ORIGINAL

OFFICIAL TRANSCRIPT OF PROCEEDINGS

Agency: Nuclear Regulatory Commission
Advisory Committee on Nuclear Waste

Title: Working Group Meeting on Unsaturated
Zone at Yucca Mountain

Docket No.

LOCATION: Las Vegas, Nevada

DATE: Tuesday, December 14, 1993 PAGES: 1 - 392

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UNITED STATE NUCLEAR REGULATORY COMMISSION'S

ADVISORY COMMITTEE ON NUCLEAR WASTE

DATE: December 14, 1993

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NUCLEAR REGULATORY COMMISSION

ADVISORY COMMITTEE ON NUCLEAR WASTE

WORKING GROUP MEETING ON

UNSATURATED ZONE AT YUCCA MOUNTAIN

St. Tropez Hotel

455 Harmon Avenue

Las Vegas, Nevada

Tuesday, December 14, 1993

The above-entitled working group, commenced at 8:15 a.m.

ACNW MEMBERS PRESENT:

WILLIAM HINZE, CHAIRMAN

MARTIN STEINDLER, MEMBER

DADE MOELLER, MEMBER

PAUL POMEROY, MEMBER

BILL FORD, CONSULTANT TO ACNW

WILLIAM SACKETT, CONSULTANT TO ACNW

PAUL DAVIS, CONSULTANT TO ACNW

DARRELL LEAP, CONSULTANT TO ACNW

LYNN DEERING, STAFF

PARTICIPANTS:

APRIL GIL, DOE
J. DLUGOSZ, DOE
ERNIE HARDIN, UA
MIKE CHORNACK, USGS
ALAN FLINT, USGS
ED KWICKLIS, USGS
JOE ROUSSEAU, USGS
ALBERT YANG, USGS
BO BODVARSSON, LBL
C. NEWBERRY, YMPO
LINDA LEHMAN, LINDA LEHMAN & ASSOCIATES
LARRY HAYES, USGS
JERRY BOAK, DOE
DAVE KREAMER, UNLV
MYRA WILLIAMS, NEVADA
NICK STELLAVATO, NYE CO.
RAY WALLACE, USGS
MARVA JOHNSON, STATE OF NEVADA
STEPHEN CARRUTH, M & O
CARL JOHNSON, STATE OF NEW YORK
SRIKANTA MISHRA, INTERA
STEVE FRISHMAN, NEVADA
MIKE LUGO, TRW
PHILIP JUSTUS, USNRC

PARTICIPANTS: (continued)

CADY JOHNSON, WOODWARD-CLYDE
ABE VAN LUIK, INTERA
JIM YOUK, WESBS
MARSHALL WEAVER, CRWMS
JOHN ROSENTHAL, WESTON
DEBRA EDWARDS, USGS
DWIGHT HOXIE, USGS
DAVID APPEL, USGS
TERENCE DANIELSON
SCOTT TYLER, DRI-UNR
ERNEST HARDIN, AZ
WILLIAM FORD, NMSS
MIKE MIFFLIN, MIFFLIN & ASSOCIATES

P R O C E E D I N G S

MR. HINZE: I want to welcome everyone to the advisory committee on nuclear waste and unsaturated zone flow at the potential Yucca Mountain high level waste repository site.

I'm Bill Hinze, a member of the committee who will be chairing today's meeting. We have with us today the members of the committee. On my right, Martin Steindler, the chairman of the committee; Dade Moeller and Paul Pomeroy.

We also have with us three consultants. I would like for the consultants to introduce themselves. There are three of them -- Paul Davis, Darrel Leap and Bill Sackett. Just introduce yourselves and state your area of expertise.

MR. DAVIS: I'm Paul Davis from Sandia National Labs. My educational background is hydrology although most of my work is in performances estimate and I am currently in charge of the integration of performances estimates and characterization for the WIP program.

MR. LEAP: I'm Darrel Leap. I'm a professor of hydrogeology at Purdue University and I'm a member of the ACNW hydrogeology unsaturated flow.

MR. SACKETT: I'm Bill Sackett from the University of South Florida. I call myself a hydrogeochemist. I've been involved in studies on uranium thorium series nuclides,

tritium, carbon 14 for dating oceanic processes and also presently looking at OX18 as a measure of indicating something about the flow of ground water in south Florida.

MR. HINZE: Thank you very much.

Seated on my left is Lynn Deering, who is the designated federal officer for today's meeting and deserves the plaudits of all of us for putting this group together finally. It's been a long haul.

This meeting -- I am forced to say this meeting is being conducted in accordance with the provisions for the Federal Advisory Committee Act.

A few words before we get into the speakers about the objectives of this workshop.

The characterization of the subsurface hydrology and the hydrogeochemistry are among the very most important topics in the siting of any high level waste repository and certainly this is true at the Yucca Mountain site.

Numerous groups have and undoubtedly will continue to review the subsurface hydrology characterization at Yucca Mountain but we on the committee believe that this is a particularly critical period in the characterization process and its interface with the regulatory framework which we are particularly interested in.

Thus, it is appropriate that our committee conduct this workshop on the unsaturated zone or, as I'm supposed to

say I guess, the Vadose zone.

We are particularly interested during the day I think in three basic areas. First of all, we're interested in the advances and we are very much looking forward to hearing about the advances made in the understanding of the processes of the fluid flow and their controls in both the welted and unwelted tuffs in the unsaturated zone.

We are also interested in the status of the data that are being acquired and the modeling.

We on the committee are also particularly concerned with the uncertainties in the unsaturated zone transport and flow that we have at the present time and any projections that we can make about the uncertainties that are likely to persist as we complete the characterization process, as the DOE completes the characterization process.

There are numerous other questions and concerns that the committee has and these have been directed to the various speakers and we are interested in hearing the answers or the approach to some of these questions.

I should state that in today's meeting we are only looking through one small window at this subsurface hydrology problem, and frankly we're looking forward to working with other groups to expand upon that and to have a more comprehensive view of the geohydrology and the hydrogeochemistry.

A few words about the mechanics of the meeting. Those of you that have attended our workshops before know that we try to hold these in a very informal way but no throwing erasers. We do try to keep it informal and thus as time permits we trust that all of us will have a chance to express our opinions and concerns and to question the speakers.

However, if you have looked at the schedule, you know that it's chuck full and I'm going to have to control my own interests and try to keep us a little better on schedule than the working group I chaired here a year ago where I don't think we even got dinner that evening. We learned a lot.

In any event, I trust that we will be able to work in an informal atmosphere.

The meeting of course is being recorded and it is therefore necessary for you when you make a comment or have a question that you identify yourself and speak into one of the microphones.

Before I turn it over to the first speaker, I would like to identify John Larkin who is here. John is the executive director of the ACNW and the ACRS.

I would also like to identify Bill Ford from the Nuclear Regulatory Commission who is our representative here today and we thank you, Bill, for being here.

With that, unless there are comments from my colleagues or anyone else, I would suggest that we move ahead and I would like to introduce Ernie Hardin who needs no introduction to most people in the room, I'm sure.

Ernie is now at the University of Arizona and he is going to provide us with an overview of the Apache Leap research program and this is an excellent place for us to start our discussions here today.

Ernie, it's yours.

MR. HARDIN: Thank you very much.

I'm a graduate student at the University of Arizona. I'm part of a group of six students who work for Professor Randy Bassett and I'm going to try to give you an overview of what we're doing at the Apache Leap research site in central Arizona.

In fact, there are a couple of major research thrusts at the site. One has to do with hydrochemistry travel time and groundwater flow paths and so forth. Another has to do with pneumatic testing and stochastic characterization of flow and transport in fractured tuff and what I'm going to focus on mainly here today is the former rather than the latter.

The subject of pneumatic testing is one that Professor Newman is working on and I think at another occasion I'm sure it would be beneficial to have him or one

of his students discuss that work. I'll show you where it's being done and, to some degree, how it's being done.

MR. HINZE: Ernie, perhaps it would be helpful for all of us to know where the sponsorship of this program is coming from.

MR. HARDIN: Absolutely. The Apache Leap program is being funded by the U.S. Nuclear Regulatory Commission and it's being funded under a couple of different contracts for about ten years.

Several principal investigators have been involved and many graduate students who have gone through the University of Arizona program have come into contact with this research program.

We're asking these questions: Can you use stabilized isotopic signatures to help you in travel time work. Our site is fractured tuff. It's very similar to Yucca Mountain and was selected because of that.

What about the flow paths, it gives isotopic significance, and what is the relationship between stabilized isotope signatures and radiocarbon and other radioisotope signatures that can tell you something about the rates of flow and transport processes.

The Apache Leap site is situated above Superior Arizona here. Phoenix is over here. This red outline that you can barely make out is the inferred extent of an ash

sheet that's about 24 million years old by potassium argon and locally very thick.

Where we're working here it's about 400 meters. It's all one cooling unit. It's felsic tuff.

The eruptive origin of this tuff is not altogether clear. It was first mapped by Peterson back in the '60s.

The Apache Leap site was selected back in the early '80s and --

MR. HINZE: Could we try turning off the lights back there?

MR. HARDIN: I have a few photographs.

[Discussion off the record re lighting.]

MR. HARDIN: From Kings Crown Peak which is southwest towards the Apache Leap -- Apache Leap is the physiographic feature on the skyline here. I'm not going to get into why it's named that. Basically it's a stack of tuff sitting unconformedly on paleozoic sediments.

It's a mining district and what you have in the middle foreground is the number nine shaft of the Magna Copper Company and some surface facilities.

About a quarter of a mile or half a mile behind those, we have two areas on the surface where we're doing our research activities.

Down in the near foreground is a canyon and there's an ephemeral stream there called Queen Creek and

Queen Creek comes into play in the research I'm about to start next.

The mining company has driven a tunnel and added really from the town of Superior over here back to the shaft and they use this for ore haulage. The tunnel passes underneath Queen Creek and when the creek flows we see discharge in major fractures that intersect the tunnel so this is a natural site for us to study the isotopic and the chemical evolution of water as it moves down rapidly through the system.

In addition, the tunnel, if you go back far enough in the tunnel you pick up older waters and at the intermediate stations you see mixtures of the modern waters with the older waters.

The older waters is the discharge from the perched aquifer that has been encountered all over Apache Leap by the mining companies over the years and we have drilled a borehole to tag that first aquifer and study so our research sites on the surface, the covered site and this deep slant borehole site are located near the shaft, up in this general vicinity.

This is a picture of Queen Creek. We have an electrical conductivity probe connected to a remote data logger that tells us when the creek is flowing. It tells us a little more than that because of the water conductance.

This is approximately where we think one of those fracture systems daylights.

The tunnel underneath was constructed with a tunnel boring machine and the invert has been widened to facilitate rail and foot traffic. This is a typical fracture. Notice the ferrihydrite colloidal iron slip that's accumulated on the wall.

At a couple of stations like this we have little weirs and the little data loggers so we can monitor flow over time and also the specific conductors, the electric conductivity of the water.

The basic rationale here is to look at how water evolves because of evaporation at the surface and potentially in the vadose zone.

Of course we get mineral dissolution in the stream bed and in the fracture system and we get interaction between a fracture flow and the adjacent matrix.

Tom Fitzmaurice is in the process of trying to model this. His observations, which of course are implant observations using a dual continuum type model and trying to understand the fracture matrix hydraulic interaction from the chemical signature over time of the water that's collected in the tunnel.

Isotopically, what I've told you about the perched water and the mixing with the modern water is borne out

here. In the creek and in the modern waters collected in the tunnel, we have tritium.

In the older waters here dated by radiocarbon, this is apparent age, we have about the same C-13 signature but a rather different sulfur 34 signature and this is because the sulfur in the modern waters here is affected by air fall from the smelter that used to be in Superior and that smelter has processed sulfur that came out of some hydrothermal deposits associated with paleozoic marine carbonates and the sulfate we're seeing up here in the older water is much more closely associated with the tuff mineralogy.

On the left here we have composition in milligrams per liter of some of the major ions. In the center panel, we're looking at the equilibrium type solution that you would get from a model such as Watech, and on the righthand side you're looking at the analysis from the older tunnel water.

Basically we've identified some of these source mineral phases microscopically in the tuff and our modeling is telling us that there are several precipitating phases here, any one of which could be significant in terms of sequestering heavy metals by co-precipitation or by absorption.

We're going to switch gears a little bit here.

This is an almost nadir view of the Apache Leap. The town of Superior is down at the bottom and there's the escarpment, and the tunnel, the plan of the tunnel, is shown in yellow. You can see where it crosses Queen Creek.

These two red dots up here are surface field sites on top of the leap. The eastern one here is what we call the covered site. That's the older site. This is one is our deep slant borehole.

Just a few words about the covered site. It was prepared back in the mid '80s. What you see here is a big plastic membrane held down with tires. It's kind of a mosquito ranch at certain times of the year.

The purpose of the membrane is to keep rain water out of the tuff near the surface, not so much to dry it out, which is not exactly what happened at all -- in fact, it wetted up slightly because you've reduced the amount of evaporation -- but to stabilize the moisture content of that tuff.

What we have here are about 20 different boreholes and the typical length or depth of these holes is about 30 meters. They are drilled in sort of a geometric array.

We've done a fairly comprehensive set of single-well packer type pneumatic injection tests with a one-meter interval throughout all the holes in this rock mass and that's been the basis for some stochastic work that Amato

Guzman is doing, and they're moving on at this point to cross-hole type testing.

If you go up gradient towards the Leap from that site, here's the mine head frame, the surface facilities.

These are the incised canyons running eastward off the escarpment, and to the right here, sort of off the picture, is the canyon that we have selected for study with the deep slant boreholes.

What you may or may not be able to pick out here is that there is a structural trend that runs about north-south this way, so when we went to site the borehole we decided to put it in with a plunge that's more or less easterly and that way we'll intersect as many of these steeply dipping major fracture zones as possible.

Looking up, this is in the general vicinity of the slant borehole, you can see that the soil cover at the site is very low. There is some kind of a spalation mechanism going on here on the surface that's contributing to the erosion. This may have to do with freeze sod. There is freezing at the site.

The site gets about I believe 24 centimeters of rain on the average and there's a fair amount of manzaneta community vegetation here.

If you look at the fractures, this is what you see. A fracture zone daylights in this way. It's typically

chemically weathered, widened, eroded and with soil blown in and it's vegetated, so we think this is the effective soil zone for the site.

In fact, the partial pressure of CO2 gas is represented. It's about ten to the minus two representative of a typical soil zone. In fact, in some instances we have observed dissolved organic carbon in waters from the vadose zone which very well could be becoming picked up here by the infiltration.

At the site, this is a little salesmanship I guess, we have constructed a flume that we think can handle the maximum conceivable runoff from the basin to the watershed of about 80 acres. We have a meteorological monitoring station that has up and down looking radiometers. We have a network of rather primitive rain gauges throughout the basin.

We have an instrument shed, air conditioned and insulated with ten kilowatt generator for power.

The deep slant borehole was drilled about a year ago. We hired Tonto Drilling Company to come in. They used a method similar to Odex. The hole is about six inches in diameter where it's been reamed. Otherwise, it's typical HQ diameter, four inches with two and a half inch core. The hole starts out at 45 degrees.

This is the Tubex tooling that they used. This is

a through casing, reamer-type tooling, drags the casing along. You are probably all familiar with this.

You withdraw this tooling and the string and then insert a core string for coring. We fully cored the hole.

We brought the core out using wireline equipment in ten-foot lengths, ten-foot barrel, and we immediately surveyed the core using a TV camera and then we cut some of it into pieces on a diamond saw using air, of course, and doing it dry, or some of it.

Then we wrapped it up in a plastic sheet and stuffed it into a core packaging system called Protect Core, which you may be familiar with, aluminized plastic and the packages can be sealed with an iron.

Since the drilling, we have weighed and re-weighed some of the packages that are now being stored under air conditioned conditions back in Tucson and we think that the water loss is minimal from them.

As far as gas diffusion through the packages, that's another question we haven't addressed.

So we have 200 meters of core. This is kind of a cross-sectional view. You can see that the hole starts at near 45 degrees and kind of heels over to about 37 degrees. That's expected.

We drilled down into the perched water zone and just a little beyond we think perhaps from some gross

lithologic indications.

We encountered various steeply dipping fractures on the way down and I'll show you some logs and so forth that bear that out. In addition, there are a few subhorizontal fractures.

Overall, the character of the rock is very similar as you work your way down, although the welting does seem to increase with depth.

One of the first things we did was in the field we took samples and weighed them. We took core samples in the field, weighed them and then proceeded to dry them out and we built a large pycnometer that could take a large core and we calculated the biometric moisture content and the apparent saturation of the samples.

What we're seeing here, the yellow curve is apparent saturation computed using gravimetric moisture and pycnometry. The red symbols -- half of the red symbols were used to compile the yellow curve and the other half are redundant from another set of samples.

So overall we're looking at a saturation curve from about 50 samples and the red symbols comprise about a hundred samples.

Anyway, the porosity decreases with depth, saturation is fairly uniform, seems to be tailing off near the surface although some of our highest biometric water

content is found near the surface where the porosity is high.

You'll notice the push water table really doesn't shine in this data set.

I'm going to talk a little bit about some of the geophysical logs. The logs that we've run at the site include natural gamma, spectral gamma, gamma gamma density, neutron, dual detector and the EM-39 induction tool, and I'm going to focus on all those except the spectra gamma and natural gamma because the formation is so homogeneous to those logs they're flat. We ran temperature logs and caliper but those are not terribly useful to us.

The neutron log, however, does show -- this is an uncalibrated log and it shows us where the water is and it compares very favorably with the data we have from cores. These zones then correspond to fractures and we have a TV lot that backs that up.

Really, the goal here is to identify what are -- if we can -- what are the channels for infiltrating water through the vadose zone and to sample those for hydrochemical analysis.

There is a piece of casing stuck in the hole right now. That's one of our projects for next year, is to hire a contractor to get that out. Consequently we get this shift in the gamma density log and this gap in the induction log.

This is a calibrated log and here we have some spikes, low density spikes, and if we go back to our TV camera and our core log we find that these are fracture zones and in some of these zones we have close to a hundred percent core recovery so we're very pleased with that. We're very excited about testing those and perhaps squeezing water out and so forth.

The EM-39 log is very repeatable. We've logged the hole ten times with the EM-39. It worked much better than some of the other induction tools. USGS, Fred Paille's group from Denver, has collaborated with us and has acquired most of these logs.

Comparing his induction tool with the EM-39, I think the EM-39 being a 3-coil design is much more stable in these high resistivity environments and we're seeing the same type of spiking behavior in the induction log.

For reference, to calibrate your eye, this is the response of the EM-39 to a thin sheet conductor. It has a half width of about a meter. Looking at these features again, you see some of them are about a meter wide so what we could be seeing here are very localized effects associated with individual fractures and then elsewhere we would probably see the effect of more than one factor wet.

This is a cross-plot of the neutron data and the induction log. These data have been bent so they're re-

sampled to a half-meter interval. Consequently they're not quite as -- that reduces the scattering of plot but we see that is a potentially useful cross correlation there.

Originally, I thought that there would be a -- that there perhaps was clay since the electrical resistivity seems to decrease rather gradually with depth. We thought perhaps what we were seeing was progressive alteration of cell spars generating smectites or other clay-like species.

What we did, or what I did, was I set about to measure some of the electrical properties of the cores to see if I could discern this effect.

I took an old sample holder that had been developed previously and modified it a little bit so that the porous plate that isolates the electrolyte for the current electrode is from the unsaturated sample. The porous plate is now outside of the silver electrode so you no longer have to compensate for the properties of the plate when you're making measurements.

Looking at resistivity versus depth from the cores, each symbol is a separate core and I think it suggests to me that we are seeing a correspondence between the log and the core but there's about a factor of five difference and that could very well be due to loss of water.

Even though I took great pains not to lose water, it's quite possible that I did. Evidently the resistivity

saturation relationship is quite sensitive for this particular rock.

This is chargeability. I collected these data hoping that chargeability would be a clay index but this is about as far as I've taken this.

I see that there is a correspondence between chargeability and resistivity so we could be looking at a poor fluid effect instead of clay.

So where are we with the physical characterization of the hole? Mainly we're doing geophysics in order to support the sampling program for the other disciplines. We will use core resistivities obtained from water squeezed from cores in the calculations. We're going to take a lot more cores and run them through the pycnometer.

We've made some resistivity measurements of the core in the dry state. We've defined our dry state as weighing to constant weight in an oven at 105 degrees C. Unfortunately, when you dry one of these cores to that state of dryness, you exceed the resistivity range of our equipment which is about 3,000 ohm meters, so apparently, as I said before, the electrical properties are very sensitive to saturation even at potentially low saturation values.

Now this is a little cartoon that I've thrown in to explain another thing we're trying to do next, which is we'd like to run some geophysical topographic surveys to

characterize this region of the rock mass, and the reason is that we don't really know what --

First of all, we would like to exercise the technology for running these surveys in a dry hole. Secondly and particular to the site is we don't really know whether we're seeing steeply dipping discrete fracture zones as they're depicted in this figure.

In fact, we could be looking at former high stands of the first aquifer table, water table, and in fact the mines have undoubtedly drained the water table so there's good reason to suspect that, and we would like to kind of resolve the geometry of the electrical properties at the site which help us make inferences about flow paths.

We're going to do that seismically and using electrical resistivity tomography and we're going to undertake some initial studies, feasibility studies, next summer if all the other project involved are all out of the way.

Now geophysics in its support role for geochemical and hydrochemical sampling, these are eight zones that we've identified for core squeezing. We've gotten started on this. You'll notice that we've taken some spikes and we've also taken some regions next to the spikes and of course the idea here is to be able to identify the in position process by change in properties adjacent to fractures.

This is the same idea, different logs. We get the same type of support from density induction and neutron logs.

This is the cell that we're using to squeeze the cores. This is borrowed from Al Lang at the USGS. This is his 80,000 psi cell in our laboratory. I guess I can't say too much about it that Al hasn't already said. We've really learned a lot about squeezing water out of rocks.

In fact, Al told us it was going to be difficult and it truly is. In some cases, we've gotten as much as 17 milliliters out of a volume of rock that's 300 ccs, but in many cases about half that we've tried we've gotten zilch.

This is some very preliminary data. We have columns of data that correspond to different water samples. The middle one -- and they are on a generalized flow path. The middle one is from one floor water sample where we got a very large yield. This is from runoff sample at the deep borehole site and this is from the first aquifer which we pumped at the site.

Basically these numbers are more or less in line with what you would expect from evolution of the water if you allow for water that's been sequestered by inhibition into the matrix to be slightly more involved than water that recharts the first aquifer by rapid flow along fractures.

There are some anomalies here. One of them is

nitrate. When we squeeze these cores, we get around 20 parts per million of nitrate whereas the first aquifer is much less.

We've tested some water pumped from the first aquifer at the Oak Flat well which DOE drilled for practice at Apache Leap and it was high in nitrate also.

The sulfate is characteristically high. Of course that must have to do with airfall from the smelter and that makes this water here a little bit older than the smelter and in fact we have done tritium analysis on the first aquifer and there is no detectable tritium, which was kind of a surprise to us.

Finally, there's a mystery that's not on here because we just found out about it last week, and that is that in some of the cores that we're squeezing -- in fact, for replicate measurements, we found about 50 parts per million of dissolved organic carbon in the cores and we don't have a lot of ideas about where that's coming from but we think that it might be that the carbon humic units are getting trapped in the interstices of the rock matrix after the water is imbibed and then the water may be re-evaporated, re-mobilized, but the humic may be trapped there somehow. That's our working hypothesis.

