS RELEVANT TO THESE SCENARIOS
- THE SCP SHOULD CLARIFY THE RELATIONSHIP BETWEEN THESE SITE CHARACTERISTICS AND THE ALTERNATE CONCEPTUAL MODELS THAT SERVE AS THE BASIS FOR THE SCENARIOS

SCENARIO CLASSES

UNDISTURBED PERFORMANCE

(A) UNDISTURBED PERFORMANCE OF ALL NATURAL BARRIERS

DISTURBED PERFORMANCE

(B) DIRECT RELEASE

(C) PARTIAL FAILURE OF UNSATURATED ZONE BARRIERS:

- CHANGE IN FLUX IN UNSATURATED ZONE
- RISE IN WATER TABLE
- CHANGES IN UNSATURATED ZONE ROCK-HYDROLOGIC PROPERTIES OR GEOCHEMICAL PROPERTIES

(D) PARTIAL FAILURE OF SATURATED ZONE BARRIERS:

- APPEARANCE OF DISCHARGE POINTS WITHIN 5 KM DOWNGRADIENT OF CONTROLLED AREA OR CHANGES IN FLOW DIRECTION IN SATURATED ZONE
- INCREASED LINEAR WATER VELOCITY IN THE SATURATED ZONES, CHANGED ROCK-HYDROLOGIC PROPERTIES, OR CHANGED GEOCHEMICAL PROPERTIES

(E) PARTIAL FAILURE OF ENGINEERED BARRIERS

DISRUPTIVE SCENARIO CLASSES BEING EVALUATED FOR YUCCA MOUNTAIN

INITIATING PROCESS OR EVENT \ EFFECT ON PARAMETER IMPORTANT TO ISOLATION	DIRECT RELEASE	CHANGE IN FLUX IN UZ	RAISE WATER TABLE	CHANGE UZ PROPERTIES	NEW DISCHARGE POINTS	CHANGE SZ PROPERTIES	CHANGE EBS PERFORM
EXTREME CLIMATE CHANGE		X	X		X	X	X
OFFSET ON FAULTS		X	X	X	X	X	X
VOLCANIC ERUPTION	X	X					X
IGNEOUS INTRUSION		X	X	X	X	X	X
TECTONIC FOLDING, UPLIFT OR SUBSIDENCE		X	X	X	X		
EPISODIC CHANGE IN STRAIN		X	X	X	X	X	
SUBSIDENCE OF MINED ROOMS		X					X
FLOODING OVER SEALED SHAFTS		X					
EXPLORATORY DRILLING	X						X
EXTENSIVE IRRIGATION		X	X	X		X	X
ENGINEERED IMPOUNDMENTS		X	X	X		X	X
EXTENSIVE MINING		X	X	X		X	X
GROUND-WATER WITHDRAWAL		X				X	X

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TESTING PROGRAM ADDRESSES PROCESSES AND EVENTS IMPORTANT TO PERFORMANCE

- FLUX IN UNSATURATED ZONE
- RISE OF WATER TABLE
- PROPERTIES IN UNSATURATED ZONE
  - ROCK-HYDROLOGIC PROPERTIES
  - RADIONUCLIDE RETARDATION PROPERTIES
  - GAS-PHASE TRANSPORT CHARACTERISTICS
  - FRACTURE CHARACTERISTICS
- FLOW PATHS IN THE SATURATED ZONE
- FLOW CHARACTERISTICS OF THE SATURATED ZONE
  - LINEAR WATER VELOCITIES
  - ROCK-HYDROLOGIC PROPERTIES
  - RADIONUCLIDE RETARDATION PROPERTIES
- ENGINEERED BARRIER SYSTEM PERFORMANCE
  - LOCAL FLUID CONDITIONS
  - THERMAL HYDRAULIC EFFECTS
  - THERMOMECHANICAL STRESSES
  - GEOCHEMICAL CONDITIONS
  - RADIATION EFFECTS

TESTING PROGRAM ADDRESSES POTENTIAL CHANGES TO THE SYSTEM

EFFECT ON PARAMETER IMPORTANT TO ISOLATION / INITIATING PROCESS OR EVENT	DIRECT RELEASE	CHANGE IN FLUX IN UZ	RAISE WATER TABLE	CHANGE UZ PROPERTIES	NEW DISCHARGE POINTS	CHANGE SZ PROPERTIES	CHANGE EBS PERFORM.
EXTREME CLIMATE CHANGE		X	X		X	X	X
OFFSET ON FAULTS		X	X	X	X	X	X
VOLCANIC ERUPTION	X	X					X
IGNEOUS INTRUSION		X	X	X	X	X	X
TECTONIC FOLDING, UPLIFT OR SUBSIDENCE		X	X	X	X		
EPISODIC CHANGE IN STRAIN		X	X	X	X	X	
SUBSIDENCE OF MINED ROOMS		X					X
FLOODING OVER SEALED SHAFTS		X					
EXPLORATORY DRILLING	X						X
EXTENSIVE IRRIGATION		X	X	X		X	X
ENGINEERED IMPOUNDMENTS		X	X	X		X	X
EXTENSIVE MINING		X	X	X		X	X
GROUND-WATER WITHDRAWAL		X				X	X