Given that there are practical problems associated with squeezing water out of tough cores by consolidation,

and given that we would like to have about 50 milliliters per station to do carbon isotopes, radiocarbon, carbon 13, total carbon and inorganic carbon and then do the analysis for the major anions and cations, given that we want this much water we are starting to look at other ways of obtaining some of this information.

We've built a setup for doing vacuum extraction in which we'll try to get a boiling action or a rapid evaporation action going in the core water and hope that that tends to sparge the CO2 which we will then trap.

In addition, we'll take cores in rock samples that we have crushed and ground to fineness and leech them with acid under controlled conditions so we can capture the CO2 that comes off and the idea is to do a CO2 mass balance.

We've done a little bit of work on this with cores from the Oak Flat well and of course there's a carbonate horizon in that well and it's possible, but we haven't determined this yet, that there might be a similar horizon in the deep slant borehole that's at a depth below which you find carbonate and above which you do not find mineral carbonate and the work we've done so far is that above that horizon the carbonate appears to be associated with the water.

In other words, the carbonate concentration, the total carbon dissolved in the water, is very similar on a

mass basis or volume basis to the carbon that you can extract from a core sample that's been thoroughly dried and the apparent age of the carbon extracted from thoroughly dried samples is the same as that of the water, about 3,000 years.

There are a couple of other things I'd just like to touch on before I finish up and one of them has to do with gas extraction from water pumped out of the first aquifer.

We're looking at differential environmental tracers here and two of the ones that I haven't talked about are the argon gases, argon isotopes, argon 37 and 39 which have half-lives of about 30 days and 230 years respectively. These are cosmogonic and nuclear age isotopes.

What we did is we borrowed a Bennett sample pump, which is a closed loop pneumatically driven pump, and we pumped several tens of thousands liters of water out of the perched aquifer and we took that water and stripped the gases out in this system which was borrowed from Lamont.

Basically what this is, this is a column that you pull a vacuum on and the column contains some plastic parts which act as a high surface area medium.

The water then is sprayed under pressure into the column here. The gases are removed and then pumped off with the air and trapped. We sent some air samples produced in

this way off to Switzerland for analysis and we'll send some more off later. This was the first aquifer.

The technique that we'll use for the vadose zone above that doesn't involve this system. We'll put a straddle packer in the hole and pump it and we'll monitor with a gas chromatograph in the field until the sulfur hexafluoride we used during drilling is no longer important to us and then we'll take the sample for argon analysis.

You'll notice I hedged a little bit. We don't know exactly what the concentration of sulfur hexafluoride is going to be.

Another very similar activity involves chlorofluorocarbons, CFCs, and Mike Geddis has put together a system modeled after Ed Boozenberg's CFC measurement technology -- he's with the USGS in Reston.

Basically the idea here is as we're pumping the vadose zone, using a packer, when the SF6 concentration drops low enough then we will sample for CFCs.

His concept is that CFCs will go down as you get deeper but the measurement is going to be very difficult because he's looking at changes from background, reductions from background, and the background is a couple hundred parts per trillion.

That concludes my presentation. The message I hope to leave you with is that the Apache Leap research

site, what we have we think is very good access to a generalized flow path from surface runoff through the unsaturated zone. We have sampled the first aquifer at multiple locations and we have the discharge of the older water into the tunnel as well as the more modern waters that are collected in the tunnel.

We continue to use environmental isotopes and tracer constraints on travel time and reaction pathway modeling and we're relying on geophysical logs as the principal basis for geochemical sampling and we're running the program in an interdisciplinary way. Different students are assigned different topical areas and we're trying to encourage collaboration with other researchers in other laboratories.

Thank you very much.

MR. HINZE: Thank you, Ernie.

We do have time for discussion and any questions that we may have. Paul?

MR. DAVIS: I'm having some difficulty making the transition from Apache Leap to Yucca Mountain. Maybe an example would help me, an example of what's been learned at Apache Leap that changes my understanding of Yucca Mountain or my approach to understanding Yucca Mountain.

Can you give me such an example?

MR. HARDIN: Well, one of the reasons why you

might want to have a field site is so that you can learn about things like high dissolved organic carbon in the vadose zone waters, so you can come to terms with those technically before you encounter them at a regulated site.

Another example is that there has been many years of physical testing of physical properties of the Apache Leap tuff so it's a fairly well understood medium and this supports the work that Professor Newman is doing in the modeling of flow and transport in three dimensions in fractured media.

I guess I could keep going. We think we're developing methods and we put a lot of emphasis on methodology and procedures and developing methods and trying to understand how a methodology is affecting our results.

MR. DAVIS: Methods that we would expect DOE to use or methods, kind of an independent check of the methods that DOE uses?

MR. HARDIN: My sense of it is the latter. Also, it gives some of the -- We're closely affiliated with the center, the SRI center, and it gives them a chance to exercise some of their models on data sets collected in the field as Tom Fitzmaurice is doing.

MR. LEAP: Do you have any feel of just how closely the mineralogy of this area fits that of the Yucca Mountain and therefore contingent upon that the chemistry

and the interactions -- Is there anything that's been done in this area or is there any feeling of that?

MR. HARDIN: As a corollary?

MR. LEAP: Can you quantify any relationship -- Maybe that's not a fair question to ask you at this point but I'm interested to as Paul was to this analog, the condition at Yucca Mountain.

MR. HARDIN: Well, I would say from my own experience maybe the principal difference between Apache Leap and Yucca Mountain has to do with the large scale stratigraphic picture.

There are some very, very significant differences in stratigraphic properties as you work your way down through the section of Yucca Mountain and we do not encounter those here at Apache Leap.

On a mineralogical level, I think there are similarities. I'm not an expert in that technical area. I think it being a dacitic or peralkaline tuff is well known.

MR. SACKETT: Have you thought about using uranium thorium series nuclides to get at rates for these different processes, solution rates and so forth?

MR. HARDIN: That happens to be the area I'm working on personally. Yes, I've thought about it. In fact, what I will do is I will take the water that we squeeze from the cores and try to run uranium isotope

measurements on those, as well as the other waters that are a lot easier to sample.

We're looking for a split between 234 and 238 and I would use that to look at hopefully -- My working hypothesis is that the split does occur as the water evolves, that the ratio of 234 to 238 increases because of some of these mechanisms like preferential leeching or alpha recoil, and that as the water --

Basically what I would like to do is to look at the solid phase as well as the water phase and draw a corollary between isotopic equilibrium and thermodynamic equilibrium. That's one avenue that we're looking into.

We don't know whether the U-234 or 238 ratio will depart from unity far enough in the system in order to go any further with that as a possibility. We can sample those things. I've looked into --

I would really dearly love to develop some kind of a data methodology that involves radium 226 and radium 228 but it's an oxidizing environment and radium is pretty scarce in solution.

In addition, we have an added complication that there's some unknown degree of atmospheric exchange with the vadose zone gas so you could expect that perhaps that would complicate some of the radon analysis that you would have to do.

It's an interesting topic, just not one that we have been able to formulate real strong research hypotheses with.

MR. FORD: Bill Ford, U.S. NRC.

Ernie, in light that one of the objectives of the work at Apache Leap is to evaluate the usefulness of how isotopic sampling in the unsaturated zone for isotopes that can move both in the gas and liquid and how you can use those isotopes to either characterize the gas phase or the liquid phase, at this time are there any isotopes that you're having trouble obtaining samples or techniques to get them from the rock?

MR. HARDIN: Well, I've mentioned all the isotopes that we're studying and I must also say that this is research in progress and there are things that we're not doing that we could try. For example, we could try to extract tritium from cores.

In general, I would say we're able to sample the isotopes that we set out to sample, if that addresses your question, and it's a little early in our program for us to make final conclusions about which isotope may be more useful than another but we are placing a lot of emphasis on carbon 14.

You mentioned the physics where you have mass transport in the gas phase and mass transport in the liquid

phase and that's very complicated geometrically.

Looking forward, it seems likely to me that the isotopic data modeling is simple models -- that is, simple geometrically -- will give us an understanding of processes like water imposition, but I guess it's important to recognize the limitations on that type of understanding. It is geometrically limited.

There will always be a certain degree of uncertainty. Ultimately we'll take the deep slant borehole, we'd like to run some pneumatic injectivity tests in that hole and combine that data with other injection test data which has been acquired from the site and it's possible that we could develop a more stochastic approach. That's way out in the future for us.

MR. LEAP: I may have missed your point. When you were talking about the high concentration of nitrates, did you offer an explanation for that, or can you offer an explanation of that?

MR. HARDIN: I don't have an explanation for it. It's not a major constituent of the airfall at that site.

MR. LEAP: Could it be related to the carbon?

MR. HARDIN: It's possible. We didn't use sterile sampling methods on our core. We've done some thinking about that and there are some limits on what we can say about that.

MR. JOHNSON: I'm just wondering if you have in your preparations some kind of a gas circulation model for Yucca Mountain and what seems interesting and attractive about that is that first water zone a gas circulation model may be more analogous to Yucca Mountain than a moisture model might be. I just wondered what your status is in that area.

MR. HARDIN: I'll tell you that there was a Ph.D. dissertation done about five years ago that involved the covered site boreholes and measuring gas inflow and outflow of those holes and correlating that with atmospheric signals and associating atmospheric monitoring data at lower elevations with those up on Apache Leap.

It is a topographic prominence so you could expect some circulation behavior similar to what's been observed at Yucca Mountain. There is interest. No student is working in that area right now.

MR. MOELLER: Dade Moeller. The committee visited the Apache Leap site several years ago and, following up the previous question, one of the things that impressed me was how the land breathes, you know, in and out.

Because you've bored the holes and more breathing I presume is taking place than would naturally have occurred prior to the boreholes, in what ways might that be influencing your data, particularly the moisture data?

MR. HARDIN: As you have -- The programs that I described today don't involve things like monitoring with a neutron tool in a world which would be sensitive to long-term drying.

Chemically it's terribly important and that's why some of my colleagues think it was sort of a stroke of good luck that we lost 250 feet of casing in the borehole when it was drilled. The breathing really is kind of a fascinating phenomena.

MR. HINZE: Thank you very much, Ernie.

I believe we can move now to a series of presentations by our DOE colleagues and Joe Dlugosz is going to give us some opening remarks and introduction to the DOE program in this area.

Could we ask the speakers to just briefly introduce yourselves. We don't want a vitae. Just a brief resume of who you are and where you're coming from.

MR. DLUGOSZ: My name is Joe Dlugosz. I'm a hydrologist and a senior scientist with the U. S. Environmental Protection Agency. I'm on a multi-year detail to the Yucca Mountain project.

The purpose of this particular meeting is to examine the current understanding of matrix and fracture flow in the unsaturated zone. As a consequence, I think that we've assembled the principals here to answer hopefully

most of the questions that will come up. You don't need encouragement, but please feel free to ask in whatever level of detail you need to.

Also, we would like to address some of the concerns raised by the State of Nevada and the NRC regarding characterization, conceptual and numerical models and I'm going to talk a little bit about our accelerated surface based testing program to address some of these issues.

The major points I would like to look at is that the large Barton Oliver hydrology program is directed to the unsaturated zone and correctly so with the accelerated program that DOE is now emphasizing.

I feel that the program as I've seen it -- I've been back on -- Let me give a little background -- I worked here from '85 to '86 under Max Blanchard and Dcn Beep, in the old days I guess you would call it, and the programs really changed dramatically.

I feel it's integrated and well coordinated and a good example of this is what we did recently on UZ-14 when we intercepted perched water. It really worked well. The various aspects of the geological survey program came into being in good interaction with the saturated zone people.

Another major point to emphasize here is that the success of this program is dependent upon our ability to sample and test in the field at multiple scales.

This is just a summary of the key issues that you would like us to address today. Looking at the mechanisms for infiltration in the unsaturated zone and can these mechanisms change in the future due to climatic modifications.

We will also talk about some of the passive and active field tests and again look at the concept of scale, look at the current conceptual models considered, what are the interfaces between the site characterization and the performance assessment modeling, and what are the current results of some of the ground water age dates.

This outlines the unsaturated zone program, at least my concept of how everything is working here.

Mike Chornack is the section chief and he'll be giving an overview of the USGS unsaturated zone program and I'm sort of his alter ego on the DOE side.

Boval Bartson handles the site scale model and Ed Kwicklis does a lot of the process modeling and Ellen Flint will be talking to you about the infiltration, surface infiltration, matrix properties determination and then Al Yang will be doing the hydrochemistry and then Joe Russo will be talking about the long term monitoring program.

One of the keys here that you want to look at is our presenters -- well, first of all, let me show you how this program is integrated.

Larry Inn isn't here so I'm going to pick on him as a good example, looking at fracture geometry, you have the necessary information and then the source of this information and I won't go through all these. They're in your handout.

You can get an idea that we depend heavily on what's being done in the geologic side of the program, fracture intensity, looking at well information, as well as scan lines -- scan lines being just cross-sections on the surface, over pavements, looking at fracture density, et cetera.

Skip down to item number seven, looking at remote sensing as well and then spacial variance and fracture boundaries, looking at the mapping of pavements and again interpreting these scan lines and the fracture densities.

The idea of scaling I believe is of utmost importance primarily because it's the ability to collect the matrix and fracture data in the field and then being able to apply that and that really controls our modeling or directs our modeling activities as to what we can do with these models.

So as we proceed here today with the number of the presenters, keep in mind the concept of the scale that we're working at, whether it's a borehole scale or -- I've used the term cross borehole to determine that area away from any

influence of that particular borehole and this could be looked at from some work that Allen Flint is doing and then to the repository site analysis where everything ties together in our site scale modeling.

I would now like to discuss the surface base testing program and some of the reasons why we've had to speed up the process, some of the comments, et cetera, that we've received.

First of all, back in July of '89 in a site characterization analysis comment, it was suggested that we needed to look at the ventilation and the effects on the ventilation and our ability to do testing and this should be done before construction of the EFS and we should provide an analysis and the effects of the ventilation on adjacent rock, including both liquid and gas flows.

Our response at that time was based on another design and so basically right now this particular comment does remain open but we are working on it and trying to bring it to closure and Mike will be talking about some of this.

Another comment is based on what evaluation is to be made on the potential for air movement from ESF to adversely impact the collection of geochemical data necessary for site characterization, and again this and the other one are very similar and is under evaluation and Mike

should be able to address that a little later.

In the letter from Carl Johnson to the NRC in February of 1993, there was a concern about the continued priority assigned to the early excavation of ESF and suggests that the current schedule may be an inadequate characterization to support the performance assessments, and there were some recommendations as to delay the tunneling.

Our response is that the schedules is under review and we looked into doing an answer to the space data acquisition program. We worked very closely with and of course took the technical recommendations from the U.S. Geological Survey.

We are looking at establishing baseline conditions in the unsaturated zone, implement this pre-ESF disturbance and accelerate the test program to look at baseline conditions within or close to the repository but far enough away from construction and then develop and implement the similar test programs along the alignment of the proposed ESF excavation.

The program we looked at here, and this is in your handout as well as the overall schedule for FY94 and the out years.

Essentially what we're looking at is doing pneumatic testing in two, four, five and six, and then as UZ-14 becomes available go in and do the similar work in

that as well as go into the monitoring program.

This outlines the accelerated surface based testing program as it stands right now and the schedule is not going to change. It's the position of DOE that any changes in this is more like a slippage.

If you take a look at this, the flags show when the TBM would come tumbling through this particular area, whether it be 2-B, NRG-5 or 6.

With that, I'll turn it over to April Gil.

MR. MOELLER: A quick question. We saw that same slide yesterday and it always shows down at the lower righthand corner two different versions of the proposed repository area. What I'm talking about is this little -- you see the lower righthand corner of your figure?

Apparently there are two opinions about whether the repository area would extend out or cut off.

MR. DLUGOSZ: No, no. This is preliminary. One of these is going down into another ramp, going down potentially into the Calico Hills.

MR. MOELLER: The dashed line then is not an outline of the reaches of the --

MR. DLUGOSZ: No. This is the proposed repository boundary right here.

MR. MOELLER: Which one applies?

MR. DLUGOSZ: This one right here.

MR. FLINT: He's asking whether or not this is the boundary or this is --

MR. DLUGOSZ: No, that's just the potential repository boundary.

MR. FLINT: He's asking what is this dotted line.

MR. DLUGOSZ: I'm not sure on this particular one.

MR. MOELLER: I was troubled as to whether a decision had recently been made to make it bigger or make it smaller.

MR. HINZE: Joe, before you leave, could you give us a hand in looking at these diagrams. What are we looking at?

MR. DLUGOSZ: This does not make a very good Vu-graph. We had to work off of hard copies. Anyway, what we have is gas base testing in [illegible] B NRG-4 and NRG-6 and that will be followed then by the hydrochemistry testing after we do the air permeability testing.

Then we'll come back and look at the long-term monitoring program and as you go down below in NRG-6, and the long-term monitoring program will be discussed by Joe Russo.

MR. HINZE: What's the difference between the blue and the orange or red or whatever?

MR. DLUGOSZ: The red basically is the gas phase that's being accelerated at this particular time to make

sure we get this data prior to the passing of the TBM.

MR. HINZE: What is the red?

MR. DLUGOSZ: That's the red.

MR. HINZE: The accelerated?

MR. DLUGOSZ: Yes, that's the accelerated aspect. The boreholes that we feel are crucial that would get that information up front, and Mike will talk about this in detail.

MR. HINZE: April, your discussion is going to be concerned with the regulatory issues, is that correct?

MS. GIL: Yes, Dr. Hinze, that's correct and I don't think I need a microphone. I've never been accused of being shy or not being able to project.

My name is April Gil. I'm a geologist and I've been associated with this project for about four years, three years with SSC and with DOE for two years. I worked in the regulatory and licensing branch.

What I would like to do is just give you a briefing on the regulatory framework for the work that's going on on the unsaturated zone studies at DOE.

The repository regulations include 40CFR Part 191, which is the EPA's regulation, and this is the EPA's environmental standards for the management and disposal of spent nuclear fuel, high level and transuranic waste. It was issued in 1985 and it was remanded by the court in 1987.

The Energy Policy Act directed the EPA to issue standards for Yucca Mountain and, as you are aware, this is currently undergoing review by the National Academy of Sciences.

The second regulation is 10CFR Part 960, which is the Department of Energy's regulation. This is the general guidelines for the recommendation of sites for nuclear waste repositories. It was issued in 1984. It focuses on site selection primarily and we currently have a DOE task force that's been set up to consider if any changes are necessary to Part 960 in light of the NWPA amendment of 1987, the Energy Policy Act of 1992 and additional program changes.

The last regulation, 10CFR Part 60, is the NRC's regulation that governs the repository and that will be the focus of my presentation today.

The first requirement is the NRC overall system performance requirement which requires conformance with EPA environmental standards for radioactivity.

There are also subsystem performance requirements. This one states that the pre waste emplacement ground water travel time along the fastest path of likely radionuclide travel from the disturbed zone to the accessible environment to be at least 1,000 years or such other travel time as may be approved or specified by the Commission.

In general, the favorable conditions require that

a combination of the engineered barriers must provide reasonable assurance that the performance objectives for the waste installation are met.

There are a number of favorable conditions related to unsaturated zone hydrology. These include again 10CFR60 122(b)(7) which relates to the pre waste emplacement ground water travel time. and in 122(b)(8) specific items to the unsaturated zone which include low moisture flux, no fully saturated continuous with the water table, low permeability hydrogeologic unit above the host rock, a host rock which provides for free drainage and the climatic regime in which precipitation is a small percentage of the potential evapotranspiration.

There are also a number of potentially adverse conditions related to unsaturated zone hydrology. and generally they must be adequately investigated to determine the extent to which they are present and their impact must be assessed within the context of performance objectives.

Continuing with the potentially adverse conditions, in general the potential for human activity, natural phenomenon or structural deformation to adversely affect ground water flow.

In addition, these three listed here -- changes in hydrologic conditions that would affect the migration of radionuclides, changes from climatic changes and also ground

water conditions that would increase the solubility or the chemical reactivity of the EBS.

Also geochemical processes that would reduce absorption of radionuclides or adversely affect the EBS, ground water conditions in the host rock that are not reducing, ground water conditions that would require complex engineering measures and, finally, the potential for the water level to rise to the repository horizon, potential for perched water to saturate the repository or provide a faster flow path and, lastly, the potential for movement of gaseous radionuclides through the unsaturated zone to the accessible environment. Those are the potentially adverse conditions.

Now how is the Department of Energy implement project evaluating or assessment or evaluation of our compliance with these regulation?

Well, we have the geohydrology program which is composed of site investigation, modeling and approved study plans and this part of our program will be discussed in detail today.

Our study plans include those listed here. I've highlighted those related specifically to site unsaturated zone hydrology. Mike Chornack, the next speaker, will be discussing these in more detail.

MR. HINZE: Who is responsible for integrating all of this?

MS. GIL: Well, I would say that integration is the responsibility of all of us on the program, but more specifically it would be the WBS managers at DOE, so that would be Joe Dlugosz and also Claudia Newberry who will be speaking to you today, along with the PIs involved at USGS.

MR. HINZE: Are the M&O contractors involved at all in that?

MS. GIL: Yes, sir, they are.

MR. HINZE: What is their role?

MS. GIL: Well, the M&O has the responsibility for overall integration on the program. They also do a lot of work for us in planning, budgeting, scheduling and allocation of resources, so they work very closely with the WBS managers -- work breakdown structure managers -- at DOE as well as with the PIs at the USGS in performing that function.

MR. HINZE: So they track the activities and the progress and so forth?

MS. GIL: Yes, the planning, the budgeting, the scheduling of the work that comes in is part of the work that the M&O does for us.

What I've done here is just put together a couple of matrices that show you the favorable conditions and then on the next slide the potentially adverse conditions and this is just the relationship between those specific study

plans that address each of the favorable and the potentially adverse conditions.

Like Russ Stoddard would say, I have a magic decoder ring if you all are interested in the specific names of each of these study plans. I also have a listing of the status of each of the study plans if you're interested in the details.

In addition to the geohydrology program and the approved study plans that the PIs are working on, we also have our annotated outline process which I think is very helpful in letting us evaluate our compliance with the regulations.

Now we talked a little bit about the annotated outline process yesterday in the context of issue resolution and, as you can see, the issue resolution activities are linked to the annotated outline as we discussed yesterday. Many of the reports that will come out of issue resolution would be referenced in the annotated outline.

The annotated outline for license application would become the license application itself if the site is found suitable and the LA is submitted to the NRC.

Content in the annotated outline is specified in the NRC's format and content reg guide, or FCRG which you see on the lower right. The FCRG is linked directly to the regulatory requirement in Part 60 as are our site

characterization, design and performance assessment activities.

This I think gives you kind of an overall sketch of the annotated outline process and shows the relationship between the AO and the regulations.

So, in conclusion, I hope I've given you just a kind of a thumbnail sketch of the regulatory framework under we're workinn and an evaluation of our ability to meet the requirements that have been set up by the NRC. We've got our geohydrology program, and that's the focus of the rest of the presentations here today. And, in addition, we have our annotated outline process.

I might mention that Revision 2 of the AO went to the NRC staff in November, and the main focus of Revision 3 was Chapter 3 which contained the site description, the geology of the site. So we're anxious to get comments back from NRC staff on this draft of the AO.

MR. HINZE: Thank you, April. Let me ask. It is my recollection from yesterday that as a part of issue resolution that you have, one of the study groups is concerned with the disturbed zone and the ground water travel time.

Can you give us some insight as to where you expect that to end up? Not in terms of specifics, but is that leading to a topical report or is that leading to a

technical report? Those are obviously quite different. How is the process being done? What is the connection with the science that is going on at the site at the present time?