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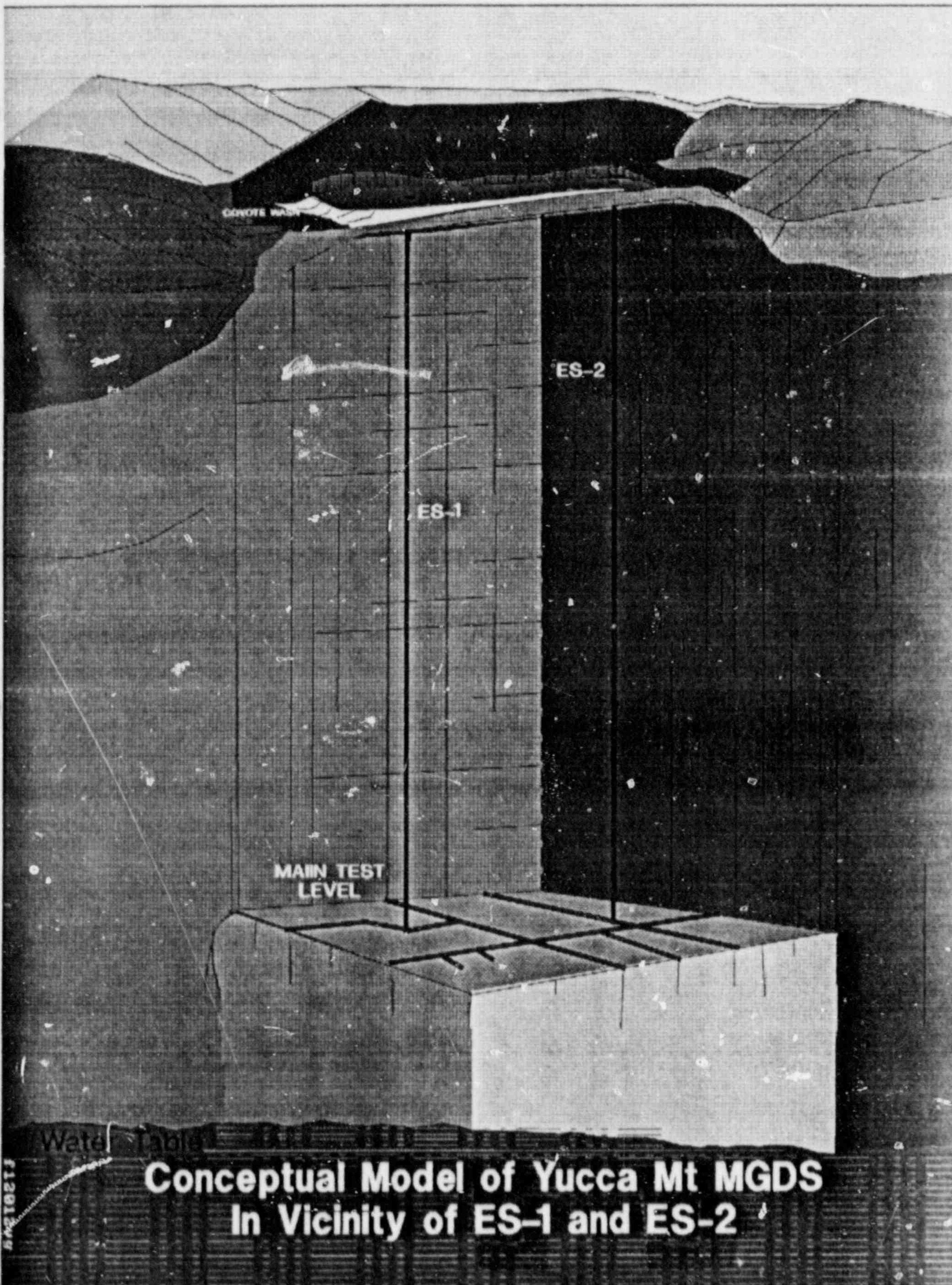
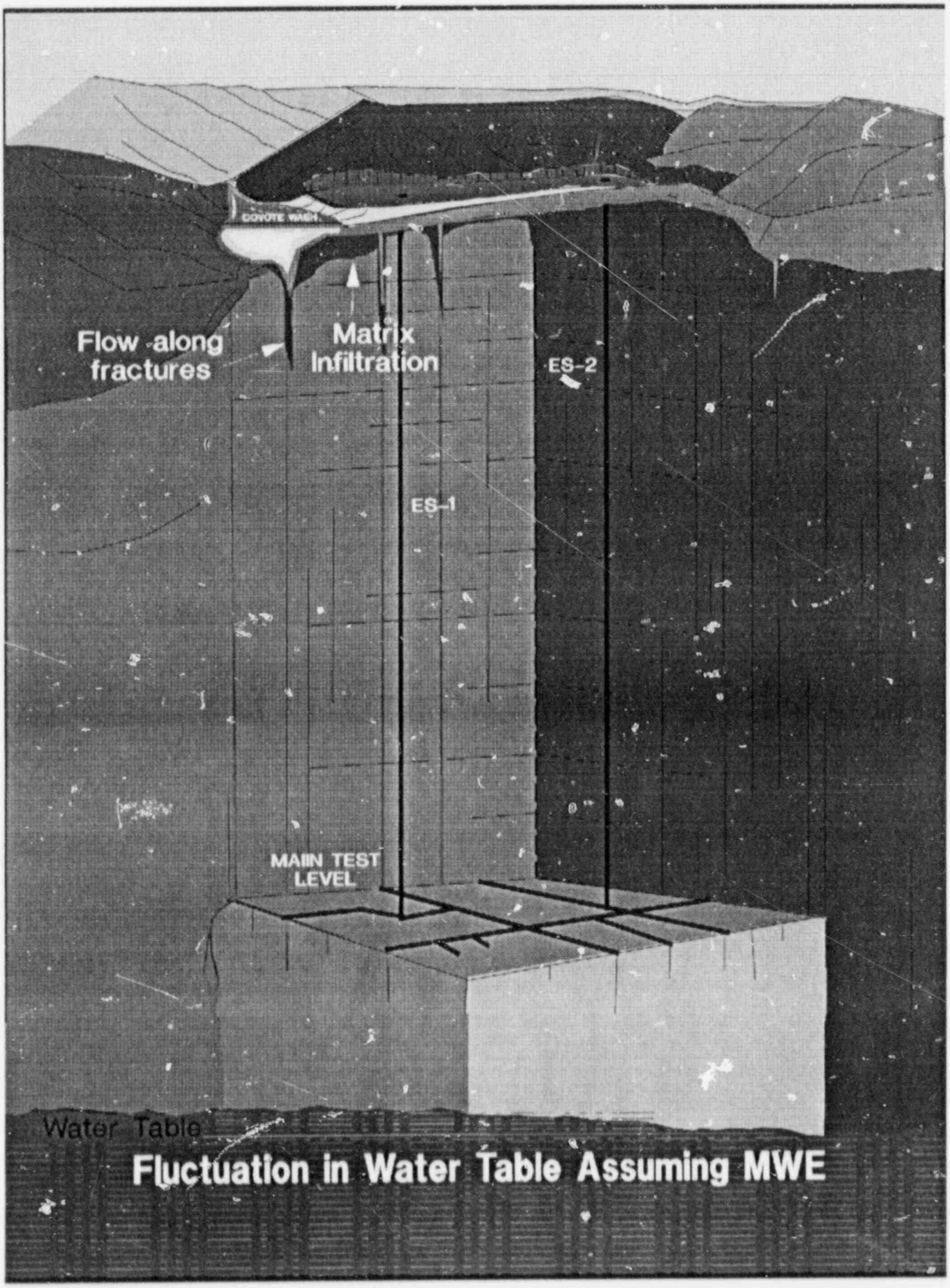
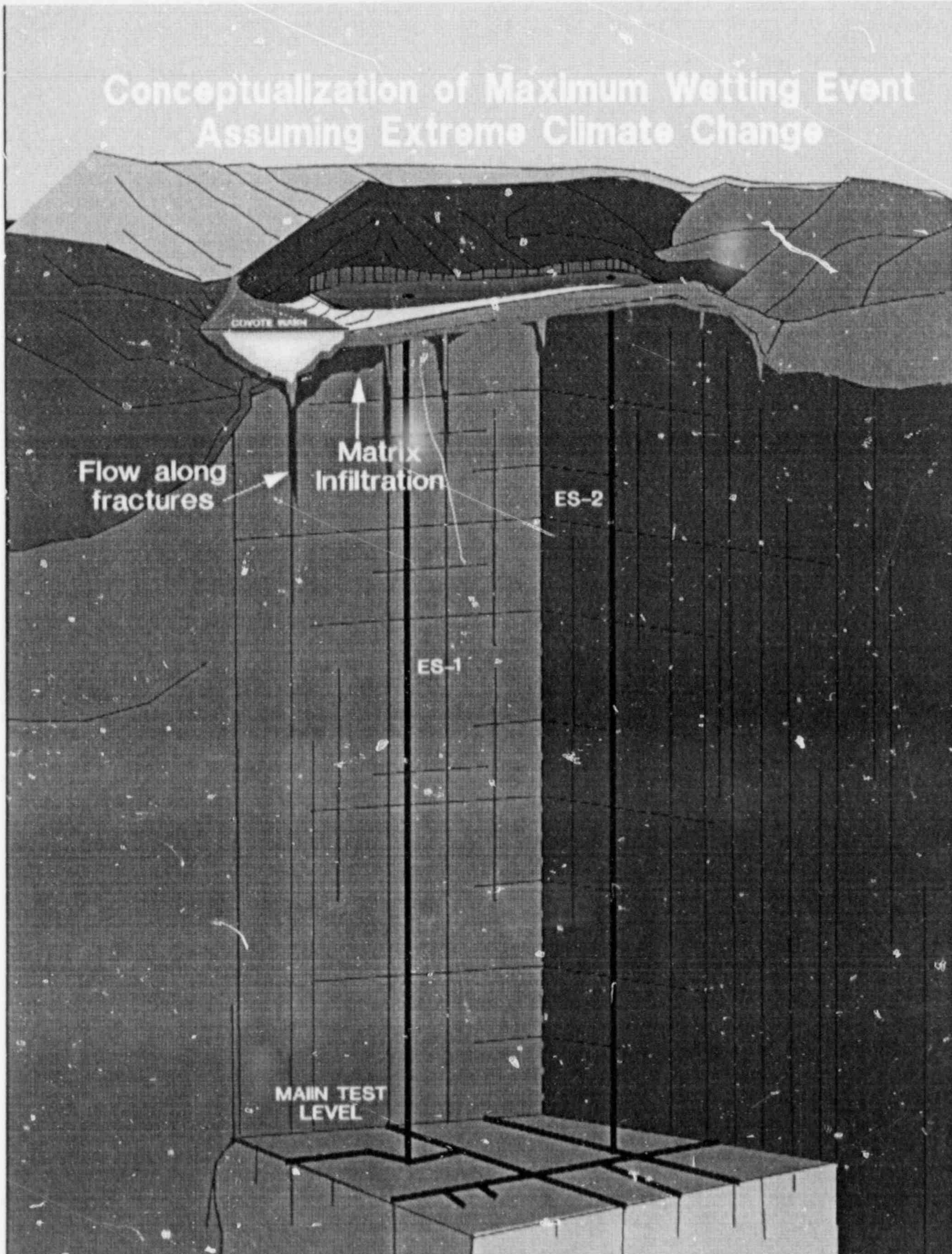