MS. GIL: Yes, Dr. Hinze, you're right. We've got an issue resolution working group set up to look at ground water travel time, and that was combined with the disturbed zone working group because they're so closely related.

As a matter of fact, we have a technical exchange planned with the NRC coming up in March on the ground water travel time issue. And as we talked about yesterday, there is some clarification that we need from the NRC staff on the definition of ground water travel time, the definition of disturbed zone, what's actually meant by likely radio-nuclide travel. So those are areas that we'd like to get together with the NRC and discuss common understanding, and also work that's going on at the center.

As far as planned reports, Claudia Newberry works with us at DOE and is on the working group for ground water travel time. Claudia, could you answer his question on what reports we're planning?

MS. NEWBERRY: Yes. It's my presentation later this afternoon. But we're planning a topical report for sometime later during FY '94. I think FY '94, maybe '94, FY '95. And we do have an exchange planned in March of next year, this fiscal year, to talk about it.

MR. HINZE: A topical report?

MS. NEWBERRY: A topical report.

MR. HINZE: You are coming up with your own definition of ground water travel time based on 69, 60 and so forth as well as the disturbed zone?

MS. GIL: Are we coming up with our own definition of ground water travel time based on 960?

MS. NEWBERRY: Our problem -- 960 we have difficulty in interpreting what it is we asked ourselves.

[Laughter.]

MS. NEWBERRY: So we're looking at possibly reinterpreting what we meant in 960, conveying that to the NRC, so that when they're looking at 60 they can take into account what we think ground water travel time ought to be.

MR. HINZE: Who is making this decision? What kinds of people are on this working group?

MS. NEWBERRY: We have technical people and we have regulatory people. I suppose regulatory people think they're technical, too.

[Laughter.]

MR. HINZE: Good for you. Does this include PIs that are currently involved in the program?

MS. NEWBERRY: We are consulting with some of the PIs. We do have representatives from USGS in the group, as well as the M&O who are concerned with the ground water

travel time issue.

MR. HINZE: We'll look forward to seeing that, and I suspect you'll look forward to completing that.

MS. NEWBERRY: Yes.

MR. HINZE: Questions? Paul?

MR. DAVIS: Yes. I personally have always been confused between potential conflicts between siting criteria and final disposal criteria. For example, you'll have the potential for gas leakage, you'll have that. How do you weigh that against a site that maybe does comply with the EPA standard but doesn't comply with your site --

MS. GIL: Yes. This --

MR. DAVIS: How do you view that?

MS. GIL: This is some problems with the differences in the regulations, and this is part of the reason that we've set up a task force to look at 960 in light of exactly what you're talking about with the changes that are going on with the EPA regulation to look at 960, which is primarily a siting regulation, to try to answer some of those questions.

Now, the task force has been set up and we are on schedule to have a plan out in January to look at the exact things that you're asking about: how are we going to reconcile the differences in 960 with 60.

MR. DAVIS: Or if there are remaining differences,

how do you decide the site suitability? Let's say, if I violate one of your conditions but I pass the EPA standard.

MS. GIL: Those are some of the questions that we're talking about that we're working on with the working group that's set up to look at 960, and some of the things that we're wrestling with. So I don't really have an answer for you right now. It's just something that we're looking at.

MR. DAVIS: On the other side of the coin, NRC will still have their potentially adverse conditions. That's probably not going to change. You could have potentially adverse conditions and still pass the EPA standard. How does DOE view that?

MS. GIL: Well, the NRC regulation is the -- I don't want to say the driving regulation, but it's the one we're focusing on now since Part 60 is the main requirement for the work that we're doing for license application. So I would say that -- although I know 60 has undergone, I think, 13 revisions since it was first issued.

So we need to come to some kind of common understanding and finalization with these regulations and hopefully in the near term.

MR. LEAP: This is an off-the-cuff question and maybe you don't have an answer to it.

MR. HINZE: Grab that mike, we can't hear you.

MR. LEAP: I'm Darrell Leap. I want to ask, is the styles in your travel time in the eyes and minds of the DOE really realistic? It's been changed. In this current state of knowledge, is it realistic, do you think?

MS. GIL: I don't know if I'm the right person to ask that of, Darrell. Would somebody else care to answer that? Mike or Joe, one of our hydrologists? Is the 1000 year travel time realistic?

MR. HINZE: Perhaps we'll be in a better position at the end of the day.

MS. GIL: Perhaps they'll come up at the end of the day. Sorry.

MR. HINZE: Further comments or questions? If not, we'll turn to Mike and we'll look at some of the slides.

MR. CHORNACK: We seem to be a little head of schedule. We'll just go ahead because having -- listening to talks by the next three presenters after me, some of us tend to get a little behind.

MR. HINZE: Don't mention any names.

MR. CHORNACK: I won't mention any names, and miracles still might happen. This is the right season for it.

Anyway, I'm Mike Chornack. I'm the Unsaturated Zone Section Chief for the Unsaturated Zone for DADO

studies. I have to apologize for the sort of pink shades of my overheads, but that's all I could find in the copier room when I went to make them.

[Laughter.]

MR. CHORNACK: But I guess it sort of fits the season. It's too bad I couldn't find green, also.

Both Joe and April said I'm going to talk about a lot of things that I didn't know I was going to talk about in this overview. I'm going to try to make the overview as brief as possible because I think we really want to get into talking to the technical people because those are the people who are going to present some real data for us.

But as my introductory slide says, I'm going to present an overview on the unsaturated zone studies at Yucca Mountain.

And April has already shown this, this is basically the breakdown of the -- starting at the top of the geohydrology program, broken into regional hydrology, the site on saturated zone hydrology and also the site on unsaturated zone hydrology. And today we're talking about the site unsaturated zone hydrology.

Being composed of all these various study plans, the U.S. Geological Survey is responsible for all these study plans except two. Unsaturated zone infiltration is Alan Flint, water movement tracer tests is a Los Alamos

study. June Fabrica-Martin is the principal investigator on that. And Alan will be speaking today.

On saturated zone percolations, service based studies is Joe Rousseau, and he'll be speaking also. The unsaturated zone percolation studies in the ESF, I will be talking on later. And the ESF studies, right now we're primarily right now we're in the planning stage. As you all know, we've just completed the starter tunnel and we're in the process of mining our first alcove. We expect to do some serious testing sometime later on this fiscal year, possibly as early as January or February of 1994.

The diffusion tests and the ESF is another Los Alamos study that June Fabrica-Martin is the principal investigator for. The unsaturated zone gaseous phase movement studies, we won't have anybody talking about these studies today because, unfortunately, there are a lot of individuals involved in these studies. Because of the work schedule, we can't get everybody together at one place at one time. But the gaseous phase movement studies are involved in studying the natural circulation of gas and water vapor at Yucca Mountain.

We've got a couple of people from the research program, Ed Weeks and Don Forstensen, who are assisting us on this study. The principal investigator for that is Charlie Peters with the U.S. Geological Survey.

The unsaturated zone hydrochemical studies, again, Al Yang, and he'll be talking on this later on today.

And last we have our two modeling studies, fluid flowing on saturated rock and lastly, which is more of a site scale -- small scale fractured rock studies. This study really supports a lot of our ESF studies because we'll use the fractured rock modeling to do -- both to plan some of the tests and also to help analyze the results of tests, some of these smaller scale fracture modeling activities.

And the last is our -- we're also involved with the Lawrence Berkeley Laboratory, which is also doing work under this study plan. And lastly is the site on saturated zone modeling and synthesis. We'll have two individuals speaking on this today, both Ed Kwicklis with the U. S. Geological Survey and later on Bo Bodvarsson with Lawrence Berkeley Labs.

Basically, what we're doing is -- all of these studies are feeding data eventually to the site scale. They use the site scale model. So what we use, it's sort of an interim process, we feed data to the models, then the models get back to us and tell us if we're giving the right kinds of data or if they need more data.

Really briefly, this is a cartoon of the stratigraphy at Yucca Mountain. What we've done is we've made them two different types of units. We have our

stratigraphic unit, which is basically a lift-off stratigraphic unit based primarily on eruptive histories.

The column on the right is a geohydrologic unit and these are rocks that are composed of ash flow and ash flow tufts that have similar hydrologic properties. Basically, the difference between these are, we have the welded units and then the non-welded units.

In the welded units, flow is dominantly through fractures because it's very, very low permeability. In the non-welded units, it's the opposite. Flow primarily occurs through the matrix because these units are -- because they're not as welded they don't tend to fracture as readily as the welded units. So in the non-welded units, it's matrix-dominated flow; in the welded units, it's fracture-dominated flow.

MR. HINZE: Mike, does the fracture also include faults?

MR. CHORNACK: Yes. We include faults with fractures, yes. And as we know, if there are faults -- well, let me just elaborate on that a little bit more. But we'll all have an opportunity to see this tomorrow when we go out in the field. We'll actually visit some of these out-crops and look at some of these features.

Primarily we have two types of fractures in the welded units. We have cooling joints, because these are ash

flow tufts and as they cool sometimes they tend to develop joints. We also have what I like to refer to as technologically induced fractures.

Now, what's interesting about the stratigraphic or the hydro-stratigraphic column at Yucca Mountain is where we have fractures in the welded material, the fractures don't tend to propagate through the non-welded material. The fractures tend to die out either at the contact or very shortly into the underlying non-welded material.

So what you have, you have the opportunity for water that's moving down in fractures, where the fractures terminate we tend to get a buffer or a barrier to a rapid flow through the non-welded units. But as you know, faults -- there are some fractures that propagate through the units and obviously faults go through the whole stratigraphic column.

But even faults in the non-welded units, because they are non-welded we tend to develop a clay gouge and a lot of filling in the faults and fractures in the non-welded unit that tend to impede the rapid downward movement of fluid, or the upward movement of vapor and gases in these units.

MR. HINZE: Is that a generalization or is that --

MR. CHORNACK: That's a generalization, yes. But

from what we see in both war hole conditions and also from surface mapping, we find that it tends to be a fairly good generalization for these units.

MR. POMEROY: That statement that you just made, where you said "it tends to be," that bothers me a great deal. Could you elaborate on it?

MR. CHORNACK: Well, in geology nothing -- I mean you can't -- a lot of times you can't make a statement and claim it holds true for everything. So there are some exceptions to these rules. I mean I don't think I can elaborate on it more than that.

MR. HINZE: I think one of the concerns that I would have is how this mapping has been done. Most of your holes are vertical and, therefore, you're having a hard time intersecting the holes in both the welded and unwelded units and it's difficult to observe these in outcrops.

MR. CHORNACK: It is, and maybe I should add to that that these -- maybe the statements I just made are from my own observations at Yucca Mountain because I have done quite a bit of field work at Yucca Mountain. These are based primarily on surficial features where we do have primarily -- we have a lot of exposure. We see this Tiva Canyon welded and the paint brush non-welded unit. There's quite a few exposures with that at the surface, and based on observations at these outcrops that's why I make this

statement.

MR. HINZE: That's something that I would hope perhaps tomorrow, if there's any chance, we can --

MR. CHORNACK: Yes. That's one of the stops I have. We've got an area where we'll look at the upper TSW, Topopah Spring weld and we'll walk up to this non-welded unit and see the base of the Tiva Canyon welded. So we'll be able to actually observe these things out in the field, and then you can question me all you want out there and we'll be able to actually look at the rocks.

MR. HINZE: Well, presumably, this will also come up in the further discussions today, too.

MR. CHORNACK: Yes.

MR. POMEROY: Mike, just let me state a reason for concern here. I hope we're going to hear a lot today about the uncertainties involved in that determination of that travel time compliance. And I hope that we'll hear some discussion of whether there are possible fault paths or fracture paths that could run these non-welded units. And so --

MR. CHORNACK: Yes. That will be brought up in some of the following talks.

MR. POMEROY: Okay, fine.

MR. CHORNACK: Unfortunately, I have to move this around. I can't get it all on the overhead at one time.

This is a cross-section, a generalized, not-to-scale cross-section of Yucca Mountain. Basically, what I've done here is overprinted the various unsaturated zone studies. In the case where they're U.S.G.S. or Lawrence Berkeley PIs worked on the study, I've listed thee names by the studies. In the case of the water movement and diffusion tests where it's Los Alamos, I haven't put the name of the principal investigator, but her name is June Fabrica-Martin.

What I'd like to do is go through very briefly and give a very, very brief overview of what these studies are and some of the questions we're trying to answer in these studies.

I'd like to start from the top and work down. I've got this rain cloud here and that's just to show that we do indeed get precipitation at Yucca Mountain and we do indeed get runoff and infiltration and exfiltration from Yucca Mountain.

The study that supports -- we have our meteorological study that supports the -- we're doing the characterization for the meteorology for site and regional hydrology. The principal investigator for that study is Alan Flint.

What we're looking at is present day climatic conditions, both the amount and the variability of rainfall

at Yucca Mountain. It gives us some initial flux boundary for the natural and infiltration studies, which sort of leads right into the shallow UZ study, which Alan Flint is also involved in.

This consists of three separate studies. The natural infiltration study, where we're looking under the present climatic condition what happens to rainfall, precipitation that lands on the surface of Yucca Mountain.

The second study is the artificial infiltration study. And by this we're going to simulate a wetter climate condition principally through ponding experiments, and also ponding experiments and artificial rainfall simulation experiments to see what happens to the infiltration rate under an assumed wetter climatic condition.

The last activity under this study is the characterization of surficial materials at Yucca Mountain. Basically, what we're looking at is the hydrologic properties of the surficial materials, both unconsolidated materials, soils, alluvium, colluvium and also bedrock outcrop at Yucca Mountain. By this whole study we hope to produce an infiltration map for Yucca Mountain.

MR. STEINDLER: Do you have some reasonably recent analysis on the chemistry on the rain as it's currently --

MR. CHORNACK: Yes, we do. And I believe Al Yang will talk about that, or he can talk about that later. But

we have collected rainfall samples both for -- to look at the spacial distribution of the rainfall and also for chemical analysis of the rainfall, both summer and winter precipitation.

MR. STEINDLER: Are you able to make any estimates of what the chemistry of the rainfall was, a short time prior or a longer time prior to the present?

MR. CHORNACK: Al is shaking his head no, so I'll have to agree with him on that. I'm not sure.

MR. CHORNACK: How would you relate the impact -- but you have chemical impact of the -- okay, so you understand the question.

MR. CHORNACK: Yes, how we relate the rainfall of different chemistry, how would that affect the infiltration characteristics of that rainfall. Alan, any feel for that?

MR. FLINT: Well, we know that there's some difference in the chemistry from storm tracks. We know that in historical times there were differences in oxygen-18 diliterium ratios. And some of that information Al Yang will talk about and we can use that for winter versus summer types of precipitation. But as far as looking at long, long term, thousands of years ago trends in rainfall chemistry, that's something I don't think any of us have looked into.

MR. CHORNACK: Okay. The next -- if you go by WS numbers, the next study is the water movement tracer test.

Again, this is the Los Alamos National Lab study, and it's June Fabrica-Martin. She's primarily looking chlorine 36, primarily balm pulse chlorine. She gets samples both from deep bore holes and also shallow bore holes, and she analyzed this for chlorine 36 to look at basically infiltration times and ground water ages in both the shallow and the deep unsaturated zone.

I've got a representation of a fairly deep bore hole with a very crude derrick on top of it. Most of our bore holes, the deep bore holes are drilled as part of the deep UZ percolation study. The principal investigator for that and the project chief for that is Joe Rosseau, and he will talk more on this later.

But, basically, under the deep UZ percolation studies there are three activities. One is the matrix-hydrologic properties testing. This is a study whereby we take our core samples back to the lab and we, as the study plan says, test for matrix properties, both physical properties and hydrologic properties.

This testing is done at the hydrologic research facility that we'll visit tomorrow, and we can get a more in depth look at what they do there.

The other study is the Solitario Canyon horizontal bore hole study which is off for some time in the future. That's basically a horizontal bore hole drilled from the

surface in the welded Topopah Spring.

And one of the major features is to look at because the majority of the fractures are nearly vertical, by drilling a horizontal bore hole, be able to intersect a lot of these features and get maybe a good idea of what the fracture frequency and the characteristics on these high angle fractures are.

MR. HINZE: Is that going to be discussed, Mike?

MR. CHORNACK: I don't believe Joe is going to talk about that? Joe?

MR. ROUSSEAU: I don't have any plans to discuss that program.

MR. HINZE: The reason I ask is I'm wondering, according to the maps we've seen there is a drift schedule to go to the Solitario. Why the drill hole program and how will that complement the drift into the Solitario?

MR. CHORNACK: Well, a second use for the horizontal bore hole would be to also emplace long-term monitoring instrumentation in that bore hole to look at changes in water contact, water potential, and things of this nature in that bore hole also. So in addition to getting the fracture information, I said there would be some long-term monitoring, similar to what Joe will talk about for the vertical bore holes.

But it's planned for way off in the future. Joe?

MR. ROUSSEAU: Let me clarify it a little bit because that program was put together before the ESF was in its present configuration.

MR. HINZE: That's why I'm asking.

MR. ROUSSEAU: Right. There were no provisions at that time to do anything in the Solitario Canyon with the shaft design concept.

MR. CHORNACK: So there's a chance it could drop out of the program in the future, I guess.

Okay. The last, the activity that we're actually pursuing now in this program is the deep UZ bore hole drilling and testing program. Basically, what we're doing in those bore holes, and I'll go through the sequence of activities, when we drill a bore hole, even though there is one principal investigator project chief, many, many people get data out of that bore hole and get access to that bore hole to use it. As I mentioned earlier, June Fabrica-Martin got chlorine 36 samples out of our deep bore holes.

But just going through the sequence of the testing activities, after the bore hole is completed, Al Yang, under the UZ hydrochemistry program, goes in and basically pumps the bore hole until he thinks he's got all of the drilling induced, atmospheric air out of the bore hole. Then he collects samples of both gas samples and also water samples for an hydrochemistry analysis.

Next, Gary LeKane, who's the principal investigator for the air permeability testing studies, goes in, and using a Paco System he does air injection testing at various intervals up and down the bore hole to look at fracture permeability in the bore hole.

Lastly, Joe Rosseau will come in and he will semi-permanently install his bore hole, long-term bore hole monitoring instrumentation in the bore hole. Joe will talk about that a little bit later on today.

There was some talk about the gaseous base circulation studies. And as I mentioned earlier, Charlie Peters is the principal investigator for the USGS. But we're getting excellent support from some people from the National Research Program, both Ed Weeks and Don Thorston, on the study.

Basically, what we're doing here is looking at the natural, topographically and barometrically induced air flow in and out of air holes that have been drilled in Yucca Mountain. We're looking at the physical characteristics of this flow, the temperature of the volumes, the relative humidity of the air coming out, and also looking at the isotopic signature of a lot of the gases to try to determine at what age, at what depth this circulation occurs.

We're only studying this phenomenon in the presence of bore holes. We have looked for areas where we

thought there might be this naturally occurring circulation occurring out of natural fractures, faults and things of this nature. As of yet we've found no areas where this is occurring. So it's strictly in the presence of bore holes where you see this activity occurring. Unfortunately, there will be nobody speaking on this today.

I'll go to our ESF studies, exploratory studies facility. Again, Los Alamos. June Fabrica-Martin has the diffusion test in the ESF. And then for the USGS, we have our ESF testing on which I'll go into more detail later on today.

Basically, we haven't done any active testing in the ESF since we're still waiting for completion of the testing facilities. But, basically, we've got a series of studies, some that we call construction phase studies that are planned to be done while the tunnels -- while the ramp and the tunnels are being constructed. Then we have some post-construction main test level studies that will take place after the loop is completed in the underground facilities that are mined out exclusively for testing. And as I said, I'll talk more about these later.

And then we have our two modeling activities. As I said earlier, they use fractured rock, which is sort of a small scale fracture modeling which supports a lot of the ESF testing, and then the larger site scale modeling.

MR. POMEROY: Mike, can I interrupt you there for just one minute?

MR. CHORNACK: Yes, sir.

MR. POMEROY: Can you tell me a little bit about -- you have modeling people working on specific models. How does the data flow here work, not only to those people but also from the data to the TSPA people and from the modeling people back to the TSPA people?

MR. CHORNACK: I think we've got a real good system. First of all, we all -- at least within the USGS Unsaturated Zone and some of the other laboratories, we conduct fairly frequent -- we try to conduct quarterly modeling meetings where we present data and we get a lot of feedback. We work real closely with our own modelers, Ed Kwicklis, Larry, Anna, and the people doing the modeling at LBL under Bob Bodvarsson.

Maybe I should let Ed or Bo talk a little bit more on this, how our data flow goes. Would you care to, Bo or Ed?

MR. KWICKLIS: I think it's going to come out in the course of the day's presentation.

MR. POMEROY: If it's part of today's presentation, fine.

MR. DAVIS: I want to know, are you talking about the models that are actually going to be used with

performance assessment or for analyzing travel time, or is this a detailed level of modeling that will be simplified later for uses?

MR. CHORNACK: Ed? I missed the question, I'm sorry.

MR. KWICKLIS: The latter.

MR. CHORNACK: The latter. Not ladder, latter.

MR. HINZE: Let's make certain we have that connection at the --

MR. CHORNACK: I think we will. Bo will elaborate more on that in his talk.

MS. GIL: Mike, just a second. Claudia Newberry is going to talk about the integration of data collection in the modeling. So, hopefully, some of your questions will be addressed during Claudia's talk later this afternoon.

MR. CHORNACK: I think that just points out how integrated we are, that we all back each other up on these subjects.

[Laughter.]

MR. CHORNACK: Of course, you don't want to see us behind closed doors, though.

Last, this is just a logic program of the geohydrology program. Obviously -- and is the ultimate geohydrology program. As in the other block diagram, we have the surface water, the unsaturated zone and the

saturated zone. Basically, it shows the parameters we're looking at and the studies we're doing here and how they feed in to support the various sub-models in the site unsaturated zone model.

I don't have a summary because I'm sure all the various presenters are going to summarize their own data. I'd hate to say something they won't back me on.

MR. HINZE: You best not.

[Laughter.]

MR. CHORNACK: With that, I'll open it to questions.

MR. MOELLER: I had a general question. You work for the USGS?

MR. CHORNACK: Yes, sir.

MR. MOELLER: And the work you're doing here is what, a subcontract or a contract to DOE?

MR. CHORNACK: It's an inter-agency agreement.

MR. MOELLER: Inter-agency agreement.

MR. CHORNACK: Yes, sir.

MR. MOELLER: Well, how much independence do you exercise in terms of the work you do?

MR. CHORNACK: We are very independent and I think that's going to come out in the talks. As far as the science and the actual -- our studies at Yucca Mountain, except for working in the constraints of quality assurance

and the safety constraints, we're pretty much free to do -- pursue it as we see, following the outline of the SCP and the various study plans.

Now, the study plans go through quite a lengthy review process, and we've got study plans for all the activities. They go through an internal review, DOE review, and eventually have to get approved by NRC. So within those guidelines, within the guidelines that we outline basically for ourselves and get general agreement upon, we have quite a bit of flexibility and freedom to our work.

MR. HAYES: Could I add to that? There is a written agreement that DOE has with all technical participants. I believe it's AP 1.3, but I may be wrong in the number. My name is Larry Hayes and I'm with USGS.

That agreement says when a technical participant sends a technical report into DOE for DOE policy review, that if there's a technical dispute the originating technical organization will put the report out as that technical agency sees the situation, with perhaps an alternative view from DOE. But DOE has acknowledged that each technical participant must have freedom to say this is how we view the situation, and that can't be changed.