Conceptual Model of Yucca Mt MGDS In Vicinity of ES-1 and ES-2


COYOTE WASH
Flow along fractures
Matrix Infiltration
ES-2
ES-1
MAIIN TEST LEVEL
Water Table
Fluctuation in Water Table Assuming MWE


Conceptualization of Maximum Wetting Event
Assuming Extreme Climate Change
Matrix
Infiltration
Flow along
fractures
ES-2
ES-1
MAIIN TEST
LEVEL
arw12012

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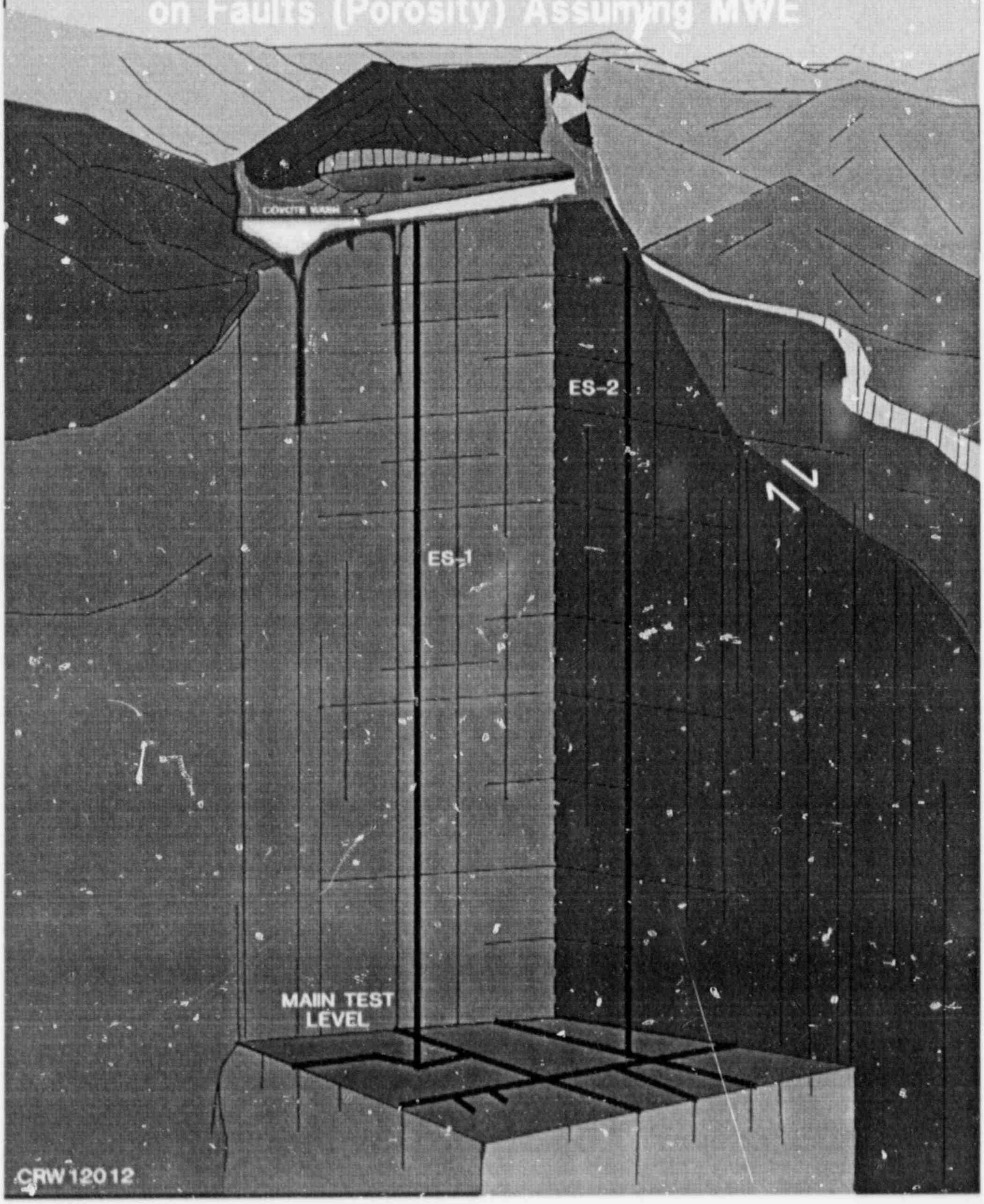
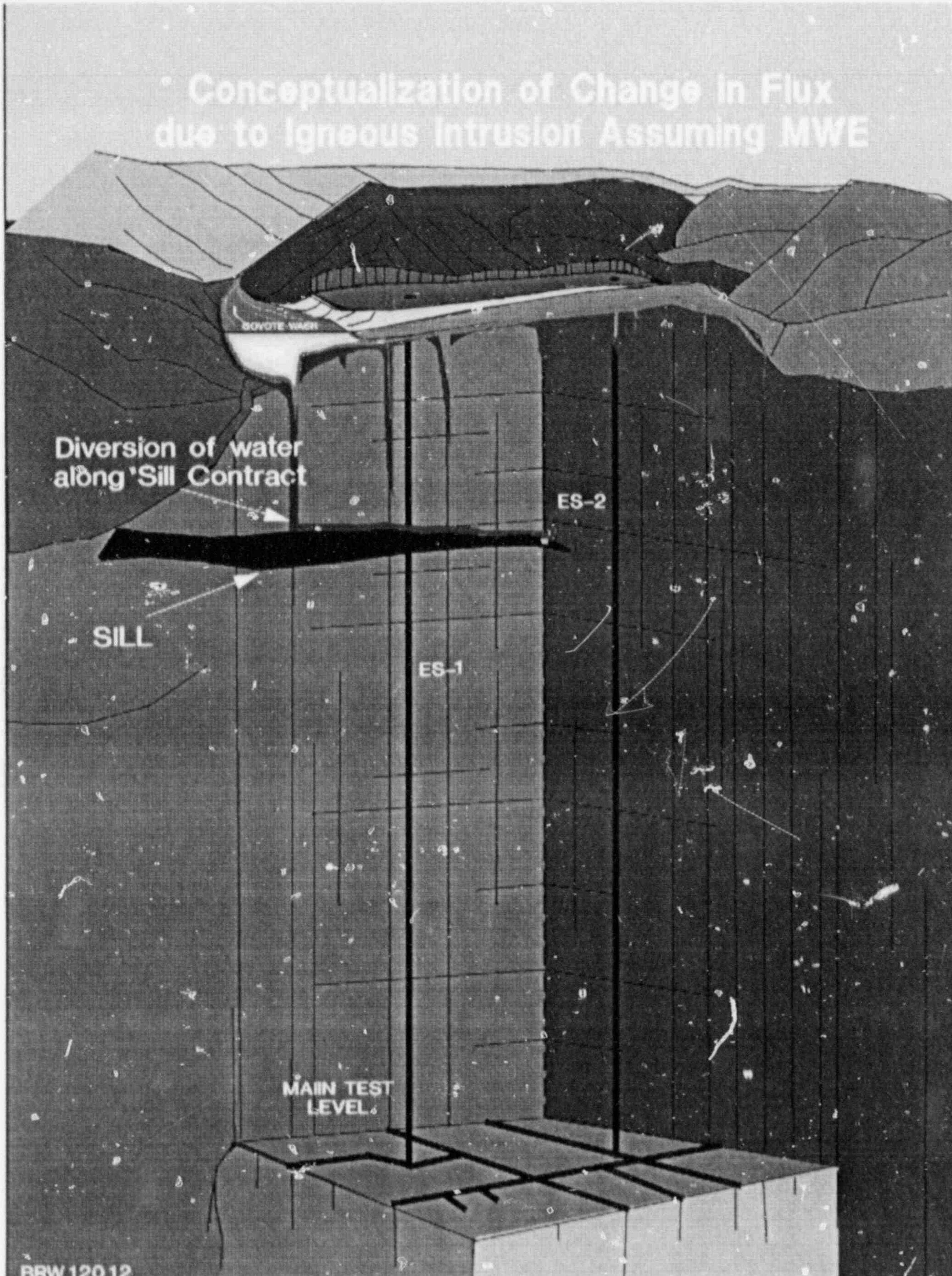
Conceptualization of Change in Unsaturated Zone Properties due to Offset on Faults (Porosity) Assuming MWE