MR. DAVIS: On the other side of that coin, ar you free to go out and investigate the concerns raised, say, by the State of Nevada?

MR. CHORNACK: Yes. Maybe I should elaborate on that a little more. We've gone into sort of an accelerated surface base testing program. And as I believe Joe pointed out earlier, based on a letter that Carl Johnson had written on concerns of not collecting pre-ESF background data, particularly on some hydrochemistry data and also gaseous base circulation data, that the natural movement of air in fractures primarily in the welded units of Yucca Mountain; based on these concerns, the USGS had -- basically came out and we said we agree a hundred percent with Carl Johnson and we would like to collect this background data.

Then through discussions with Department of Energy individuals, we now have this accelerated surface base testing program where we're basically trying to get some bore holes in the near vicinity of where the ramps and the main north/south drift is going to go, to try and collect some of this background data before the area is disturbed by the mining of the exploratory studies facility.

MR. HINZE: I'm somewhat confused by this accelerated surface base testing. We hear all the laments about the amount of funds that are available. Does this mean that some other part of your specific program is being delayed, and how is it being accelerated?

MR. CHORNACK: I guess by accelerated I mean we've accelerated that aspect of our surface program to collect

this specific data, although it's data that we would eventually go and instrument these bore holes anyway.

We have, let's say, the order in which we're instrumenting some of the bore holes has been changed a little bit to collect this background data. But it's something we have to do to enable us to get this undisturbed in situ type data before the construction of ESF.

MR. HINZE: So there's sufficient elasticity in the funds available in your program so that you can accelerate without de-accelerating some place?

MR. CHORNACK: Right. Well, the unsaturated zone, the USGS unsaturated zone studies and a lot of studies, we have programs both at the ESF and also at the surface. And depending on who you talk to, whether they have ESF studies or surface base studies, they're going to say, you know, they might complain about their part of the program being hurt by the other. But, in general, I think right now we've got a fairly balanced program.

I think that our testing schedule, Joe Rosseau has done a very good job on planning his instrumentation program in the deep bore holes to where he's built enough flexibility into his program to where he can accommodate these minor changes in the sequence in which he instruments his bore holes.

MR. HINZE: Larry?

MR. HAYES: Larry Hayes, USGS. Since I get involved in the overall budget process, I would like to add to what Mike said.

There is a limit to the amount of money. When one accelerates one activity, it is done at the expense of something else. That's a fact of life. The way the project funded technical activities this year, it was based on ESF construction. Anything that needs to be done to support construction was funded.

We had irretrievable loss of data. Any type of data collection activity, if we stopped that data collection activity we no longer would have an opportunity to collect those data. Those sort of things we're funding.

Then we have what we call site suitability studies. Most of what you'll hear today fall into the realm of site suitability studies. Some have higher priority than others based on ties to certain things, such as collect data before the ESF construction gets ahead of the data collection.

So some areas were sacrificed to some extent in order to accelerate the ESF type data collection program. Some examples are the climate program, was significantly reduced, although DOE did help us find some money for the climate program in the end, although not as much as we would have liked. Tectonics program --

MR. HINZE: Is that the field program?

MR. HAYES: That's the field program. I'm talking about the field program. Mainly what was, I think, sacrificed were those things that are supported or supporting the surface base testing program. Because of the very touch schedules we're facing on the ESF, technical activities that support the ESF or vice versa, were funded adequately.

Some of the other things, some of the surface base programs that perhaps we can delay and catch up on next year were to some extent sacrificed. Some of the tectonics programs, some of the climate activities, mineral resources a little bit, those sort of things that when you have to make these tough choices, because there's simply not enough money, some of those things did not get funded to the extent that both DOE and the technical group would have like to have seen. But the hope is we'll catch up on those later.

MR. STEINDLER: I was going to ask what's your principal means of publication of two things, data and conclusions?

MR. CHORNACK: Within the U.S. Geological Survey we have basic data reports, open file reports. And then since we're in the Water Resources Division, anything with interpretation would come out under -- well, we also publish journal articles, and also in various meetings like the high

level nuclear waste management and the various other GSA/AGU, those types of journals. But then within the survey it would be the Water Resource Investigation Reports that would contain conclusions, not just data.

MR. STEINDLER: What's the delay between formulating conclusion or having the complete data package and it sees the light of day?

MR. CHORNACK: I'll let my branch chief answer that.

[Laughter.]

MR. CHORNACK: I don't want to touch that one. I've got a ways to go in the organization, I hope.

[Laughter.]

MR. HINZE: I already have an answer.

MR. CHORNACK: Dave only has one year until he retires. He can say anything.

MR. HAYES: It has been a problem, for sure, getting out the data in a timely manner, getting the interpretive information to the public in a timely manner. It's been a real problem. We are working on some solutions.

For the data, one solution is a survey with concurrence from DOE, has set up a process this year where we scheduled a number of data submittals to what we call our local record center. Then within a certain time frame, and I forget what it is, ten or 30 days, somewhere in there,

those data are then sent in to Las Vegas to the central records facility and then are available to anyone who would want those data.

This was done in order to try to accelerate getting data out to the public, whomever that might be, State of Nevada, whatever.

On the interpretive reports, in order to try to get interpretive information out to the public in a more timely manner, the Survey and the Department of Energy have agreed on a number of products in 1994 which we call analysis papers. What they are is interpretive information based on whatever data are available.

We give that interpretation to DOE, it does have director's approval. It's not something the Survey is going to publish in a water supply paper or something else, and it's the publishing part that really takes a long time.

So what we'll do is have these analysis papers, limited copies, we'll give them to DOE, and, again, those are open to the public. Whoever would like a copy of those analysis papers, DOE can make a copy and send them out to them.

What we're trying to do is avoid this long delay of collecting data, collecting data, putting it into files, not seeing the light of day. We're trying to deal with this very long process of publishing. So through this process

we're going to try to address this very difficult issue you've brought up.

MR. HINZE: I suspect we'll come back to data and data availability later on today.

Paul, I think you were next in line here.

MR. DAVIS: As I understood it, the testing program that is preceding the ESF was to define the ambient conditions --

MR. CHORNACK: That's correct.

MR. DAVIS: -- what's the feedback between the two. And that is, if the USGS says we don't understand the ambient conditions yet, would the ESF stop?

MR. CHORNACK: That's a very difficult question, one that I probably can't address. I'm not sure if we said stop whether they would actually stop or not. I don't know if anybody here can.

MR. DAVIS: Would you continue or --

MR. CHORNACK: I --

MR. DAVIS: -- these conditions if you made that statement, what would happen?

MR. HINZE: I think we heard the answer to that yesterday.

MS. GIL: May I speak up?

MR. HINZE: April, please.

MS. GIL: That question was asked yesterday. Max

Blanchard was asked what would have to happen to stop work in the ESF. And he went through a number of conditions. Number one, if perched water is encountered at any time, ESF construction would stop.

He said there was another procedure, which I'm not intimately familiar with. But what he said was that any of the PIs or scientists working in the ESF could say, "Hey, wait. We need to stop here because I don't understand what the conditions are. We need more time before we go ahead with the TBM." It came up while we were talking about the TBM.

MR. HINZE: I think the answer is yes.

MS. GIL: So, yes, the answer is yes. Work would stop if any PI or scientist comes up with questions that necessitate the TBM to stop.

MR. HAYES: I want to add to that. I don't think any one scientist alone would be able to right then stop the TBM. I think the practicality is if the scientists see what they consider conditions that warrant stopping the TBM, they're going to have to take that situation to DOE, to their own management, make the case that the impact, the risk if we don't stop justifies DOE perhaps losing, I don't know, close to a million dollars a day.

We have to do this on a risk-type basis, not just "I see information I think I need." We're going to have to

stand up. The scientists, the technical community are going to have to very much take a strong position and say, "We have to stop, here's why we have to stop and here's the impact to the program if we don't stop." Then DOE is going to make a decision.

I feel comfortable that if technically we make our case, DOE will stop.

MR. HINZE: There's a mechanism but not a pull chord.

MR. HAYES: That's correct.

MR. DAVIS: Has the first step been taken in terms of saying what's the risk if I don't understand ambient conditions, and that's a --

MR. HAYES: Pardon?

MR. DAVIS: -- statement I can make without the data right now. What's the risk of not understanding the ambient conditions? I can say that now. Has that evaluation been done?

MR. HAYES: I'm not sure I could --

MR. DAVIS: Does USGS feel comfortable going forward with the program if the shaft just went ahead and destroyed that data?

MR. HAYES: No, we do not. We feel to meet the regulations, as were discussed by April, we have to understand the ambient conditions because we're talking

about pre-emplacement travel time.

MR. DAVIS: So now my question becomes a series of timing in terms of I would not think that just the collection of the data would be th. understanding, and is there a study that --

MR. HAYES: That is correct.

MR. DAVIS: -- published before the shaft goes forward?

MR. HAYES: Yes. In fact, you'll hear some from Bo Bodvarsson on the 229, the modeling he's doing, some of the work Ed Kwicklis is doing, that will provide us some of the analysis we need to help us assure ourselves that these data we've collected indeed are enabling us to understand the ambient condition. So we intend to analyze these data as we proceed --

MR. DAVIS: -- before the shaft goes forward?

MR. HAYES: Correct. You're absolutely right, just to collect the data and do nothing doesn't tell us anything.

MR. LEAP: I'm Darrell Leap again. I want to ask Mr. Chornack a question, back to the publications issue. Although you work with DOE and they help you find the funding, you're independent, you say, in your research. Are you also independent in your publications? Do you have to get clearance from DOE to publish any of this information,

data, or papers?

MR. CHORNACK: We generally get concurrence from DOE. We do send them a pre-publication copy. Normally at the same time we send for director's approval we send a copy to DOE for concurrence.

MR. LEAP: Now, in the case where you might have some serious disagreements between interpretations, between DOE and USGS, how would you resolve that as far as publishing? Could you still go ahead and publish this information?

MR. CHORNACK: I'm going to have to defer that to --

MR. HAYES: Okay. Again, I think it's AP 1.3. I'm not sure of the procedure number. But in that it specifically states if the Survey were to submit a publication to DOE, DOE were to disagree with that publication, we would elevate that dispute to my level, to the DOE management level.

Based on input from the technical side of the house, I would either agree to some resolution or I would not agree. But the document, the AP specifically states that I have the controlling decision, that if I decide what we said is correct, the Survey stands behind it, it will be published just as it was submitted to DOE.

MR. HINZE: I would like to mention to you, Mike,

that you're not as brief as you anticipated.

[Laughter.]

MR. CHORNACK: Well, I let Alan and Larry talk and they probably talked as much as I did. And I've used up all of Alan's spare time.

MR. HINZE: I think if you ever had a reputation, it's lost.

[Laughter.]

MR. HINZE: With that, we'll take a 15-minute break. We'll reconvene at twenty to.

[Brief recess.]

MR. HINZE: We'll come to order. I think we're finally underway. We are a little behind schedule, but Alan said it will come out of Joe Rosseau's time --

[Laughter.]

MR. HINZE: -- so I guess we're right on schedule. I guess there's no problem.

I am asked to remind you that we would very much appreciate it if you would sign it at the door some time during the day. And with that, Alan Flint will be discussing characterization of the unsaturated zone and filtration.

MR. FLINT: Right. I'll start up here. I wanted to point out one thing. This is Joe Rosseau's talk and this is mine. His is a lot thicker than mine is, although I do

have four slides per page.

[Laughter.]

MR. FLINT: Another thing is that my group often gives me a word that I'm supposed to work into my talk. The word was "rigmarole." It's too hard to do. If I could have gotten it into the talk, I would have gotten a free scotch out of it. Since I couldn't work -- I just did it in, so I'm okay.

[Laughter.]

MR. FLINT: We can turn down the lights. What I'm going to try to do is cover a lot of information with a lot of slides, very slowly. Actually very quickly.

The talk is characterization of unsaturated zone infiltration. These three study plans are what really cover most of what I'll talk about. The first one, characterization of surficial materials, characterization of natural infiltration, and characterization of artificial infiltration.

The matrix property testing program and the meteorological program also support the study that I'm going to talk about.

This is the site that we're working on. You're going to see this diagram in a different schematic when Bo Bodvarsson talks. This is the boundary of the site scale model, and you can also see the boundary of the potential

repository at Yucca Mountain. And you're going to see two different kinds of things here. One are the washes that are unique to the repository, versus the different kinds of washes we see to the north of the repository. And you'll see that show up from time to time.

MR. HINZE: What is the heavy line?

MR. FLINT: This heavy line that you're looking at here is the site boundary for the three-D site model, and that's the area that Bo will spend quite a bit of time discussing. But that's just to show you that we're going to be doing most of our work within this boundary for the first part of -- well, mostly for this year. And we'll extend beyond that for some watershed scale stuff later on.

The objectives of the study are to evaluate the past, present, and possible future net infiltration which we define as water infiltrating below the zone where it can be readily removed by evapotranspiration processes. That's not to say that it won't come back to the surface through large scale convective transport, but we're looking at simple evapotranspiration processes. Anything that gets below that zone we consider as net infiltration, not necessarily recharge.

We're going to get to this by evaluating the mechanisms and processes by which precipitation becomes net infiltration, assessing the spacial distribution of net

infiltration, assessing the temporal distribution of net infiltration, and then modeling that infiltration by using conditional simulations of precipitation, which was developed from the meteorological program and a site calibrated watershed model.

The approaches that we're going to go through to evaluate net infiltration will be seen in this diagram. And I'm going to come back to this from time to time to show you where we are and to kind of summarize what we've covered so far. So we will spend quite a bit of time in this area.

The first part would be to identify the field mechanisms that contribute to net infiltration. How does net infiltration occur? Second, identify the physical and hydrologic properties that influence net infiltration, that are necessary to produce infiltration maps, and to put inputs into flow models.

We'll talk about the soils contribution, we'll talk about the bedrock contribution. We'll then talk about a way to evaluate the methods to quantify net infiltration. Here are the mechanisms, the properties and then what is the net infiltration.

We use a water balance approach and we use 1, 2, and 3-D models. And then finally we're going to look at modeling surface net infiltration on a sit scale under varying climatic conditions.

So we're going to go to the first part: identifying the field mechanisms that contribute to net infiltration.

MR. STEINDLER: Can I --

MR. FLINT: Sure.

MR. STEINDLER: Not being in this business, if you can go back one slide, is the product of your exercise the second bullet -- the third bullet, second tick? In other words, are you aiming everything at the second tick?

MR. FLINT: This one --

MR. STEINDLER: Is that really what the focus is?

MR. FLINT: A lot of the work we do is to produce information that will be used for a model. Modeling is going to be an essential part of site characterization for a long-term study --

MR. STEINDLER: Modeling of what.

MR. FLINT: Modeling of infiltration into the mountain and modeling of water flow through the mountain. Water, as we understand it, is the most likely mechanism for radio-nuclide release. And so water flow is what we're after. So these 1, 2, and 3-D flow models, I'm going to show this in the talk, how we use these models to predict bore hole saturations and fluxes at various time scales.

MR. STEINDLER: And the experimental program is aimed at providing information for the flow models?

MR. FLINT: Yes.

MR. STEINDLER: Thank you.

MR. FLINT: So the first thing we're going to go through is we're going to talk about what are the mechanisms of net infiltration, how does it occur. And these studies are site specific. These are for Yucca Mountain and what we know about Yucca Mountain.

The things that we have to consider: one, we have a variable depth of alluvium; two, we have fractured bedrock, we have variable bedrock porosities underneath this alluvium, we have a variety of topographic positions, which provide differences in radiation loads, soil depth, slope, runoff and run-on; and then, third, the timing of precipitation. All considerations when we look at air/land hydrology, particularly at Yucca Mountain, we'll talk about these.

This is the site we're looking at, Yucca Mountain. This is the welded tuff on top. This is that non-welded paint brush tuffs, and then these are the welded Topopah Spring units, and this is a lot of the alluvial cover looking at the site from the west side of solitario Canyon.

This is an idea -- to give you an idea of the welded tuffs. This is the top of the Topopah Spring unit, welded unit. You can see some of the fracturing in here on the exposure of Solitario Canyon. This is a non-welded

unit. You can see some of these fractures at the surface, are strato-bound, like Mike talked about earlier.

You can also see some of the old fractures that were filled with carbonates that continued on up through some of the units but then also were strata-bound. So fracture that occurred when this was probably the old surface horizon. You can see the weathering at this location and you can see further ash flows on top of that.

The site that we're going to look at, this is about where the repository area would be, underneath an area about that big, on the site. So we're looking at these types of washes.

A little bit of information, we're in the northern Mojave Desert. We get more than half our precipitation in the wintertime as rain and snow. And we have a pretty good monitoring program to give us an idea of what the distributions are. We do continue to collect precipitation data for hydrochemistry analyses also.

The kinds of topographic conditions we're going to deal with through this talk, the major ones we have identified. The ridge tops have a certain kind of influence on the site. These are representative of bore holes. We have side slopes with different thickness of alluvium; terraces, which where old channels might have been or runoff events would leave sediments if we had large runoff events;

and then finally the active channel itself.

The data set that I'm going to present, we have two watersheds. One of them we refer to as erosionally controlled. That is, the patterns are dendritic in nature and they're controlled by the uplifted block and simple random erosional processes. That's one in the south. Another one is fault-controlled where the wash structure is completely dependent on the fault sets.

Eighteen neutron holes, six to 19 meters deep in each watershed, and those topographic conditions that I mentioned earlier we're going to consider. We have monthly readings of volume metric water content at .1 meter depth intervals for three years. So I'll show that data. So the data you're going to see is from our neutron monitoring program looking at near surface infiltration.

This is a neutron probe. This is one of the bore holes. We have a rain gauge collecting data from each bore hole so we know about how much rain we had at each location, and we log this on a monthly basis.

This is an aerial view with the points marked for some of the bore holes. This is the mouth of Pagany Wash. These are two bore holes as we go further up the wash. And we have a very detailed cross-section. We continue on up, one up on the ridge, and then finally at the head waters we also have some bore holes that we'll look at.

This is one of the ones over the fault block itself, some bore holes on the ridge, some down on some side slopes across the wash. Again, side slope holes, a wash hole, and then further on down. This is the site that Joe Rosseau may talk about, UZ 16, at this location.

This is an example of the kind of data we see in a terrace or a channel over the site. These are water contents with depth. This is barometric water content at different times of the year. What you notice in here is very little change, below about three meters.

In terraces and channels for the most part, we do not see penetration of water below these depths, most likely due to carbonates that are formed in layers that are stopping the flow, and also because of the high storage capacity and relatively low amounts of rainfall we get.

These are high porosity materials. The water is held up in the root zone. We do not see penetration most often below this depth and, therefore, this water is held near the surface where it can be readily removed by plants when ET processes pick up, if we were talking about springtime precipitation events.

So this is an important point. In terraces, channels and alluvium, very little water moves down deep.

MR. HINZE: Could that simply be a matter that you are not mapping this in fractures that carry the water?

MR. FLINT: This is all in alluvium. This is all in a porous material. So that's just to give you an idea of how these porous materials behave. And these carbonates develop because that's where rain moves to. You put a certain amount of water on certain porosity, it's going to go a certain depth and it's going to stop.

If it comes back up in vapor, it leaves the carbonates there. Carbonate layers form and now it works as a barrier. So when these soils were developed, these carbonate barriers existed. They still exist, and if you change climatic conditions dramatically tomorrow these carbonate barriers would still exist. It may have a major impact for a long period of time.

MR. DAVIS: Could you hold that a second? You're saying little flux, not --

MR. FLINT: You could have some flux.

MR. DAVIS: No change in moisture?

MR. FLINT: Well, you could have flux with no change in moisture content, but these are variable processes. This is not going to be in steady-state conditions. Under steady-state you can. Under transient-state you're going to have to have a change in water content.

MR. DAVIS: Do I have a pot of chloride with that there?

MR. FLINT: June Martin is doing some work on chloride. I do not have any chloride data. We do have tritium data. I haven't shown it here, but I'll show you what the tritium data would like. We would see high levels of tritium and then we would see this tritium come down and we would see it drop off, and it would drop out.

MR. DAVIS: And the chloride would have a bulge in --

MR. FLINT: I'm not sure what the chloride looks like. I know the tritium stops there. I think the chloride in the chloride-36 studies that they've done, the chloride is all up in the top. The problem with chloride studies, particularly chloride-36, is that it's very, very difficult to make interpretations about chloride if you're still in the root zone.

I think the chloride peaks that they've seen in other studies are in this kind of location.

MR. DAVIS: Okay.

MR. FLINT: If we look at a side slope now, this is the tuff alluvium contact, same depth versus water content. What we see in the side slopes is this increase in water content down to about 12 meters. Another area, we see increase in water content to five or six meters. This is the south facing slope. We get very little penetration because the water on contact with these fractures is not

there very long. It evaporates.

North facing slope, a lot longer contact. The soils stay wetter longer. We can get water moving down through the fractures and into the matrix. And I'm going to talk a little bit later about the fractures and what the character of these fractures are.

I don't think they're open fractures. I think they're filled and I have good evidence to show that. So we do get good depth penetration in these side slopes, but much greater than we see in the washes, and I'll show you what the volumes look like in a minute.

This is what we see at a ridge top site. Higher rainfall at these ridge tops, too. Penetration down maybe seven meters in this case. On this wash we see it at about 12 meters. Higher porosity material on this particular ridge top, lower porosity material here, but still pretty good penetrations.

The ridge tops at Yucca Mountain are generally the upper cliff unit of the -- of the Tiva Canyon, which is a high porosity material. So it has a high permeability on its own in its matrix properties, as well as having fractures.

This is a compilation of a data from a series of bore holes, whether they were in a channel, a terrace, side slope, or ridge top, between October of '92 and March of

'93. It's important to point out we had about ten inches of rain or .25 meters of water deposited on the site over the- - I think it was January, February and part of March. And these are the water content changes that we measured in the bore hole, so this is -- we're seeing wetting up.

The channel had the least amount of water in it when we made our measurements. It wet up the least, most likely because the water was held near the surface and evaporated and continually evaporated through that period when it was raining, evaporating; raining, evaporating.

As we move up to the terraces, a little bit more, probably not significant. And then ridge tops had the most water in them. They wet up the most because that water got down into those fractures and went deeper into the ground and did not get removed by a plant because we don't have plant roots down there.

This much rain, about this level. You can see quite a few have more water in them. That's because of run-on. Some of these sites were in smaller channels up on nearly flat terraces and water came from another location. So in addition to the ten inches of rain, we had probably two or three inches of run-on onto the site. And then some of these might be indicators of where we had the runoff coming from.

So what you learn from this, what we learn from

this is that the ridge tops have a greater volume change of water content because of the higher porosity material and because of some of the fractures. So the ridge tops and side slopes are very important, contrary to what a lot of people think about desert hydrology, in this particular case at this particular site.

This shows us what has happened over a time in a couple of different bore holes representing those channels, side slope and ridge top. We have water content, and this is for about 1200 days, since 1990. And what we're looking at is the water content of the top meter, one to two meters, two to five meters, and five to ten meters.

We had a very dry year in '91. We get a little bit of precipitation, increased the water content in the surface, back to some zero-point. Up again, down, up again. So we're seeing the surface wet-up. One to two meters, you can see it wets up, but you can see a lag. And then if you look deeper down in the system, in the channel, we don't see the water penetrate. So the water doesn't penetrate very deep. That's what this shows in a time series and it shows the delay of water moving down.

Side slope, same wet-up each time. But you notice we have a little bit faster response, yet it's a lower volume of water. So we're still holding a lot of water up in the side slope and near the surface.