Conceptualization of Change in Flux
due to Igneous Intrusion Assuming MWE
Diversion of water
along Sill Contract
SILL
ES-2
ES-1
MAIIN TEST
LEVEL
BRW 12012

PERFORMANCE PARAMETERS EXAMPLES FOR DISRUPTIVE SCENARIOS

PROCESS	PERFORMANCE MEASURE	PERFORMANCE PARAMETER	TENTATIVE GOAL
WATER TABLE RISE-CLIMATE CHANGE	RADIONUCLIDE TRANSPORT THROUGH UZ	MAGNITUDE OF RISE FOR 10,000 YRS	DISTANCE BETWEEN REPOSITORY AND WATER TABLE > 100m
FAULT OFFSET CREATES PERCHED WATER OR WATER TABLE RISE	RADIONUCLIDE TRANSPORT THROUGH UZ	PROBABILITY OF TOTAL OFFSETS >2m IN 10,000 YRS	$< 10^{-1}$
IGNEOUS INTRUSION	RADIONUCLIDE TRANSPORT THROUGH UZ	ANNUAL PROBABILITY OF INTRUSION WITHIN 0.5km	$< 10^{-5}$/YR

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CHANGES TO THE SCP

- TEXT WILL BE ADDED TO RELATE TESTING PROGRAM TO ALTERNATE CONCEPTUAL MODELS
- SCENARIOS THAT WILL BE TESTED WILL BE MORE CLEARLY EXPLAINED
- SCENARIOS THAT HAVE BEEN SCREENED OUT AND THAT WILL NOT BE TESTED WILL BE EXPLICITLY DISCUSSED
- TEXT WILL BE ADDED TO CLARIFY THE RELATIONSHIP BETWEEN THE TESTING PROGRAM FOR PROCESSES AND EVENTS TO THE SCENARIOS
- NO CHANGES TO THE STRUCTURE OF THE SCP DESCRIBED EARLIER

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CONCLUSIONS

- BECAUSE OF FOCUS ON PERFORMANCE OBJECTIVES AND DESIGN CRITERIA, SITE CHARACTERIZATION IS STRUCTURED TO ADDRESS RELEASE SCENARIOS
- THE SITE INVESTIGATIONS ALSO NEED TO CONSIDER LEGITIMATE ALTERNATE CONCEPTUAL MODELS
- ALTERNATIVE HYPOTHESES AND SCENARIOS HAVE BEEN SCREENED OUT AND WHICH WILL NOT BE TESTED WILL ALSO BE DISCUSSED IN THE SCP
- INFORMATION OBTAINED DURING SITE CHARACTERIZATION WILL BE USED TO ASCERTAIN WHETHER PARTICULAR MODELS CAN BE CONFIRMED OR REMOVED FROM CONSIDERATION

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Tape 9

DOE BRIEFING TO THE ADVISORY COMMITTEE
ON NUCLEAR WASTE

SUBJECT: TREATMENT OF ALTERNATIVE HYPOTHESES IN THE SCP

DATE: JUNE 28, 1988

PRESENTERS: DR. STEPHAN BROCOUM

PRESENTERS' TITLE/ORGANIZATION: 1. ACTING CHIEF, SITING AND GEOSCIENCES
OCRWM OFFICE OF FACILITIES SITING AND DEVELOPMENT

PRESENTER'S TEL. NO: 1. (202) 586-9247

TREATMENT OF ALTERNATIVE HYPOTHESES IN THE SCP

ACNW Meeting (June 28, 1988)
Dr. Stephen Brocoum

HISTORICAL PERSPECTIVE

OBJECTION 1 OF THE NRC's POINT PAPERS (MAY 11, 1988) ON THE CONSULTATION DRAFT OF THE SITE CHARACTERIZATION PLAN STATES THE FOLLOWING:

- PERFORMANCE ALLOCATION PROCESS FAILS TO ADDRESS THE INVESTIGATIONS NEEDED TO CHARACTERIZE THE SITE WITH RESPECT TO THE FULL RANGE OF ALTERNATIVE CONCEPTUAL MODELS AND ASSOCIATED BOUNDARY CONDITIONS CONSISTENT WITH EXISTING DATA.
- WITHOUT IDENTIFYING ALL POTENTIALLY SIGNIFICANT INVESTIGATIONS, IT CANNOT BE DETERMINED WHETHER CONDUCTING ONE INVESTIGATION WOULD INTERFER WITH AND POSSIBLY PRECLUDE CONDUCTING ANOTHER INVESTIGATION NEEDED TO OBTAIN INFORMATION NEEDED FOR LICENSING.
- THE PRESENT PROGRAM MAY FAVOR PROVIDING DATA THAT CONFIRM THE "PREFERRED" MODEL AND BOUNDARY CONDITIONS RATHER THAN DATA NEEDED TO DETERMINE WHAT THE "PREFERRED" MODEL AND BOUNDARY CONDITIONS SHOULD BE.