Finally the ridge top. We don't see the response in this particular case, but as we get the big rainfall events, which is what we need to get water into the side slopes -- or into the ridge tops. These things all follow together very, very well. So we're seeing all this water penetrate quickly into the system and is uniformly distributed throughout that profile.

It's important to note that when we did not get a large rainfall event, we could not get water to flow into here. The two years that we're talking about were high rainfall events at a very short period of, in a couple of months. And that's what it takes to get some of this fracture flow movement.

Another way to look at this is using, rather than the water contents, just to look at the variability. All we did is for the neutron records for a year, 12 readings, we would take the standard deviation, or the variance in this case, and plot variance. So it tells you a little bit about change and incorporates -- or it gets rid of random variability in the instrument a little bit more than the other graphs.

This is simply -- nothing changing in this part of the profile indicates there was probably no water flow. And here is where we see all the water flow occurring, where we see the variance, thee highest. Side slopes, again deep

penetration. Ridge tops get deep penetration.

MR. HINZE: How far have you been able to trace these pulses? To what --

MR. FLINT: The farthest pulse we've been able to trace has gone down about 12 to 13 meters in the north facing side slope at a bore hole that's drilled down to a depth of about 260 feet. So we have quite a bit longer to go. That's also a bore hole which we have high chlorine-36 data down to about 14 meters also. So there's good support for the chlorine 36 data, that this was going on before the bore hole was drilled and that we're seeing the same process.

MR. HINZE: Is the limitation here the lack of bore holes? Do you have projects for any deeper neutron holes that would trace this to greater depth?

MR. FLINT: The bore hole depth that we have for some of these is actually deeper than any penetration we've seen. So the bore hole depth is deep enough for the most part. The limitation that we have is that we can't get drill rigs on the side slopes which cover -- probably 80 percent of the site are side slopes. And yet we can't put drill rigs there to get the core data that we need.

So we're doing a lot of surface measurements where we can go up there with small hand-held drills and getting core plugs and taking some other measurements using other

instrumentation.

MR. LEAP: Did I understand you to say that this is all matrix flow, there's nothing about fractures here?

MR. FLINT: No, those were fracture flows.

MR. LEAP: Fracture flows.

MR. FLINT: Fracture flows. I'll show you how the flow in the fractures occurs at the surface of Yucca Mountain. I think it may be different from what you've seen, or understand as a fracture flow.

What I want to show here is the -- the red is the depth of alluvium for this series of bore holes and the green is depth of variation. Simply note how deep the alluvium is and how shallow the variability is in the channel. It doesn't go very deep.

As the alluvium gets thinner, the depth of variation goes higher. There's this inverse correlation. The thinner the soils, the more likely you can get high saturations as the water moves down and contacts the bedrock, and the more likely you can get water flow into the matrix and into the fractures. So thin soils, mostly likely places where you might see net infiltration occurring.

One other bit of information, and that has to do -- these are all bedrock coals.

MR. HINZE: Isn't that just telling us that we've got a big sponge there and it's holding the water and it's

evaporating there?

MR. FLINT: Right. I couldn't have gotten rid of all these slides and just said that. I should have. But, yes, you're absolutely right. The thick soils with the carbonated layers hold most of the water. If we have thin soils, water gets down into the fractures.

The difference between the soils and the rock, because they both have carbonates in them, is that the fractures can flow water because of the way they were laid down in the fractures. And I'll show some diagrams of that.

Three types of bedrock, all exposed at the surface. A welded tuff, that's the yellow; we see some variation but not very deep. A not moderately welded, 20 percent porosity and fracture tuff; that's where we get our deepest penetration of water. Non-welded tuff, 30 percent porosity, no fractures; we get good volume, but we don't get much penetration.

So the rock type that's underlying the alluvium has a very important factor in controlling what happens when water gets through the alluvium. And that, I think, has a significant impact on where we might find fresh water bodies or other evidence of current day flow from past climatic conditions.

These moderately welded tuffs that are fractured may be some of the more important ones, although later on

I'll give an argument for these non-welded tuffs being good for past long-term climate changes.

Let's look at a summary of what we've figured out from the net infiltration processes in terms of just identifying these processes. Ridge tops have the deepest penetration of the wetting front and the largest increase in saturation. The movement of the wetting front is faster in the ridge tops.

The penetration is influenced by the timing of precipitation, the potential for runoff, the storage capacity which is influenced by the depth of alluvium layering and the porosity of the bedroom; and the occurrence of fractures in water potential or saturation when the wetting front reaches the bedrock.

If you have a fully saturated soil when it hits the bedrock, it can flow into open fractures. If it's not fully saturated, it's not going to be able to fill into open fractures. So that gives us an idea now of the mechanisms for infiltration.

MR. HINZE: Alan, you don't have type of precipitation there. Does that mean that essentially is the same as --

MR. FLINT: Well, the snow has a different behavior than rainfall because it stays on the ground for a longer period of time, it has more contact, and we can keep

water flowing for a longer period under snow melts. But we see about ten percent of our winter precipitation as snow.

So it's -- it may be an important factor under future climatic conditions and it probably, most likely will be an important factor because future wetter conditions will most likely be because of winter storms, not summer storms. But the snow does have an increase -- causes a significant increase in infiltration.

Okay. Now let's look at some of the -- the next part of the evaluation. So we looked at the mechanisms that contribute. Now we're going to try to do some characterization. What are the properties of the materials that we can identify at the site so we can start to map out where these processes would occur. And in particular we're now going to look at the soil material.

We're going to look at a two-dimensional horizontal analysis of the hydrological character on consolidated surficial materials or soils. So we're going to look at sort of a map view, what's happening in the top meter or less of the soils.

The environmental parameters are important to us, precipitation, solar radiation, net radiation, air temperature, soil heat flow, and evapotranspiration. And the soil parameters that are important, what are content and what are potential; the hydrologic conductivity, the water

retention functions, texture, porosity, in particular depth of restricting layer, and vegetation. So those are the things we're going to be looking at when we look at some of these surface soils.

Initial modeling that we want to do is looking at water content changes. We want to know why and can we model water content changes over time. It's the water content that's going to control how water is going to flow into the underlying bedrock or deeper down into the system.

So the change in storage of the surface is equal to the precipitation, minus the evapotranspiration, minus any runoff, plus any run-on, minus this drainage, the low field capacity. This drainage is estimated at this point, and we're going to later on, I'll show later some results of using a Richard's equation based sub-model to model that flow process. So once we get rid of water, what happens to the surface water, and that's what we're going to try to water.

To do the evapotranspiration model, which is the most important part because we measure precipitation, we use a very simple equation. The bottom line on this is the evaporation is controlled by, one, the net radiation, and then finally it's controlled by the water content of the soil.

When the soil is wet, the radiation controls the

evaporation. When the soil gets dryer, than the soil controls it. Even though there's plenty of radiation available to evaporate water, the plants can't take it up because the soil won't give it up. And so the soil controls it.

What we want to do is find out what is the controlling factor in the soil and what is it related to, so we can map it. Is it texture, is it the water retention function, is it porosity, something we can map.

Well, how do we do in making a model like this work? And that's what this diagram shows. This is soil water content of about the top half meter of a soil over 1500 days. These are our measured points from a neutron moisture at the surface, and this is our model. And you can see that these are a pretty good match.

We did pretty well, we had to have the two controlling factors. We had to know what the radiation loads were, which those are simple to model because we know the site geometry. And then we needed the soil parameters. We calibrated this one at a particular site, and I'll show you later, and we're working on this kind of modeling. What we want to find out is what soil property controls this.

To do that we set up a transects in a wash. These are those bore holes I showed earlier, and these are the locations of the three transsects that we dealt with in

trying to measure some soil properties. This is a diagram that shows from ridge top through the wash through ridge top again. You'll see this in the next couple of slides. Elevation. And this is that same transect that we looked at.

Textural information, just to show you that the sand content is high, 60 to 70 percent. And it looks pretty uniform. Clay also is pretty uniform, although at the ridge top we have a higher increase in clay, most likely because it's a more stable surface and has clay formations there. But basically textures are fairly uniform.

We look at radiation load. This is a role variable. We have three different times, June, August and September. If you look at September, very low radiation loads on the north facing slope. We get higher radiation loads as we get better angle of incidence to the solar radiation, and as the slope flattens of we get a decrease in radiation loan. Of course, in June it's pretty uniform over the site.

That's very important if you did it in the summer thunderstorms. But it simply says there's radiation geometry to be considered when you're doing modeling, and that you're going to have a difference in evaporation from these two slopes based purely on radiation load, and soil properties aren't going to matter.

Monthly variation in radiation versus water content in one of the locations in the channel. What I wanted to show in this diagram is here we have a precipitation -- water content, I'm sorry, in March, and it decreases fairly slowly as the radiation load is slowly going up. Same water content from a June rainstorm, dropped very quickly under high radiation load. So that it does show this influence of the radiation load.

The winter precipitation takes a lot longer to get rid of the water. A summer precipitation event, you can get rid of a one-inch rainfall in three to four days. It doesn't take very long with the high convective conditions that we have at Yucca Mountain.

Just to show you how this works very easily, this again is water content, and this is in June after a precipitation event. You see the large variability in water content in the nearer surface. In August, back to pretty much uniform water contents.

So we had to go from this location down to here. In the same time period we went from here to here, or here to here. That just shows that radiation controls it and the soil water content controls it. These soils which started out still fairly dry didn't change very much because the soil was controlling evaporation processes.

One of the things that we're trying to do now that

we know that there's soil control and radiation control, this is simply a diagram that shows a bulk density or a surrogate for porosity, which may be an important factor. It's a simple model or map that we're trying to make.

So at each of these locations anywhere within this watershed, we will use the radiation model to control most of what we need to know. And then we might use porosity as the surrogate for the soil controlling factor, or we might use water retention or something else. This is just a diagram to show a process of mapping that we're trying to do now.

MR. HINZE: Alan, could you go back to the last one for just a second? What depth is that at?

MR. FLINT: This is the top half meter.

MR. HINZE: Top half meter.

MR. FLINT: Right.

MR. HINZE: And this is after a storm event?

MR. FLINT: In June we measured the water content after a storm event, and you can see that this is probably a summer storm that was small and it wet up a lot of this part of the wash. We might have lost some water here, but I don't think we got very much rainfall in this part of the wash. I think the rainfall was more to the north of this particular site. So we got the edge.

But even though we have this large variability, it

all came to some uniform water content. And it's important because this is the water content that's going to be in contact with this rock for a long period of time.

Let's look at a summary of the 2-D horizontal, what we have learned. The most -- one of the main things, as you would have all guessed but I needed to say anyway, precipitation sets the initial distribution of surface water content. So rainfall controls how things get set up. The available energy controls evapotranspiration processes until the soil reaches some critical water content, and then the soil properties control evapotranspiration.

And, thirdly, the soil properties control the drainage away from strong evapotranspiration processes. If you have a very coarse soil, you get a lot of rain, that water is going to be moved away from the surface quickly and it's not going to evaporate. If it's held up because of carbonated layers like we see in the marshes, it will be held up and it will eventually go as evapotranspiration.

MR. POMEROY: Before you leave that completely, about 15 slides back you showed us --

[Laughter.]

MR. POMEROY: -- between modeling and measured values. And I believe the modeling was from an equation that you had on a previous slide which had runoff and run-on assumed to be zero.

MR. FLINT: Assumed to be zero.

MR. POMEROY: So is my assumption from that that either the run-on and runoff were essentially zero in the particular instance you were showing us?

MR. FLINT: In the instance, they were zero. And where we're working at now, and for the most part, we don't see evidence of surface run-on and runoff. There are a few locations where we do. And part of our studies that are being done with the Nevada Sub-District Office here in Las Vegas, they're setting up some runoff gauging stations, and we're starting to look at where we get runoff and run-on. So we're doing a lot of detailed work, and I'll show a picture of one of the ones that has been set up.

MR. POMEROY: Great. thank you.

MR. FLINT: Okay. So we did that one, right? Yes, let's go on. We've got enough slides.

I'm going to look at a one-dimensional and a two-dimensional analysis of hydrologic character. Horizontal analysis is pretty easy. Vertical gets a lot tougher. You need bore holes, you need exposures. But to do this vertical analysis, we have an objective.

One is to determine the hydrologic properties that we need for numerical modeling; again, numerical modeling is important, these desert alluvium. And then to develop a transfer methodology. It's a lot more difficult to move

this information around, and we have to come up with a way to do that.

There are five methods in this characterization of the vertical variability in soils, and I'll go through each of these five in very short form.

One, define the important properties. What do you need to know to model? Two, establish some methods for the field and lab to get that information, where you can use multiple sites, or multiple methods. Conduct field and laboratory measurements to collect the data, develop the transfer methodology.

In this case we're going to look at geophysics and soil properties. And then, finally, establish a modeling scheme that incorporates all of the field and lab data. We use history matching to calibrate the models. We employ some prediction for model verification. And we will also use inverse modeling to incorporate -- to evaluate some of the properties.

I will go through these five very quickly. Hydrologic properties needed for modeling: Unsaturated hydraulic conductivity, and moisture characteristic curves. And, if you are doing finite difference modeling, the boundary conditions are required. For short time periods -- if you are going to model a short time, you also need initial conditions. If you are doing long-term modeling of

thousands of years, the boundary conditions will set up the initial conditions.

What this says is you don't need bulk density, you don't need organic matter, you don't need porosity. All you need are water retention function and the unsaturated conductivity. But, we need the other properties to get at these because these are the hardest things to measure.

Number two. We have established field and lab methods. This is a handout you can read if you want to later. We are looking at moisture retention and different ways to do that -- pressure plates, water activity meters in the lab. In the field we can use our neutron probe data and tensiometers to get at water retention.

For the subsurface we are stuck with inverse modeling. If we want to measure saturated conductivity we can use texture in the laboratory as an estimate, or we can use the tempselmate direct measurements. We use an infiltrometer for the surface in the field. We do not really have a way to get at it in the subsurface. So, we use inverse modeling, moisture retention and, assuming Van and Octon function of Brooks and Corey.

We just set up a series of ways we are going to try to get at these properties we need for modeling unsaturated flow, using the Richards Equation base model.

MR. HINZE: How do you constrain that inverse

modeling?

MR. FLINT: The inverse modeling -- the way we try to use our inverse modeling techniques is that we will use -- for instance, there was a paper written by Zimmerman & Bodvarsson that talks about the influence -- or inverse modeling using sarptivity as a measure in which you are going to test your conductivity and alpha and end parameters for the Van and Octon function. We will use that technique with the measured value of sarptivity. We will look at those values. We will compare those values to what we see in the lab. Then we will go to another location, measure the properties in the field, use lab estimates, and then try to predict the sarptivity experiment that we used in the first one as our inverse modeling. And we go back and forth that way, between the lab and the field and the model, until, at any location, we can use any one of those techniques to be able to predict what the other measurement would be or the other model prediction would be. If we can't successfully do that at the end, then we haven't figured out how to do the characterization.

MR. HINZE: How well have you been able to do it with the inverse modeling? You have obviously checked this enough.

MR. FLINT: We have done fairly well in a few cases. There was a NUREG that was published as part of the

symposium on fractured rock hydrology. It was a University of Arizona -- actually, it was just published this year, although it was done three years ago. That is -- nothing against how long it takes NRC to publish -- but --

[Laughter.]

MR. FLINT: And there were some points in there that was actually a diagram of how we did the inverse modeling and some inverse modeling results for core experiments. We are still working on the field experiments. We haven't finished that. The high-level waste this year -- we have several papers. One of those is very much concerned with predicting, from the experiment I am going to show you in a minute, using inverse modeling to get at the properties. We do not have the results back.

Okay. We are going to go to the field and conduct these experiments.

Let's look at the site we are going to work with. This is in 40-mile Wash. You will see this site tomorrow. You won't stop at the site, but you will see this area. We see these different beds of materials. You will get a little closer look. This is where the bore-hole experiment was that we are going to talk about. You can see some of the layering that we have in here.

Diagrammatically it looks like this. This is that bore-hole we were seeing the top of, and here are the

different layers we tried to characterize. We have carbonate layers, we have boulder layers, and then we have all of this material in between that we are going to try to study.

We have picked this site because we can use the bore-hole which is what we -- we have 98 other bore-holes that don't have this surface exposure. This one we can compare what we see at the surface with what we see at depth.

We set up an infiltration experiment. This is a large ring with smaller inner rings. We put water in it about 10 centimeters ahead, and we let this experiment run for a couple of weeks. We took the rings out and put plastic over it and let it run for a couple more months and looked at the redistribution of water. The kind of data we see. This is the time -- and this is in hours -- of cumulative infiltration. How many meters of water we put into the soil. We can see we kept going. Yet, if we look at the mass balance calculated from the neutron probe, these two are in good agreement for a while, and then we didn't see water moving into the neutron probe, where the neutron probe measurements were being taken. You can guess from that diagram I showed earlier -- I will go back to just real quick -- water moved down and started moving sideways across these carbonate layers. That is something that is going to

happen in a lot of these sites. That is what I talked about in the washes. Water is held up in the washes.

One of the implications from this is that, if you have a run-off event in a wash, the water is going to hit his carbonate and it may go sideways and still stay near the surface. So, anyway, we have some measurements now that we can start doing some modeling work on. I will tell you about what we are trying to do with this in a minute.

The kind of data we see looks just like the data I showed earlier. This is an artificially controlled experiment, so we know how much water we applied to the surface. Water content changes with time for different periods of time. These are some of the layers.

Okay. We want to look at the laboratory now to get some properties from the lab. This is out water activity meter, some of the rock or soil materials that we use to get at the water potential. A tempe cell we can use to get at conductivity of the soil material. A water retention curve that we have generated using different techniques: Water activity meter, pressure plate, tension table. This is water content versus water potential.

We also incorporate the influence of rocks, whether we have greater than two millimeter material or not, and how those things get incorporated into our water retention curves.

We put all of this together and we get a characterization from the laboratory of what we think we are going to see in the field. We have two equations we use to use texture as a surrogate for conductivity, until we get our conductivity measurements all finished. This is the log of saturated conductivity with depth. Here are the alpha and in coefficient for the Van and Octon function, which we use to fit our water retention curve and also to estimate unsaturated conductivity, which are pretty uniform, but now we have a set of properties. These are the layers that we have in the soil. So, now we have a set of lab properties. We also have a set of field experiments, and we are going to try to match those two together.

I want to talk now about how we are going to transfer this information, with our geophysical logging and some of our soil information. How do we take what we got in the lab and go to another location where we don't have access to the surface outcrop to get that material for the lab?

These are the kinds of materials we are dealing with, looking at soil texture -- different size fractions. This is what the profile looked like. This is the total fraction, 100 percent. That is everything that was there. As you can see, the greater than two millimeter, the core soil, the rock fragments were about 75 percent of the

material -- 65 to 75 percent of the material. The fine soil, which people look at, agricultural soil is a good thing for plant growth -- was a very small proportion of that.

If we take this two millimeter size fraction and put it over here, we can see that most of the two millimeter size fraction was sand. So, very sandy soil is actually fairly uniform in material, with a little bit higher clay content at the top.

We looked at the analysis of all of this textural material. Was it a useful technique to get at the water retention function? No. It didn't work. It didn't give us much information. So, texture was one that we might have to throw out. But, sometimes you have to try those things. If you are going to do any cocreting analysis, one of the things we found is the correlation coefficient was high enough that we could reduce our estimation uncertainty by using texture in a surrogate form, if we had enough measures of the water retention functions themselves. So, for cocreting it may be of some value.

We used geophysical logging as another way to get at these bore-holes. This is a small geophysical logging vent the USGS has that we keep onsite for doing a lot of the work in these shallow bore-holes.

This is just an example of the data set that you

will see from any particular bore-hole. I will go through a few of these.

This first one -- that is just natural gamma, nothing. These things are fairly uniform for a natural gamma signature, so we do not see anything there. Although natural gamma works well in some of the volcanic tuffs.

The density logs. Here is a density log. You can see the high correlation with the layers that we see over here in several cases. Here is the other short space detector density log. So, we have good resolution with the density log matching up with the natural profiles -- the profiles that we see from the site. So, the density tool worked pretty well.

This is the neutron log. Neutron logs are a little more difficult to work in unsaturated case bore-holes. We used a five curie source with this one. I am sure that those of you who are familiar with geophysical logging and neutron logging, particularly, an increase in counts means a decrease in water content. That depends on the source detector spacing. The shorter the source detector spacing, if you have a very short one, an increase in counts gives you an increase in water contents. And the detector spacing in the bore-hole sides are very important in doing this analysis.

You can see, with the two gamma tools, they both

follow very well. But, if you look at the two neutron tools, they go backwards of each other, they are inverse. One of the detectors is on one side of the curve, and the other detector is on the other side of the curve. So, increasing water content will give you an increase in counts on one detector and a decrease in the other. It makes it a little more confusing. We are doing a lot of work to try to understand how to use these geophysical logging tools and unsaturated bore-holes. But, we have made great progress. We have good calibrations for these now, and we have had good success with them.

But, I want to show you how you put all of this data into something useful, and that is what we see here. Well, it is actually a little -- see, it is kind of fuzzy. Geophysics is that way.

[Laughter.]

MR. FLINT: This is the porosity estimate. This is a porosity profile. It matches these layers fairly well. They may be offset a little bit because of the way the beds are set up. We do match the major layers.

This is the data from the neutron log in the field from our experiment. It shows you where the wetting front went to, from the surface to the bottom at about seven meters, after -- this was after maybe three months -- 14 days of being fully saturated at the surface. And we only

saturated about the top meter. Below that we have unsaturated condition. So, we are dealing with unsaturated flow here and we are dealing with saturated flow on the near surface. One of the things we hope to do is saturated a larger part of the profile and look at drainage as a way to get at some of the properties. But, this techniques produced some useful information.

The modeling scheme that we are going to do, which we haven't done yet -- I will just go through on some brief summary. We are going to use a tuff code for the 1, 2, and 3-D models, so we can incorporate the liquid vapor and heat flow. We are going to set up a 1-D model first and use mass balance data from the neutron bore-hole as a flux boundary condition. This removes some of the loss from lateral flow. So, we are going to use that lower flow rate, and try to look at what the 1-D system would look like. Then we are going to use the 2-D model and use mass balance data from the large infiltrometer as a flux boundary condition. So, we have two flux boundary conditions, and then finally, the third one will be to set up the 2-D model and use the water potential boundary condition to let things go on their own. We are not going to force water in under the boundary conditions that we had measured.

We are going to use also many submodels. We don't just use one -- although this is the code we use, we use a

whole series of other codes for some of the simpler modeling, but this one allows us to incorporate some of the vapor flow that we will do later on.

3-D modeling, I am not sure we are going to need that at this particular site.

So, this is the summary of the 1 and 2-D vertical characterization of unconsolidated materials. One, very important. The large-scale soil layering may strongly influence the penetration of water and may cause lateral flow in washes. Even if we get run-off in some of these washes, a lot of that water is going to be held near the surface.

Without model verification, the methodologies that we present produce uncertain results. We need model verification or we are not going to be able to believe what we see. These two need to be worked together.

The bore-hole geophysics can provide the initial conditions and guidance for establishing the layers. It is very important. These layers may be the most important thing to know where they are.

Rock fragments need to be accounted for in the soils, and we determined water retention curves.

We couldn't really find any data that supported the use of textural information to estimate hydrologic properties, although it may be useful in cocreting analysis.

In locations with no access to subsurface samples, 76 of the neutron holes were drilled before we could get subsurface samples back in the early '80s. At any rate, without that information, the flow experiments and bore-hole geophysical data may be the only ways to get the properties of these soils vertically.