MEETINGS AND AGREEMENTS BETWEEN DOE AND NRC

MEETINGS HELD TO DISCUSS NRC's CONCERNS:

- MARCH 21-24, 1988 - DOE/NRC MEETING TO DISCUSS NRC's POINT PAPERS.
- APRIL 11-14, 1988 - DOE/NRC/STATE OF NEVADA MEETING TO DISCUSS ALTERNATIVE CONCEPTUAL MODELS. TRANSCRIPTS FROM THIS MEETING ARE CURRENTLY BEING REVIEWED FOR ADDITIONAL COMMENTS BY DOE.

AGREEMENTS FROM ALTERNATIVE CONCEPTUAL MODEL MEETING:

- DOE HAS AGREED TO PROVIDE TABLES THAT MORE CLEARLY DESCRIBE ALTERNATIVE CONCEPTUAL MODELS.

ACTIONS TAKEN BY DOE RESULTING FROM MEETINGS

CREATION OF WORKING GROUP 8:

- RESPONSIBLE FOR ADDRESSING CONCERNS OF THE NRC. MODIFICATIONS TO THE SCP INCLUDE:

  1. CHAPTERS 1 THROUGH 5

     - CLARIFY DOE's CONSIDERATION OF ALTERNATIVE CONCEPTUAL MODELS (ACMs).

  2. SECTION 8.3.1

     - EXPAND TO INCLUDE DOE's GENERAL PHILOSOPHY ABOUT CONSIDERATION OF ACMs.
     - PREPARE A "ROAD MAP" EXPLAINING THE MANNER IN WHICH ACMs ARE PRESENTED IN SITE PROGRAMS.
     - PROVIDE LINKAGES BETWEEN ACMs IN THE SITE PROGRAM AND NUMERICAL MODELS USED FOR PERFORMANCE ASSESSMENT AND DESIGN.
     - PROVIDE ACM TABLES FOR GEOHYDROLOGY, GEOCHEMISTRY, CLIMATE, AND TECTONICS IN SECTIONS 8.3.1.1-17.

  3. OVERVIEW AND SECTIONS 8.0, 8.1 and 8.2

     - EXPAND TO INCLUDE PERTINENT ASPECTS OF DOE's GENERAL PHILOSOPHY.

ALTERNATIVE CONCEPTUAL MODEL TABLE OUTLINE

CURRENT REPRESENTATION	ELEMENT-BY-ELEMENT DESCRIPTION OF THE CURRENT REPRESENTATION OF THE SYSTEM.
UNCERTAINTY IN CURRENT UNDER-STANDING	FOR EACH ELEMENT, IDENTIFY AND EVALUATE SIGNIFICANCE OF THE UNCERTAINTIES IN THE ASSUMPTIONS UNDERLYING THE DESCRIPTION IN #1.
ALTERNATIVE HYPOTHESES AND SIGNIFICANCE	FOR EACH UNCERTAINTY, IDENTIFY ALTERNATIVE INTERPRETATIONS, HYPOTHESES OR ASSUMPTIONS THAT ARE CONSISTENT WITH UNCERTAINTY AND EXISTING DATA.
TYPES OF TESTS PLANNED	FOR EACH SET OF ALTERNATIVES IDENTIFIED IN #3, DESCRIBE THE ACTIVITIES THAT ARE PLANNED TO DISCRIMINATE AMONG THE ALTERNATIVES HYPOTHESES AND/OR TO REDUCE UNCERTAINTY.

ADDITIONAL CONSIDERATIONS:

- PRIORITIZATION OF SITE ACTIVITIES IN ORDER TO AVOID INTERFERENCE BETWEEN TESTS AND TO ATTEMPT TO RESOLVE MAJOR CONCERNS WILL BY CONSIDERED.
- TABLES AND SUPPORTING TEXT WILL BE INCLUDED IN AT LEAST GEOHYDROLOGY (8.3.1.2), GEOCHEMISTRY (8.3.1.3), CLIMATE (8.3.1.5) AND TECTONICS (8.3.1.8).

OIA

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dlc
6/28/88