MR. POMEROY: Alan, before you go on to the next one, back there a ways, you showed us N-85 bore-hole I think.

MR. FLINT: Right.

MR. POMEROY: And you showed us a profile of water content with depth. I think you indicated that because of the Caliche Layer at about three meters or so, that there was sideways flow, and so that there was some protection from the lower layers. How general a statement is that? Is that true over most of the Yucca Mountain site?

MR. FLINT: I think that is true over a lot of the washes over the repository area. There is another wash, Pagany Wash, which has a series of bore-holes that go from the side slope, through the wash, through the channel, up on the other side slope. We see very very good evidence that the water moves down there and then moves laterally. Because, after a run-off event back in the early '80s, we were trying to do some modeling, we had trouble with our mass balance calculations. When we finally ran a 2-D model,

the model had water popping out the sides. We went over and looked at the bore-holes that were actually on the sides, our side boundaries, which we held constant, and found out that they really were changing in the locations our models said they should be.

So, we are going to take this artificial infiltration experiment and go back to that site and run it right there were we have good field evidence for this lateral flow in one of the major washes that we are doing studies on.

MR. POMEROY: Thank you.

MR. FLINT: As I think Larry mentioned earlier, or Mike did, the artificial infiltration experiments were set to look at future weather conditions. But, one of the main purposes of the artificial infiltration program is to try to characterize the flow properties. Flow properties that you measure in a rock core may be more representative from the lab to the field, but taking a soil which has multiple layers is almost impossible to take into a laboratory. So, if you want to know porosity and flow -- or not -- porosity you can measure a little bit easier in the lab; but, if you want to know flow properties, you need to do it in the field. Artificial infiltration is a way to control the experiment. We are just taking the lab to the field so to speak.

Okay. Now I want to look at --

MR. HINZE: You talk about model calibration and model verification. What about model development? Is that in the process?

MR. FLINT: I am not sure what you mean by model development.

MR. HINZE: Well, I am talking about, considering your using the tuff model here.

MR. FLINT: We are using the tuff code.

MR. HINZE: Yes.

MR. FLINT: We set up the model based on whether we have fractures or matrix, or matrix fraction interactions and what the properties are, but we use the tuff code. We have written codes. We have written quite a few different kinds of codes -- water shed codes, stochastic rainfall models that are codes that give us the kind of data we need for rainfall. So, we have set up a series of codes that we use. And then we have a series of models or representations of how the system works or how the site looks.

We have a radiation model -- a solar radiation model that we have written for the site that handles blocking ridges and all sorts of stuff.

MR. HINZE: You are looking at this in a relatively small volume at this point in time. You are going to have to move to the 3-D -- you are going to have to

remove the question mark from the 3-D, right?

MR. FLINT: Right. Bo has the job. He has got this big question mark, and he walks around with it, saying when do I get rid of this thing.

Okay. I want to look at the bedrock. Now, we have considered the surface soils. We looked at the horizontal variability of the properties, we looked at the vertical variability. Now, let's look at what is underneath this alluvium, and does this have any influence on how water is going to penetrate deeper down into the mountain?

As I showed earlier, it does have an influence in that one diagram. It was probably a couple of slides back -- maybe 30 or 40.

So, now I am going to talk about the bedrock material. This may be one of the most important controlling factors for what happens under alluvium. If what we are thinking works out, we may be able to not worry so much about what the alluvial properties are and really just concentrate on this particular one.

This is the site again that we are looking at for these materials. And I am going to show you sort of pseudo bedrock map and what that influence is going to be on infiltration through the site, if we get rid of the alluvium for a minute, to think about what is happening underneath.

So, I am going to go through this process. How

are we going to estimate surface moisture flux? Another way to get at surface moisture flux, and I will go through that in detail, and then just show you one map -- we are not through with this yet, and so it is preliminary; but I want to give you an idea of what we are trying to do.

The first thing we do is we determine the surface tough hydrologic properties. Everywhere there is tuff exposed to the surface or everywhere under alluvium there is going to be tuff. What are its properties, right there at that exposure?

We want to group these into surficial tuff -- into flux units. Then we are going to locate these on a lithologic map, excluding the alluvium, so we know what is underneath the alluvium now. Then the first approximation of flux is going to be simply the saturated matrix permeability -- matrix, not fractures in this case -- used to identify distinct zones of infiltration potential.

So, let's look at all of the bedrock. Where do we have high zones of potential flux because the bedrock is very permeable?

Then the next step is to estimate the current water content and water potential of those surficial units at a depth where the annual fluctuations are reduced at the tuff alluvium contact, if it is deep enough. We assume a unit gradient, and we use the relative permeability as the

second approximation of flux. So, that gives us a little better information, but it is a little harder to get that information. We are working on that right now.

The next step is to add the fracture density and fracture permeability, using fracture fill properties, and then we incorporated the matrix properties as a third approximation. So, now we are going to add fractures to this system. And then, finally, we go back and we refine the field measurements to better determine these properties and what the potential gradient is -- if its a unit gradient or not.

These are some of the properties that we have identified -- just the general -- these are not complete yet. These are just sort of a starting point to put some things down on paper for the different units that are exposed somewhere on the surface of Yucca Mountain or underneath the alluvium. We have some mean porosities variabilities, conductivities -- different conductivities that we are going to start looking at. We are going to start mapping these out. So, we have some properties now.

We have done this from collecting samples from surface outcrops and from bore-hole data, and from wherever else we can get information. Well, what does that look like when you put it on top of Yucca Mountain? This is very important when we try to look at -- identify the area that

Joe Rousseau talked about -- some of the perched water kinds of things.

This is a repository block. This is a 3-D site scale model. In particular, I want you to look at the PTN unit. This unit may be the most permeable bedrock, including all of the fracture bedrock, on the site. This unit is most likely the place where we would see the highest flow rates occurring at Yucca Mountain. We see that occurring here in drill hole wash. And this is where UZ-1 and UZ-14 is, where we have the high saturation of the perched water body. We also see it in Pagany Wash. This is an area where we expect to see a lot of vertical flow through the non-welded unit, and another area to the north. We also see it on the side of Yucca Mountain at a few other locations. But, these are very important.

UZ-16, down in this area, we have a Tiva-welded tuff on top, one of the lowest permeable units. So, if you put these together and you look at just the ability of the alluvium -- of water getting through the alluvium and hits the bedrock -- if it hits rock that has a low permeability, the water is going to continue down from here off to probably a fault in this location. Here it is going to continue on down until it comes up to a permeability barrier. Then it could continue down and a lot of lateral flow will occur. I think Ed Kwicklis will talk a little bit

about the potential for lateral flow in this area and so will Al Yang.

If you were going to pick a spot to find perched water -- if you were going to go out here and drill and look for perched water, I think you would look under here, you would look under here, or you would look under -- over here. Those are the three areas that I would look for for perched water. This is the area where we found it. This is the area where we have the steep gradient, although I do not think that these properties are necessarily related to that at all.

So, there is good evidence that the properties are the right way for perching to occur, because of the high permeability underneath the alluvium. In a lot of cases, this is exposed directly at the surface.

MR. HINZE: That does not take into account the permeability that may be associated with faults; is that correct?

MR. FLINT: That does not take into account faults. I will spend a little time on this, because I think this is an important point. Faults have different affects at different times, at different locations. I believe that the faults on the surface of Yucca Mountain are, for the most part, filled or low-permeability materials, because of the carbonate materials that have filled them up. We have

drilled bore-holes through some of the faults. One of the neutron holes has -- and we find that a lot of cementation goes along with these faults at the surface.

So, for a first approximation, I would guess the faults are low in their permeability capacity at the near-surface. However, if you get a lot of water that moves through the large volume of rock, that is exposed at the surface, or even the alluvium, and it doesn't go in he faults, and it continues on downward, and it hits an area where it cannot go through the matrix because of the permeability, and it starts to go sideways -- for instance, the paintbrush non-welded tuffs -- when that water then hits a fault, the fault there is most likely open and allows for water to flow. You may have perched water bodies building up behind the fault, or you may have flow directly into the fault. All of the water that goes laterally may run into this Bow Ridge fault along in this location. So, if the surface faults may be plugged, and we may not see water flowing in them at depth, we may see a tremendous amount of water flowing in them, because you have a large collection area turning the water sideways along some of these different units that we see.

One of those, in particular, is the vasal vitrifer of the Topopah Spring. That is an important point, because that is the least permeable unit underneath the repository.

Water that got contaminated that would hit that most likely could -- if it was at a saturated state, like we see at UZ-14, could be perched there, and that water may be moving sideways down dip, because these are dipping rocks, toward a fault, and then go down and bypass the Calico Hills material underneath it. So, they may be very very important in how they behave. That is why the work that Joe is doing in his surface base testing and some of the other studies are critical to our understanding of how these faults operate.

Now, I want you to look at what the fractures look like at Yucca Mountain on the surface and if -- you probably will drive by this area tomorrow if you go up to UZ-14, and if you're interested, you can probably stop up there and take a look at this.

This is an area where they put in a drill pad for one of the bore holes and this is an exposure of the bedrock underneath the soil materials. If we look closer, we can see what's happening with these fractures. These are fracture materials and you can see the fill. Here's a fracture, fill material; other fractures, large blocks.

These big white areas -- you can imagine that this is a fracture that goes in sideways into the screen, this way, and here's another one in this direction. So this is a big block that's been cut off. So we've exposed the surface. Most of these fractures from our drilling, from

exposures like this that we get from some of the pads we put in, most of these are filled materials; they are filled properties here.

If we look in detail, we can see that same area, the carbonates in the tuff matrix block around it and you can see the fracture density and the fracture network and how they were connected and also how they were filled.

One of the things that we found in one of the bore holes we drilled after a one-inch rain storm, two weeks after that rain storm we drilled a bore hole. At about 15-foot in depth, we went through a unit that looked very similar to this and we brought a piece of core back in about that size, back into the lab. It had this fault material right in the middle of it. That fault material -- not fault material; I'm sorry. That fracture material was completely saturated or near saturation. And water was flowing down in it. Yet the matrix on either side of it was slowly imbibing the water and that water most likely moved down to great depth. There were no roots in there and so water that gets into this side -- and you can see very little soil cover -- this could be a major conduit for water flow. But not as an open fracture; as a fracture fill material.

So we take some of these rocks and some of this fill material and we take that into the lab. This is an example of a small rock core. Some of the fracture fill

material on the face here are the different rings that we cut off of the core that look just like this because we wanted to know not only what the fracture fill looked like and what its properties were but how the rock was altered. And Jenny Curtis did a lot of work putting this together and trying to come up with water retention curves for what we're trying to characterize.

So now let's look at water potential versus water content. These are the water retention curves for that piece of tuff that you saw. This is the water retention curve for the fracture fill material. So the fracture fill has definite characteristic. Definite material. We've done permeability measurements on them; they are more permeable going down the fracture than they are going across the fracture because of the way these have been laid down in the rock itself, but we can characterize them. So I believe that if we are going to model fractures in the surface of Yucca Mountain, we have to account for the fracture coating and the fracture film materials and use those properties, not just use the standard -- you know, thousand micron fractures that go from the surface of Yucca Mountain to the water table. We've got to put some constraints on it that are real and that match what we see in the field.

In addition to the fracture fill material, we have some modeling perimeters for fractures and this is work that

Ed Kwicklis did and provided to me to give us some characteristic material to apply to where we think there may not be fracture fill in this material.

One of the things you have to consider here, very important when you do modeling work, is this: If you're going to deal with a fracture -- let's say a 250 micron fracture -- here's the water retention profile and here's the permeability. A very high permeability fracture, that's the kind of thing we look for. Have high permeability fractures, but associated with that permeability because of its size is a water retention curve that at 10 centimeters of suction, is drained. So you cannot get -- you can get a lot of water to flow into that fracture but you can't get it out of a matrix that's drier than 10 centimeters of suction. So a rock that's at 99 percent saturation cannot get water to flow into that big fracture.

If you have a fracture like this one that is filled at almost a bar of water potential so you can have a filled fracture, the permeability is real low. But you've got to make sure that these two are consistent. They are not independent of each other. The permeability of a fracture is not independent of its water retention function. And you've got to keep those two in mind when you do this.

Okay. So that's looking at simply the fractures. That was the next step of what we wanted to do, is try to

incorporate this material into our surface map.

Okay. Now I'll go through and look at an evaluation to quantify net infiltration. We have an idea of what the properties are like where infiltration could be occurring. Let's see if we can get some numbers now and see how we do.

We're going to use the water balance approach. That's taken about the same way you saw earlier where the infiltration -- that infiltration which is what we're after -- is precipitation minus evaporation minus run-off, run-on plus this change in storage from any one time to another. I mean, most of the water is going to go into storage early on and then over long time periods we can account for that net infiltration by modeling this perimeter. So I'm going to go through and show you how we do some of this work.

This is the neutron moisture meter again and one of the washers so we can measure that change in storage, an important perimeter. This is a rain gauge and pagany wash so we can collect some rainfall information as far as rainfall rates, intensities, and durations of storms and total quantity. We also have a series of smaller gauges. This is one of the ones used for chemical sampling.

This is a Bowen ratio station for measuring evapo-transpiration. This is one of the gauging stations; this is sort of a natural flume that's been set up; this is just to

monitor run-off that we see in this wash. And we didn't get any run-off for years in this wash until they put it in; then we had it a week later. Or else we had it all the time and we didn't know it. I think it just happened a week later. And mostly from the road that was up above it. So we have the ability to measure some of the run-off that's going on in this location.

We throw all that stuff into a big equation, U being the precipitation evapo-transpiration run-off and run-on; the rest of this is just solving Richard's equation. We get these properties from the lab.

And here's how we do. You saw a diagram that was similar to the first one. This is the zero to point one -- or point three to one meters and we do a pretty good job of matching with this modeling technique. And now we're going to look at how well did we model vertically. We do a pretty good job of following the profile. In all three cases we can see this long-term trend. Notice we're getting the increase in precipitation and increase in water content in the surface, and yet we're still seeing a long-term drying trend. There's a disequilibrium going on in here. But we did a pretty good job so we're able to make some modeling efforts. When we get this system calibrated and we try it at a couple locations and we show that we can have good success with it, then we're going to start to use that to

look at what net infiltration will be by seeing what's happening at the bottom of some of these models.

But that's just to give us an idea, not so much to identify net infiltration from this process, but identify the mechanisms that are important to understand for net infiltration and to look at areas where net infiltration may be greater or lower by how this system responds.

1-, 2- and 3-D flow models are used to predict bore hole saturations and fluxes. So I'm going to show you some examples of some of the modeling work that I've done in the last year or so.

To do our modeling we've got the first bore hole that we drilled on Yucca Mountain since 1986; this is bore hole N-55. One of the small rigs went down about 260 feet. And this is an example of the data and some of the model run. This is depth, zero to 80 meters, the measure data is in red, that's the water content; you can see it increasing in saturation. As we get to the top of the non-welded unit it decreases because of the non-welded unit's high porosity. Water content is actually higher here, but its relative saturation was less. It picks back up at the cap rock, a very impermeable rock, and then drops back down again.

If we take the properties that we know for Yucca Mountain from surface outcrops and we simply said there is no flow at Yucca Mountain at all, what would our model

result show us? In equilibrium with the water table, this is the green line. So there's an equilibrium with the water table. The not welded tuff looks pretty good. The welded tuff on top, it's -- something's wrong because it doesn't match that no-flow condition. So obviously it's wetter than that, so there must have been some kind of flow going on.

Well, I set a high flow saturation right here, and I looked at an equilibrium with that. And you can see that we don't match this profile very well here and we don't match the PTN very well. But it was wet here. So then the next thing I tried to do is I started at this set of conditions and I looked at what's happening at the surface of Yucca Mountain. I added a negative .05 millimeter a year exfiltration discharge. What happens is is that pulls this down and we get this profile which starts to match; it also pulls some water out of storage in the PTN but doesn't do as good a job as I would have liked. But what this tells me is that if we want to match the current conditions at Yucca Mountain we have to know two things: One, what was the past climatic condition like that wet this up, and two, what is the current climatic condition like that's drying it out.

So we have a series of wetting and drying conditions and to do any modeling to match these profiles I could not find any steady state flux rate that would ever match the profile. I couldn't do it in these shallow bore

holes that are 250 feet deep.

So what I did is I looked into the literature for past climatic change information. There were two sources that I looked at. One was the old data from IMBRIE, the ocean core data from oxygen 18 or del-oxygen 18 or the oxygen 18 deldeterium from calcite veins that Ike Winegrad had done. This diagram shows those two together. To show you that we have climatic change, this is warmer drier conditions, gets wetter and colder and it keeps going through the cycle. Ike Winegrad's data does a fairly good job of matching this. There are differences in what he sees from what the Ocean Core sees and he describes that very well in the science paper which is worth reading, but I chose to go ahead and use the longer term record because the cycles were about the same. In the frequency demand, these were very, very close.

So I chose to use this as a climate change. In my current modeling work I found that that .05 millimeter a year worked pretty well but I went ahead beyond that and picked a negative .1. This is a simulated net infiltration; negative .1 millimeter a year at the current conditions. And I said at some time in the past the net infiltration was .2. That's going to be some positive infiltration rate. And I chose .2 because what I was trying to model with all of this was the UZ-16 bore hole. And I was trying to model

UZ-16 before they drilled it. So I had to make up properties from surface out crops and I tried to use some climate change scenario based on the neutron N-55 information.

The saturated permeability of the welded tuff, the UZ-16 right under the alluvium is about .2 millimeters a year. So I assumed that any water that got below that alluvium to that bedrock interface would continue on down gradient. And it wouldn't go into the bedrock. And the bedrock would take it in only as fast as its saturated matrix permeability. I did not include fractures in this particular analysis. And this is, again, from present to minus 700,000 years.

So now let's look at what this looks like, this past climate change, 700,000 years, in terms of flux at Yucca Mountain at UZ-16 based on the model. That's what this diagram is.

So here's our -- what we're saying is happening at UZ-16. One thing I want to point out, there is an average mean of this system, about .6 millimeters a year. And that's what we see right here. That's the average mean, the white line, .6 millimeters a year.

What we're seeing is a changing flux rate at the surface; green, present conditions. Negative flux at the surface; that's at .1 millimeter a year. If we look past

25,000 years ago, the way the model works is here's a positive flux rate of little greater than .1 millimeters a year. But you notice how these two go back and forth across each other. When we have positive flux at the surface, we have a lower than the average flux in the sub-surface because it's responding to a pass of change. It's like a soil temperature profile. As soon as it starts getting cold at night the surface soil cools off quickly but the sub-surface is still heating up from the heat pulse moving through the system. So we're just simply looking at this change.

Two important points: One, look at the alluvium. The alluvium has a tremendous control on slowing up the system. And this is in a 1-D model. If this was a 2-D model, a lot of this water might end up going sideways. But I forced this flux through. Another point to notice is that there was not an influence on the top of the paintbrush non-welded tuff. Because of the hydrologic properties, the way they are, the top of the non-welded tuff did not form the capillary barrier that we thought it could. The properties were not such that that would occur.

But yet, although my line is a little off, at the base of the paintbrush non-welded unit is the top of the Topopah Spring cap rock. That does control flux to a tremendous amount because of its low permeability. And you

can see that we stopped this. And what happens is we stop the flow; we increase the saturation in the surface of Yucca Mountain so that when we get to that new climate change, the drier one, we pull that water back up. But in the end, we do see some net average. What this tells us, though, is that if this is the case and we can do this kind of modeling, we might see a steady state condition deep down in the mountain, even though we have a variable climate change on the surface. So this may be very useful. If you put this in a two-dimensional model, we're going to have a lot of water flowing through this paintbrush non-welded unit and I think Ed will talk about that in some detail.

What does this look like in saturations and how well did we do in matching what we predicted based on the data that we collected after the model was run? Although I corrected the geometry of my model when I had better geometry data and reran the same set of properties. The blue is the UZ-16 measured data and Joe will talk in more detail about that. The yellow is a no flux condition; that's if we say there's no flux going on at Yucca Mountain. And obviously the blue doesn't match the yellow, which means there is flux positive downward.

The red is the model .1 millimeter a year. I did a pretty good job in modeling part of the mountain and I missed in a few locations; in particular I missed in the

Calico Hills. The properties I got for the Calico Hills were about 4 miles off. That's a little farther than what we think is reasonable; maybe two miles you can go and do a pretty good job -- a paper that we had published last year.

But looking at the properties that we predicted for UZ-16 to see how well we did at predicting the porosities, this is depth versus porosity. The estimated porosities from surface out crops as much as a half a mile to a mile away and this is what we measured. I think we did pretty well at trying to predict what we were going to see at UZ-16, except for the Calico Hills. Our properties for the Calico Hills are not very good. We have more work to do. We expected to find vitric there; we found zeolitic calico and we have a lot of work we're doing in the lab now trying to straighten that out.

The prow pass, we're also not very satisfied with the porosity profile. I think we did a fairly good job in getting at some of the properties. I think the properties are going to be easier to estimate for the site than the flux rates and the climate change. And those are the things that we need to work on.

Then the final -- the 2- and 3-D models, I left that off because I thought Bo would talk about that. So Bo is going to talk a little bit more indepth about how we use a 3-D flow model to predict bore hole conditions because

that's something that he will spend some time on.

Modeling surface net infiltration under site scale climatic conditions is also something that's going to happen in the future modeling efforts that we're putting in, trying to put some of this stuff together. But I want to try to put this all into a sort of a summary of the approaches that we've used and a general -- sort of a fatherhood and apple pie statement -- one is that we wanted to develop a conceptual model. We set up a series of hypotheses, made our observations, made our measurements and did some numerical modeling to try to put all this together to develop this a little further.

Then we implemented a measurement and a modeling strategy to characterize the surfacial materials and the natural infiltration on a site scale. And then finally we need to be integrating and evaluating this data. We need to compile and analyze all available information. We need to look at the bore hole program, we need to look at your chemistry data and any other information, Cor-36, Tritium.

And then finally this needs to be put into some kind of performance assessment model for sensitivity analysis. One of the questions that was asked earlier about our modeling techniques is whether or not they were going to be used in performance assessment. What we believe and Bo will maybe describe this in more detail, but what we're

trying to do with all of this information is put it into an America model that can correctly represent or predict other locations, other bore holes that are going to be drilled off in the future. When we can do that, then we have developed a numerical model that predicts the hydrologic system of Yucca Mountain under natural conditions. So we've figured out the fractures, we've figured out the properties, some of the fluxes. From that model and from those databases which we've tested ourselves, then a performance assessment modelers using different codes or whatever they want will extract out our understanding, they will extract out our properties and all the other information they need out of the work that we've done and put into their more rolled up models that have taken out some of the detail that's been able to be successfully taken out to run some of these models, and use that to put in the repository and do analyses like that.

Well, that's all I had.

MR. POMEROY: Al, you've been saying that there's -- the amount of interaction at this point in terms of PA people using these models that you're developing is not happening at this point in time but it will in the future? Is that a fair statement?

MR. FLINT: The PA modelers now are using a lot of the data that we've generated, although a lot of time the

modeling efforts are so far along that they don't have time to incorporate the newer data that we get in, although we provide that to them and they can use that information.

The modeling that you saw, the UZ-16 modeling, that modeling that I did, was part of the performance assessment program. I get funded partly under performance assessment. So I do some of the modeling that way.

They are working from a different level and I think that someone from DOE will talk more about that. They're dealing with a higher level model of Yucca Mountain. And we're dealing with a lower level model of Yucca Mountain because we want to understand how Yucca Mountain works today. We want to verify our thinking on a conceptual model, verify that we can predict some of the kinds of properties we're going to see, some of the saturations we're going to see. We're trying to model the -- you know, get the understanding of the hydrologic system and they're trying to look at repository performance and that kind of thing. And they're not connected at this point, although we're working very hard to connect those two and get the site information, the detailed site information that we have, into the performance assessment modeling that's going on now. And we're working at that.

MR. POMEROY: Well, help me just a little bit there. I mean, I agree with what you're doing and in

essence you're trying to understand the processes that are involved as I would state it. And that seems to me to be a valid approach. At the same time, when I see a total systems performance analysis assessment, can I ask myself the question how valid is -- when that PSTA or the performance assessment phase 2 of the NRC tells me that everything is okay, that we've incorporated the abstracted models, done the performance assessment and everything looks fine, how valid can that statement be if the process is not understood?

MR. FLINT: I don't think that the modeling that they're doing -- I think -- let me try this again.

Their models, I do not think represent the site nor the processes that are acting at the site today. I don't think that the results of those models can be useful to determine the suitability of the site at this time. I think they have to incorporate the two-dimensionality and three-dimensionality of the site; I think they have to incorporate the variable flux rate, and I think they have to incorporate the time scale in which that flux rate changes. I think a lot of that needs to be done.

MR. POMEROY: Thank you.

MR. HINZE: Despite the excellent move which we've had this morning, we do have a time problem but I don't want to cut off questions. Bill?

MR. FORD: Yeah. Alan, what I'd like to do is kind of ask a -- just a kind of a series of questions and just put up a couple overheads and the reason I'm asking is to just to kind of give you folks an opportunity to talk more about the unsaturated fill and hydrology. And what I plan to talk about is just some of our initial look-see at the data from UZ-16 that the NRC staff has plotted up. So I'm going to need an overhead projector.

MR. FLINT: Can I get this for you? I'll get it for you but I won't turn it on.

MR. FORD: As long as you don't work for the NRC you're all right.

This will end with a question -- a series of questions. It's nothing to be afraid of.

MR. POMEROY: Sounds like my dentist.

MR. SACKETT: Just before you leap out of the chair, right?

MR. FORD: This is just a map to show where UZ-16 is for those who haven't seen it. And what I'm going to show -- let me get the right overhead here -- is a scatter plot of the porosity data to let the core -- and water content. I have some extra overheads that will give me more than we'll need. And what this shows is a -- you have the -- stratigraphy -- what it shows is stratigraphy from the top of the hole -- along this -- in this legend.

And this is just a scatter plot. These various symbols, correlate with various units. Now, kind of -- you see a strong correlation in this plot and the reason I think you see this correlation is that these are samples where the matrix is almost saturated. If this is core analysis of core matrix material, there's no plots in this area, this scatter plot, and no data points, because once you go more than 100 percent, that's as much as you can measure in the laboratory.

Now, what we found interesting in this plot other than you can see quite a bit of the hole -- number of plots form that line -- two of the unsaturate -- well, two of the non-welded units are colored yellow; the Tiva Canyon Shardy Base, the paintbrush tuff and the top of the Topopah Spring non-welded tuff and these non-welded units all lie together and you can see they all fall pretty much in this part of the scatter plot.

If you look at the Calico Hills unit, you see it tends to fall in this line. Now the reason we started doing this was we're read in some USGS report that water content seemed to correlate pretty closely with degree welding and of course the higher the welding, the lower the porosity and that's why you see a lot of Topopah Springs on lower part plot, and it doesn't take much water to saturate the matrix and once it gets saturated with low hydrologic conductivity,

it probably takes a very long time to ever dry out. You see some scattering here as well.

This is intriguing because we saw -- we did --in the bedded units we didn't seem to see the -- we expected the Calico Hills to fall down in this area as well where the saturation wouldn't be as fully saturated and you'd have an increase in porosity.

Now I'm going to change overheads and that will take me a minute because I'm holding more than one item. What I'm going to do is put a plot of water saturation with depth. That means that approximately one is 100 percent saturated. And if you look, the yellow is the paintbrush bedded and the red again is the Calico Hills, and you can see that the Calico Hill is pretty much saturated and yet the paintbrush is much less saturated. You can see as you go deeper in the hole near the bottom of the Calico -- I mean the Topcpah Spring, the saturation is near 100 percent. You can see at the last unit at the top at Topopah Spring where it's almost completely welded that it doesn't take much moisture to saturate the matrix and it's almost completely saturated. This is welded and this is welded; non-welded, non-welded.

Now, if I put other plots -- that would be too complex -- porosity with depth, what's intriguing to me in this plot is that the porosity in the Calico Hills non-

welded is higher than the porosity in the welded unit. And it's getting up there pretty close to the porosity in the bedded unit above. So it's kind of odd that you'd find -- it seems odd you find so much saturation down here.

Now, some of our -- I'm going to leave you with a conclusion. The question is, what are your thoughts about the distribution of water saturation in UZ-16 -- collect some data from the site; I don't expect fine lancers, just your thoughts, and some of the thoughts that kind of occurred to us, and there's more than one interpretation to get a plot of water saturation -- is that up in the paintbrush unit you'll be seeing quite a bit of drawing, quick de-watering, high permeability. Perhaps down in the Calico Hill unit you're beginning to see some perching because what I haven't pointed out to you is right below it is another bedded unit, the Prow Pass, and you can see there's a big change in water saturation; a big drying at this location, and then it begins to wet up again down below.

So it's just a hypothesis; we don't know. You do see a change in porosity data, I believe, there. I'm not sure it will show up in the next plot. But I think we saw -- anyway, it's speculation. I think we saw a little bit of a decrease in porosity at this location.

So there's two things to kind of explain -- that

we're kind of intrigued about. The other thing that we thought was -- we listed some of the modeling attempts on UZ-16 and some of the things that we're wondering about is if you look at this, you can see that if you set up your model so that basically the matrix saturated up, you'd be able to predict most of the water points for this hole. So that means that any set of model perimeters where you almost saturate the matrix would predict most of the points for this hole. But yet probably for this hole the really difficult ones therefore to predict is -- your model perimeters may be reflecting what might have actually happened or what the actual situation is. It's probably the better tuffs.

And so with that, just kind of a mixed bag of stuff to give you an opportunity to talk about UZ-16, I'll leave it.

MR. ROUSSEAU: I can try to answer -- could I ask a question?

MR. HINZE: Sure.

MR. ROUSSEAU: The condition in the Calico -- now, how are you creating or proposing to -- what might be going on? What's the physical mechanism that you would promote here to have that happen? Is it a capillary ink-bottle type effect you're proposing?

MR. FORD: The initial thought was that you may

have a layer there lower from Yudoan. In other words, when you get to the Calico Hills, you may have fewer fractures and either the water has to go into the matrix and then it gets down to the lower permeability layer and it can't get much any deeper. And that would explain why the unit below is drying out. Now, that may be wrong. Which gives you an opportunity to talk.

MR. FLINT: Okay. Although we don't know that we have all the properties right at this point, the kinds of points he was making can be shown in this particular diagram from some model results. I'll try to focus this a little bit for you.

Look at the saturation zone right here in the prow pass. Under a no-flow condition we see the same drop in saturation. What that tells us is that this yellow line, all through here, is all in potential equilibrium with the water table. Although my no-flux conditions don't work, the .1 millimeter a year flux conditions do work a little bit better and maybe even a greater flux than that under the current conditions although we don't have all the properties right.

This high saturation, the Calico Hills, is not inconsistent with the one being so close to the water table. We would already wet it up quite a bit just from capillary rise alone. We would have this decrease in saturation then

increase again because of the difference in properties, and the high saturation is likely related to a condition of past flux. The PTN unit which under no-flow conditions should be dry because of the large pores. It's not a matter of welding versus non-welding; it's a matter of porosity. And the porosity changes in a non-welded unit are tremendous. Huge variabilities. So under no-flow conditions, this should be dry.

Under a one millimeter a year flux, we can see that we're coming closer, although we're not matching. Again, we don't have all the properties right yet at this point. And yet this model result -- the fact that the model with those properties is fairly consistent with this, that all of the questions you ask I think can be explained by the flux rate that's going on at the site, the timing of the past climatic change and the properties.

One of the things that we found when we did this modeling, we found these results. And I talked to the people that did Apache Leap -- or not the Apache Leap; the Los Crucius trench study. The one thing they said when they looked at the model results I've got here and then we talked in detail about why did we do so well, and the reason they felt we did so well and why we could have done their modeling too, they said, was that we conditioned our model on reality. We put what we knew about the site; the right

unit thickness, the right permeabilities if you can measure them, or at least close, the right water retention functions.

If you put as much information as you know about the site and use deterministic processes rather than stochastic processes, you will do a much better job of modeling what you see there. It's real, the layers are real, the fractures are real, the properties are real, and they can be known; they can be predicted. And we have papers that talk about how to use deterministic processes rather than stochastic processes. If we use the deterministic processes, we put that in our model, we can answer all those questions.

We don't have all the details yet. We've gotten a lot of mileage out of one bore hole, one unsaturated bore hole from the time we've been in this program. We'll get a lot more information out of the third unsaturated bore hole. And the fourth. And I think we'll make a tremendous amount of progress. But I think we can explain a lot of that. And this modeling results that we see here and why we didn't match this, I tried to show in this particular one, we had the wrong properties. So we didn't do a very good job here.

And I think Joe Rousseau will talk a little bit of detail, but one of the things that Bill said was right. Look at the change, this rapid decrease in porosity. We get

into some welded prow pass in this location. This might have an influence. In fact, this probably does have a major influence on changing water table elevations. If we have climatic change that causes the water table to rise and fall over thousands of years, this low permeability zone may have some effects on how the site works in terms of where the water table is and how it moves up and down. And I think Joe will talk in some detail about that.

But I think we can explain all those, and I hope I did explain why we saw that one higher. This particular point which you made, it's an equilibrium condition. So we did a pretty good job. And if we get our properties right, maybe we can explain all of it. But what this suggests is that this system isn't some kind of a steady-state flux that is most likely the average of a long-term million-year trend. The near surface, that's a little more difficult.

MR. HINZE: Thank you very much, Alan. Are there further comments, questions? We are approaching a time when it might be well to get a little nourishment and I'm wondering if Ed and Joe would have any objections to putting their presentations off until this afternoon.

MR. ROUSSEAU: No problem.

MR. HINZE: No problem; all right. We are behind schedule and that's not all the speaker's fault. It's our infrastructure here in terms of the audio. What we will do

if we will -- unless there are further questions, we'll reconvene at 1:30.

[Whereupon, the meeting was recessed for lunch, to reconvene at 1:30 p.m., this same day.]

AFTERNOON SESSION

[1:34 p.m.]

MR. HINZE: The meeting will reconvene. We'll pick up where we left off, and it's now 10:30 -- 11:30, and Ed Kwicklis will discuss the unsaturated zone modeling. Ed?

MR. KWICKLIS: Well, I don't think there's too many stones that Alan left unturned this morning, but I'm going to try and fill out what few gaps exist in his presentation.

My talk this afternoon is going to consist of two fairly distinct parts with the first part being fairly general. I'm going to talk about the objectives, motivation, and general organization of the site modeling study for which Bo and I share responsibility. And then the second half of the presentation will become much more specific. I'll be presenting water potential and water saturation profiles from four unsaturated zone bore holes and I'll talk about an analysis that I did with Alan Flint and with Rick Healy, also of the USGS, which analyzed our frequently used major properties data set in conjunction with those profiles to estimate flux set those four holes.

First, a short overview of the objectives and organization of the site modeling study. In the last year or so it's become increasingly evident that the emplacement of waste at Yucca Mountain is going to greatly perturb the

natural hydrologic system and therefore the question has arisen as to what relevant characterization of -- and specifically modeling a natural flow system would have on the ultimate behavior of the system. And I think that the objectives that we've enumerated in our study plan in part answer that question.

Our first objective, as stated in our study plan, is to develop credible quantitative models of the natural flow system. We feel that the development of credible quantitative models of the natural flow system including the movement of environment traces, enhances the confidence of the scientific community and the public in models for which no experimental or observational data are going to be forthcoming, such as those models that predict radionuclei migration hundreds of years hence forth. And so we feel that a credible quantitative model -- conceptual model of the system and the validation of that model again observed by comparison of observed data with model results greatly enhances confidences of models which predict radionuclei migration down the road.

The second issue involves integration of site data and analysis. Data is going to be collected over a variety of scales ranging from a clear scale to bore hole scale to scale of VSF. And models provide a useful way of both organizing and integrating that data in a way that indicates

the importance each data element plays in the hydrologic system.

And because of that function, it's -- the site model can be used to help guide the site characterization efforts. We can look at the influence of various types of data and their influence on individual processes as well as look at how the spacial distribution of data contributes to either particular processes or the overall performance of the site and thereby prioritize the type of data -- prioritize our data needs both in terms of the type of data that is being collected and the location from which that data is collected.

A major goal of the study is to estimate fluid fluxes. The fluid fluxes under ambient conditions, under the natural conditions may indicate the degree to which reliance must be placed on engineered barriers or waste generated heat to keep the canisters dry and may indicate which locations in the mountain one might wish to avoid during waste and placement activities.

One doesn't go out and measure flux but instead infers flux indirectly from knowledge of the gradient and effective hydrologic conductivities. And models are ideal in performing this function. Where we're called upon to make estimates of fluxes under expected future climatic conditions, our study plan calls for us to incorporate the

effects of waste generated heat and evaluate their influence on flow quantities and flow path.

Another goal would be to test the hypothesis concerning the hydrologic behavior of the site. Numerical models are useful conceptual tools in both formulating and testing conceptual models at any site and it's particularly valuable to have such tools in a very complex hydrologic environment like that which exists at Yucca Mountain.

And finally we want to produce estimates of hydrologic perimeters. Modeling of the natural system invariably involves calibration of the model against observed phenomena and that calibration process would incorporate, quote, unquote, hard data, such as permeability values that are calculated on the bore hole tests as well as soft data such as observations of seeps or -- into the SF. And those perimeter estimates, and we're talking about things like flux, hydrologic conductivities, effective porosities, those perimeters could be subsequently be used in performance assessment models of the site, including those models that look at the effects of thermolodes in more detail and also could be used in those models to predict radionuclei migration.

So it's a long introduction as to the objectives and the study was divided into five activities. The first conceptualization of the unsaturated zone hydrologic system

seeks to identify those processes or physical characteristics that control the behavior and ultimate performance of the site and this study provides the hypotheses to be tested that guide both the site characterization program and the overall modeling effort.

The selection development in testing of hydrologic model computer codes -- the codes developed under that activity would implement the conceptual model developed under the first activity and to date, based on the processes that the code addresses, its general robustness, its geometric flexibility and adaptability to double porosity systems where you've chosen the tuff code as the code to do our site scale simulations, one drawback with the code is that it doesn't presently have transport capability and we need transport capability to help interpret the distribution of environmental isotopes and the implication that distribution may have on flow mechanism, such as fracture versus matrix, flow direction versus diffusive flow, and on flow path definition. So we're presently about to start coupling a particle tracking code with the tuff to enable it -- to give it those transport capabilities.

Simulation of the natural hydrologic system. In addition to examining the existing state of the system, our study panel also calls for us to examine the possible past and expected future of the states of the system under

varying environmental conditions. And as I said, those environmental conditions would include the effects of repository heat.

Output from such a model would be liquid and gas fluxes, seepage velocities, and as I said perimeter estimates and some quantification of the uncertainty in those perimeter estimates.

Now, uncertainty can arise from a variety of different causes. It can arise from geometric uncertainty, conceptual uncertainty, and perimeter uncertainty, among other sources. The conceptual uncertainty is, to some extent, being addressed by the submodels which are being done under this study in addition to the main three-dimensional model, and also under a related study that the fluid flow and unsaturated fractured rocks that Larry Hanna is now in charge of.

To account for the perimeter uncertainty we would want to do a sensitivity analysis and stochastic analysis indicated here in the fourth activity. We would want to characterize our input variables, the uncertainty in our input variables and characterize our output in a statistical sense by doing stochastic simulations as well as sensitivity analysis.

The final activity on this slide is kind of an ongoing activity that just is a continuous reevaluation of

the prevailing conceptual model and an assessment as to whether the appropriate hypotheses are being addressed and whether the appropriate data is being collected. And that evaluation occurs in a variety of forms within the U.S. Jeseta codes and our bi-quarterly modeling meetings. It's being coordinated to some extent by ATARA and it also takes place in peer review groups such as the one being held here this morning.

MR. STEINDLER: Excuse me.

MR. KWICKLIS: Yes.

MR. STEINDLER: Two simplistic questions. One, in the first slide you talked about the estimation of fluid fluxes. Could you help me define what a fluid flux is in an unsaturated zone?

MR. KWICKLIS: It's the volume of either water -- for water flux, it's the volume of water per cross-sectional area per unit time.

STEINDLER: That's the definition of a flux, but what's the concept of a fluid flux in an unsaturated zone?

MR. KWICKLIS: Well, the same concept applies whether it's saturated or unsaturated.

MR. STEINDLER: Okay. The second issue, then, is you indicate that you're going to do stochastic modeling. This morning I thought we heard a strong comment that stochastic is not the approach to use. And I thought he was

from the same agency that you work with.

MR. KWICKLIS: Yes.

MR. STEINDLER: Would you help me out on that?

MR. KWICKLIS: It may ultimately be that most of the variation can be accounted for in a deterministic way and that there is no point in doing a stochastic analysis. That is more likely to be true with the matrix properties. However, when you consider the variability in the fracture network and how that may vary spatially, one might need to account for the uncertainty in the fracture properties at any point in a stochastic framework that attempts to account for the uncertainty at any location that arises from heterogenating.

So I agree with Alan to some extent that the matrix properties were laid down in such a way that they are fairly deterministic and most of the process that we're interested in can be accounted for by considering the distribution of properties to occur deterministically. That may not be true for the fracture networks.

The remainder of the talk is going to discuss the four unsaturated zone profiles, water saturation, and water potential profiles. An outline for the remainder of the talk is provided in this slide. First we'll just give an overview of the objectives, what we hope to get from the analysis. We'll describe the porosity saturation and water

potential profiles for those four holes and assess the error in saturation and water potential that we observe in those holes.

Then we'll talk about regression, the relations that we derived on the basis of data collected from two other holes not directly involved in this analysis in which we derive correlations between certain hydrologic perimeters, specifically focusing on the perimeters for the van Genuchten functions which describe moisture characteristics and effective permeability of the function of saturation.

After giving the regression results we'll apply the results to the four used -- unsaturated zone bore holes using 4, 5, 7, and 13, and we'll estimate water potentials at those holes on the basis of the saturation which will compare against the measured water potential. We'll estimate effective hydraulic conductivities and then we'll combine our estimates of water potentials and effective hydraulic conductivities to Darcy's Law, which is the most basic equation in hydrology and in order to estimate a continuous profile of liquid fluxes at the four holes, and then to evaluate our uncertainty, we'll compare our predicted and measured effective hydraulic conductivities for a select number of samples.

And then we'll evaluate the consistency of our

results of isotopic data which include tritium data from UZ-4, -5, and -7, and carbon 14 data from UZ-4 and -5. Then we'll give some conclusions. So the objectives are to -- where -- of the particular study I'm reporting on what -- to examine the internal consistency of data collected state, from field and laboratory experiments, measurements, an estimate liquid water fluxes to the non-welded embedded units in the unsaturated zone.

Now, water movement in the more densely welded units may be even more difficult to characterize if water movement is predominantly through the fractures, spatially intermittent, and temporarily intermittent and spatially localized. And we think this may be true, at least in the near circuits. And therefore the relatively sparsely fractured non-welded embedded units offer a better opportunity to estimate flux using conventional methods developed for porous media such as the direct application of Darcy's Law.

So we're going to rely primarily on the data that we've collected through the non-welded embedded units. Then we want to better understand recharge mechanisms and redistribution of infiltration beneath the surface of Yucca Mountain. Alan addressed the surfacial processes but there's a lot of indication that there can be a lot of lateral water movement beneath the mountain as well.

In particular, we're concerned that locally intense infiltration pulses -- we're interested in looking at how those spatially focused infiltration pulses might be dispersed in time and spaced by the non-welded embedded units and an analysis of our water potential and saturation data may indicate the degree to which that is occurring.

So I'm going to just give you a quick overview of the profiles for each of the four holes, highlight the trends and differences and emphasize the role of the microstratigraphy in controlling distribution saturation.

The four holes I'm going to talk about are UZ-4 which was drilled in the alluvial channel of Pagany Wash, UZ-5 which was drilled 38 meters to the southwest of UZ-4 in the bedrock side slope. We're going to talk about UZ-7 which was drilled 2.6 kilometers southwest of UZ-4 and -5, also in the alluvial channel, and I'll talk about UZ-13 which was drilled on the main north Turning Ridge.

The data on which the correlations for hydraulic properties were derived were USWG-4 locating what may be the central repositories law and USWG-3 located not far from UZ-13. Additionally, there was some additional information on effective hydraulic conductivities taken from UE-25-A1.

This shows that the porosity saturation, water potential, and stratigraphic information for bore hole UZ-4. We observe that this hole of the Tiva Canyon, Yucca

Mountain, Pah Canyon, Topopah Spring members are relatively thick at this hole, and there are three intervals of bedded units which were deposited by airfall rather than ash flow processes, labeled bedded intervals 1, 2, and 3 from bottom to top.

Getting back to the question about the determining processes, there are certain things we are going to see in each of the four bore holes that we're going to look at. One is that when the porosity profiles reserve an abrupt entry in porosity at the base of the Tiva Canyon member, for the two thicker ash flow units we observe local minima in porosity at the center of those units reflecting the slow cooling and greater compaction at the center of those units.

We also within individual bedded units -- we see an overall increase in porosity but with depth that reflects that the course -- the settling of the coarser material prior to the finer material in the ash clad. And at 110 meter depth in bore holes 4 and 5, we also see the low porosity vitro caprock that Alan alluded to earlier and which we'll talk about a little more later.

In terms of the saturation profile in the each of the holes you see an overall decrease in saturation with depth, but we also see that there's roughly an inverse correlation between porosity and saturation which suggested to us that in order to account for a lot of the variability

in our saturation profiles and to properly model them, that we were going to need to account for the porosity variations that we observe in this profile and the variation in hydraulic properties that's associated with those variations in porosity.

We also observed on our water potential profiles, for reasons I might have time to allude to later, we don't have a lot of confidence in the measurements made from the more densely welded tops. Within the non-welded embedded intervals, where water potentials are generally in the range of .1 to .6 mega-pascals, we removed a lot of the small scale variability by fitting border polynomials which we'll use later in the analysis.

These are similar data for four-hole UZ-5 because it's only 38 meters southwest of UZ-4. The stratigraphy and the porosity are essentially the same. The saturation profile is a kind of a reflection of what we see at UZ-4 and the water potentials are in the same general range with slightly different curve.

Four-hole UZ-4, again the large increase in porosity at the base. The low porosity vitro caprock, the overall decrease in saturation with depth. Water potentials -- what we find is that in the 20 or so meters above the vitro caprock, the water potentials are roughly in a state of hydrostatic equilibrium and we're going to talk about the

significance of this later. We also see that in terms of stratigraphy the Pah Canyon -- I'm sorry -- the Yucca Mountain member here is completely absent and the Pah Canyon member is just a meter fix. So we're observing a pronounced variation stratigraphy as we move from north to south.

I apologize for this; it's a little hard to see against this brown background. What we see here are the same deterministic types of features. Again we see roughly an inverse correlation between saturation and porosity. Water potentials are in the same general range and we see both the Pah Canyon and Yucca Mountain members are completely absent. So just a --

MR. HINZE: Before you move to that, let me ask a question. Is the variability that we're seeing among these holes predictable on the basis of the volcanic stratigraphy or are these local variations? What are we seeing here? What are these variations?

MR. KWICKLIS: I would say it has -- I'm not a geologist, but I would say it has -- most likely it has to do with distance from the source of the ash, which was the caldera -- the timber mountain caldera, about 10 kilometers to the north of Yucca Mountain. And so as we move further from the source of that ash we see a natural thinning of certain -- thinning or absence of certain beds. However, I'm -- you'd have to talk to one of the geologists as to

what influence the topography exerted on whether those strata are present or absent.

MR. HINZE: The emphasis in the study plans about representativeness and trying to ascertain the local deviations and I'm just trying to learn whether these are those local variations or whether these are things that can be conquered that they have -- they demand a little --

MR. KWICKLIS: The geologic section studies program is keeping the database that interpolate between bore holes --

MR. HINZE: But you're doing the modelings, right?

MR. KWICKLIS: Yeah.

MR. HINZE: So you have to be worried about what's between your data points.

MR. KWICKLIS: Right. I haven't gotten to that point. Bo and I, I don't think, have really -- we're at a very early stage of development of the 3-D model and right now we're just trying to work out problems associated with the actual creation of the model and not worry so much about what properties are where. But you're right. Down the road we will definitely need to account for these variations in stratigraphy.

MR. BOAK: I'm Jerry Boak, technical analysis branch chief. A lot of the deterministic trends that Alan talked about can indeed be related to the genesis of the

volcanic rock and we'll go into more detail. I think that's a third of our discussion, to talk about exactly how those variations -- but the deterministic trends that Alan has talked about can be tied and he has, in work with Cris Routman of Sandia, shown the connection between those deterministic trends. Superimposed on that there does tend to be some noise. And that's what the difference was between what Alan had said and what Ted is saying. That there's a certain amount of stochastic variation but in fact the deterministic trends often substantially override that.

MR. DAVIS: There was also another part of this that you -- hydrostratigraphic units are different from stratigraphic units. Are those following the same pattern?

MR. KWICKLIS: Well, basically the way that hydrostratigraphic units have been observed is on the base of hydrologic properties and those don't necessarily coincide in this case.

MR. DAVIS: So those deterministic trends may not be relevant for the hydrostratigrahpic units?

MR. KWICKLIS: No, they will be relevant because it will show that the other properties are strongly tied to the porosity variations.

MR. DAVIS: Thank you.

MR. HINZE: Go ahead, Larry. Say something different.

MR. HAYES: Larry Hayes, USGS. I think many of your questions would be answered by a presentation that Rick Spangler with the USGS is making at the TOP meeting this coming Thursday. Rick is developing a 3-D geologic framework for the site area. He's developed a framework based lithologic characteristics as determined by how these units were laid down. But then he's correlated hydrologic characteristics to the geologic lithologic characteristics and there is a good correlation and it does make sense. And I think he has input to Bo Bodvarsson and some of the others on what this framework is. But it is a framework that seems to make sense and you can correlate hydrologic properties in a, I think, regional basis almost to the geologic framework the way Rick set it up. He will present that.

MR. KWICKLIS: That's a revised stratigraphy that's been set up specifically to address this.

We want to check our saturation; first there's the water potential data within our non-welded embedded intervals and what we did was we plotted and measured moisture characteristic curve and although there's considerable scatter, the rough agreement in each of these individual intervals shows that we can have some confidence in our saturation water potential data, at least for the non-welded embedded intervals.

We also acknowledged that when the porosity was

small, small area in the porosity the water content resulted in sat.ration. This is probably more important in the welded unit. There was also an accuracy limitation in the psychrometer data of 100 kilopascals which is based on calibration against known standards. And in the welded samples additional error was probably -- occurred due to the lack of vapor liquid equilibrium. And we saw that the plots showed that there was considerable scatter and that reflected both measurement error and hedogen-80. So we did a regression to compensate for the relatively few measurements of moisture characteristic showings and effective hydrologic conductivity efforts for bore holes, we did a regression analysis that focused in particular on correlations involving porosity which was much more -- porosity data was much more extensive at these four holes than other information.

And so we sought to tie these two kinds of curve to porosity variations. And this was done in an attempt to account for the medium hedogen-80 as was reflected in the porosity profiles. So we examine this data set for possible correlations between hydrologic conductivity and the perimeters of a popularly used function that describes these curves and we chose this data set because although some additional data has of course been collected since then, this was the most extensive compilation of data published to

date at the time the analysis was done, which was early last year. The data was also selected because it's a database that's widely used within the -- for hydrologic assessments within the project and it contains information on tuffs that have been subjected to widely varying degrees of welding.

These are the van Gunecten functions. I won't bore you with the significance of each of these perimeters. I'll just mention that they allow saturation to be expressed as a function of water potential or water potential as a function of effective saturation. And they also allow you to produce estimates of effective hydrologic conductivity which are the conductivities at the moisture of the water saturation of inches. And the effective hydraulic conductivity depends not only on some of the perimeters for the function but also on saturated hydraulic conductivity.

When we did this regression analysis we found that at a .5 level of significance there were statistically significant correlations between saturated hydraulic conductivity and porosity. Few of the perimeters in porosity between saturated and hydraulic conductivity and the van Gunecten perimeters -- there were no correlations south between some other variables.

And this is just a visual presentation of those correlations. The red lines are the regression lines and the green lines are the 95 percent confidence intervals and

the blue lines are the 95 percent prediction intervals. This is for log hydraulic conductivity versus porosity log data versus porosity and log alpha versus log porosity.

So we applied these correlations to help us interpret our data at our four bore holes, UZ-4, -5, -7, and -13. First we applied the regression relations along with the -- the regression relationship we used with the measured porosities in saturation to estimate water potentials. Then there were -- the regression relations were used with the measured porosities and saturates which estimate hydraulic conductivities, and these were combined with both the estimates and the polynomial fits to the measured data to produce estimate for flux, which is our primary interest in this analysis.

So this shows the predicted water potentials at bore holes 4, 5, 7, and 13. To account for possible historetic affects at these holes, we doubled the value of the alpha parameter that was predicted from the regression equation. We did this based on an observation reported in the literature that the alpha parameter under wetting conditions was approximately twice that under drying conditions and so to account for the possible wetting at these holes we computed it with both Alpha and 2-Alpha. The wetting history at the holes is of course unknown but the data set on which the parameters were based were derived

under drying conditions.

So in each panel, you see that the left-most one was developed with Alpha and the right one with 2-Alpha. In UZ-4,

-5, -7, and 13 we found that the use of 2-Alpha that produced the water potential profile, it better matched the observed profile, suggesting that at these three holes the profile was wetting. At bore hole UZ-4 the opposite was true. It's very hard to see but I've also included the fifth order of polynomial fits to regress the measured codes at bore holes UZ-4 and -5, and what we see is that the predicted water potentials plot right on top of those curves.

We estimated -- so these are the estimates of effective log of effective hydrologic conductivities at the prevailing water saturations at 4, 5, 7, and 13. What we see in each of the four holes is that at the base of the Tiva Canyon unit we have much larger effective hydraulic conductivities than in the overlying units. We also note that at least at UZ-4 and

-5, that there are discrete jumps in the values of effective hydraulic conductivity within the second bedded interval and that there are also some discrete jumps in effective hydraulic conductivity in the first bedded interval.

In bore hole UZ-7 we observe some of the highest

values. Bore hole UZ-7 you remember was drilled in alluvial Wash and in bore hole 13 we observed some of the lowest values. Bore hole 13 was drilled beneath the main north south Canyon Ridge. The relative magnitude of the effective hydraulic conductivities may say something about the long term recharge under washes versus ridges, but the data is probably too limited to make any definitive judgments on at this time.

I'm going to skip the next slide. The liquid flux is computed for bore holes UZ-4 and UZ-5. To the left are negative fluxes indicating downward flow; to the right are positive fluxes indicating upward flow. In both holes what we see is that at the base of the Tiva Canyon unit and in the upper part of the Yucca Mountain member, the fluxes are fairly large in a downward sense, that they become smaller at the base of the Yucca Mountain member but then exhibit a very large discrete jump within the middle bedded inflow before again decreasing and eventually becoming positive.

We see a similar trend in bore hole UZ-5, with again some more discrete jumps at the base of -- around the first bedded interval in bore hole UZ-5.

Now, these profiles were developed without any assumptions of the dimensionality of flow of these holes. Both the discrete jumps as well as the flow reversal at the base of the Pah Canyon member suggest that there's a lot of

lateral flow coming into the vicinity of the bore hole that is causing these discrete jumps along these intervals as well as causing locally upward flow gradients at the base of the Pah Canyon.

The relatively high fluxes at the base of the Tiva Canyon member suggest to us that there might be a lot of non-equilibrium fracture flow occurring to the overlying densely welded units, although I think Alan suggested a possible alternative interpretation this morning that there is some recharge further up the wash that's moving laterally down beneath the wash.

Al Yang is going to present some tritium data later that show that there was high tritium in these very zones where our model is predicting very high liquid water flux. The scale here is from zero to two meters a year. As I'll tell you shortly, I don't really believe the absolute values but I do believe the relative trends in these curves.

Al has also found tritium data here I believe in UZ-4 along this bedded interval where we see this discrete and very large jump in the magnitude of the downward flux. So I think that the conclusions are here that there's a lot of lateral flow occurring beneath the wash. It's evidenced by discrete jumps in these profiles and also that there's a lot of factor flow occurring through the overlying Tiva Canyon member.

This is -- I'm not going to show you the flux flow file for UZ-7. This is a water potential profile in the 20 meters or so above the density welded vitric caprock at approximately 53 meters down. What this profile shows -- and I'm sorry it's impossible for you to see -- there's a linear regression line fit to the measured data here with an R square of about .69 that indicates in the 20 meters or so above that vitric caprock waters are in the state of near-static equilibrium. And we explain the fact that there is near-static equilibrium in this -- to capillary barrier effects.

Now, Alan showed you this morning theoretical characteristic codes for fractures of various sizes and he pointed out that those curves predict that fractures don't begin to flow at -- even the very smallest fractures don't begin to flow at water potentials less than about one bar or about .01 megapascale. So even if this vitric caprock were very densely fractured, one wouldn't expect a lot of water movement through it because the water potentials at the base of -- just above that vitric caprock are too negative to allow water to enter into it. So the water just sits there waiting until more water can come down and raise the water potentials, and only then will it begin to flow to that vitric caprock.

And we have experimental confirmation of this kind

of phenomena from laboratory tests that we've done, where we've placed layers of sand overlying a block of densely fractured welded tuff and what we see is when the water potential contacts between that sand and the underlying rock drop below a few tenths of the meter of tension, that water ceases to move into that block even when the sand right above it is 90 percent saturated or greater.

We assessed the uncertainty in our effective hydraulic conductivity curves by comparing them with curves that have been measured on selected samples from different intervals and we found that the predicted curves underestimated the measured curves at high saturations and overestimated them at low saturations. And this was related to the way the original data that we did the regression on was measured.

This shows visually a comparison showing what I just stated. We estimated the flux based on those measured curves. The flux estimate in both UZ-4 and UZ-5 were low for all intervals except in the Tiva Canyon there was a very large number the magnitude of which I won't even state for fear that you might remember it and the flux in the underlying Yucca Mountain member about 30 millimeters per year.

Now, as I said, we don't believe the numbers that we're getting, but I think the data is suggesting that some

time in the past -- in the recent past, there have been large fluxes beneath this wash. And based on tritium -- tritium data are subject to a lot of caveats that I'm not going to have time to give you all of the caveats that we -- we passed out a paper to Lynn and we've included all the caveats that go into calculating these numbers. But the numbers that we computed are about 35 millimeters per year in Pagany Wash over the 21-year period 1963 to 1984. The flux is about 24 millimeters per year over the same 21-year period at UZ-7. As I mentioned, the tritium peaks at UZ-4 and -5 are consistent with our i ..erpretations of fracture flow through the Tiva Canyon member and lateral flow on bedded interval two.

The C-14 data for these holes which Al Yang I think will talk about were used with an average biometric water content of 20 percent to estimate average downward fluxes of 20 and 4 millimeters per year at bore holes UZ-4 and -5. Again, there's a lot of caveat associated with these numbers. Each of the data that I'm talking about are subject to great uncertainties.

Summary and conclusions. We examined the limitation of some existing data. We identified correlations between important hydraulic parameters. The flux profiles indicated large influxes of water beneath UZ-4 and -5. Each line of evidence is subject to a lot of

uncertainty but given that all the different sources of data point to the same conclusion, it makes one at least consider the possibility that there are and have been large recent influxes of water beneath UZ-4 and -5.

We talked about the near static equilibrium profile at UZ-7 that suggest that the vitric caprock is an important capillary barrier and in fact numerical calculations -- numerical simulations that we presented recently in Denver have indicated that this capillary barrier effect will restrict any water increased infiltration associated with climate change from entering the Topopah Springs member for many hundreds of years.

Last conclusion; flow and above -- the non-welded embedded units of UZ-4 and -5 was observed to be multi-dimensional and transient and therefore any interpretations that one made on the basis of one-dimensional study model at those holes should be viewed with skepticism.

So that's what I have to tell you.

MR. HINZE: Thank you very much. We have time for perhaps a question or two. If not, we'll move on.

MR. POMEROY: Ed, let me ask it quickly then. When you say relatively large uncertainties, I don't know whether that's 10 percent or 10 order of magnitude. Would you care to comment?

MR. KWICKLIS: Okay. We're probably talking about

order of magnitude. If that one plot is showing you two meters per year infiltration I might say an order of magnitude less.

MR. POMEROY: Or more?

MR. KWICKLIS: Or more? That's an uncertain.

MR. POMEROY: Okay. Thank you.

MR. DAVIS: What's the level of uncertainty before you treated the stochastic versus deterministic?

MR. KWICKLIS: These are uncertainty in the effective hydraulic conductivity curves which Alan mentioned are the most difficult thing to measure, and we've been relying on these estimates produced from the van Gunecten functions for many years now without a large database of measured characteristic curves and if we're going to play this game where we try and estimate rocks based on calibration of models against the profiles, what we'd really need to do is to start pinning down these hydraulic conductivity functions more accurately than we have.

Within -- when I make the comparison between the predicted and observed hydraulic conductivity curve, there's usually an order of magnitude difference at some points -- in some ranges of saturation.

MR. HINZE: Well, again we thank you, and we'll move to Joe Rousseau who will be discussing the service base data collection studies.

MR. ROUSSEAU: My name is Joe Rousseau and I'm the project seed for the deep run saturated zone bore hole investigation program at Yucca Mountain. I'm going to be changing -- I'm not going to get nearly as complicated as these last three speakers have been. I'm going to be somewhat broad in my descriptions of what I'm shooting for, where we're headed with the program, some of the strategy and criteria that we've used to take a look at deep percolation processes.

Somewhat unlike the shallow investigation work, access is very limited and clearly bore holes are expensive. And what I want to try to emphasize here is that we're looking primarily at a thermodynamic process system. Though we do recover core and things of this nature, static type measurements that are made in the laboratory, a good portion of this work is done in the bore hole itself.

The things I'd like to cover during my presentation are the overall study objectives, what our bore hole fighting strategy was and the criteria that we used for the feature space drilling program, to give you a general overview of all the percolation studies or other studies that other people are doing that will be used to support our interpretation of how deep flux secretes to the water table, and briefly summarize some of the deep UZ percolation processes themselves; what are the thermodynamic processes

that could possibly be going on.

I'd like to spend a little time to discuss some aspects of the measurement program. In particular, we do have data that we've been collecting for over two years now in a prototype bore hole implementation program. I want to present some of that data so you can get an idea of what we're going to be able to measure down hole.

I also -- UZ-16 has come up several times already today. I'd like to review some of the presentation material that I gave at the NWTRB back in April in Reno, and perhaps update a little bit some of our current data that we have and probably not an understanding yet because I still there's lots of questions that are out there. Al Yang has some very interesting chemistry data. June Fabrica-Martin also has some very interesting Cory and 36 information on UZ-16.

Lastly I'd like to conclude by stating how I think we'll get to the point where we conclude the program. That is how have we achieved our study goals and when will we know that we're there.

MR. HINZE: You're good at anticipating questions.

MR. ROUSSEAU: The purpose and objectives of this study: characterize present day flux in the unsaturated zone to reveal the laboratory measurements of three things; properties, permeability and fluid flow potentials. These

are basically the crux of a study plan that we worked under or that I worked under in my program.

By and large what the emphasis has been placed on is the concentrated flux element. As opposed to some of the things that you've seen earlier that really look at matrix flow problems, we've set up certain criteria and strategy. Go look at those things at the mountain that might be the thing to give us problems.

This is a restatement of the bore hole siting strategy that is in the study plan. We wanted to target those areas, those obvious things at the mountain perhaps with the greatest potential. We have some generalized understanding of how matrix flow occurs. What we don't know is if we have some short circuits in the system, so to speak. And clearly when one views the mountain and stands back and looks at it, and says there's some real interesting structural features there. So our effort has been concentrated primarily in looking at structural features.

This is just the basic siting criteria; fairly simple. Large scale structural features, surface drainage features and topographic features. And we reduce that down to a subset of bore hole sites, where we'll be able to tell if we've got some serious problems with respect to fluid flow in the unsaturated zone.

The sites that we picked, UZ-1, UZ-14 clearly

UZ-1 was drilled back in 1983. We had to go back to the UZ-1 site, revisit it. Alan has already pointed out when you strip away the alluvial cover there, what you find in that wash is a fairly thick section of paintbrush stuff. That particular wash is quite different than when you get down for the south of the mountain when you don't have that kind of material there so that the unsaturated tuff itself is capable of moving -- taking water from any storage capacity and moving it laterally.

Pagany Wash drainage is probably very similar in character. We're seeing a hydrologic regime on the north end of the mountain that in my view is probably quite different than what we're going to see through the center section of Yucca Mountain.

The other sites that we've picked, UZ-16, bore hole already drilled; there's three other bore holes located at that general location. Imbricate Fault structure. Up to this point in time there had been no serious drilling in the Imbricate Fault itself, and we'll get back to looking a little bit at UZ-16 information. Two bore holes sited to go through the Ghost Dance Fault. Notice that all these features extend the full length of Yucca Mountain, north and south. Solitario Canyon or Fault, two bore holes.

We propose a multiple bore hole program as opposed to distributing single bore holes everywhere because we know

that we have to establish some sort of a scale relationship. What is going to be going on there? It's also my personal belief that we're not going to be able to target a site and do it absolutely correctly. You know, hindsight is 20/20 vision. We're going to see some things, we're going to take it slow; we'll do the best job we can. We'll do an analysis, come back and determine what to do next.

It very well might be that we don't have sufficient coverage in the northern end of the mountain, the way things are coming together right now. At the same token, the scope of the work that we plan on the southern portion of the mountain could in fact be reduced as we take these holes down one at a time, spend some time in the laboratory taking a look at the data, running geophysical logs, getting back together, discussing what we've seen, arguing hypotheses and opinions. And quite likely we'll probably end up, if we're smart, being able to reduce the scope of some of this, in which case I would recommend that if we're weak up in here, we move some of the dedicated resource from here up to this section.

MR. POMEROY: Joe, just tell me whether you did or not consider the possibility of using some slant drilling techniques in some of this work.

MR. ROUSSEAU: I alluded to earlier that we had one horizontal bore hole where we're going to target through

the Solitario Canyon into to Topopah Spring. I intentionally shied away from angled bore holes because one, we didn't have even a technology to drill a vertical hole; to drill it dry, to core it, to ream it. Secondly, I wasn't convinced in my own mind that a vertical hole will allow you to intersect a fault at one location that's any better than a vertical hole that might let you see the entire link of the fault system itself. Which way are you going to go? Are you going to see the fault in one datum or are you going to look at the whole structure, top to bottom? So that's -- I have not proposed an angled drilling, though it has been done in the north ramp bore holes.

MR. LEAP: Let me ask a question here. Could you show that last slide? On the Pagany Wash and the drill hole wash you have a fault with a question mark after it. Is it unclear at this time if those are faults or not?

MR. ROUSSEAU: It's not been to my knowledge firmly established that they are in fact faults. Discussions on those trends in there are they're probably stripe slip-tight movements.

MR. LEAP: Is there any plans in the works to actually investigate those to see if they are faults?

MR. ROUSSEAU: Geologic group does have plans to look at those systems.

MR. LEAP: I was going to say at this stage of the

game I'm surprised that they haven't been determined yet.

MR. ROUSSEAU: Well, they've been inferred but no one's taken them and formally given them names yet. So that's why the question marks are left in here.

For kind of a brief overview of deep percolation studies, not all the studies are done within the context of the study plan that I'm working under. I'm going to get back to the green blocks in a minute.

Our data source is basically our bore holes and multiple bore hole sites for this program. Within the contexts of the study plan we have one, two, three, four air permeability and bore hole testing program, fluid flow potential program, which is this, system implementation and monitoring program, and a vertical site profile program which I'm not going to be able to spend any time to discuss today. I gave the presentation on this to the NRC back in June.

The objectives of each one of these programs was shown to the right porosity measurements, relative permeability measurements, moisture retention curves. Basically these two are what you call the moisture characteristic curves for major properties. What is the average saturation and warp potential of a rock? Scale small because we work with core samples. Air permeability testing program; this is like bore hole work to look at

fracture and matrix permeability combined. We can't get the fractures up in the core and test them up in here, nor would we have any idea of how they're interconnected. This is a medium to large scale testing program. In a multiple bore hole environment it becomes large scale or we might be looking at air injection in a host bore hole and satellite bore holes or there could be 200, 300 feet away.

Fluid flow potential measurements, in-site measurement, temperature and water potential. These are the basic fluid flow potentials in an unsaturated zone. To determine fluid directions in gradients look at the system stability. How long does it take for that station to come back to equilibrium. It tells us a lot about the dynamics of what's going on downstairs.

This program is also designed to support a bore holed diffusion testing program probably much later in the monitoring program itself and also saturated permeability testing program. So we're configured to support that in the event that we want to go look at pure diffusion-type process. Before we can study diffusion, we need to know what the pressure system really looks like. This is considered to be a large scale-type investigation. The vertical size is a 3-D subsurface imaging technique that we intend to deploy at UZ-16 and if successful there, at UZ-6 at the crest of the mountain. Its purpose is to image the

subsurface across the middle section of Yucca Mountain.

Look at geologic structure, fault fracture system continuity. Some very primary objectives in here. One is the Imbricate Fault structure, Ghost Dance Fault, Solitario Canyon Fault. Very large scale.

The three green blocks of support percolation investigation. In your handout, Cory 36 says 50 years and that's probably what should be sitting on here -- can be used to do time dating of water in the 40,000 to 900,000-year range. The 50-year range is for your chlorine 36. This is Los Alamos investigation.

I do chemistry work that Al Yang is doing in the bore hole. That is from core samples of water and gas samples. Dating of water and gas for water chemistry, gas chemistry, and Al Yang will get into the details of this, tritium and carbon 14; here's the scale, the time scale that we're really working with here. Gas flow investigations -- this is Charlie Peters' program now. To look at collective gas flow processes primarily in open bore holes where the bore hole is allowed to breathe complete, top to bottom, produce a maximum flow gradient into the blow hole and is considered to be a large-scale-type test.

Very simply, the percolation processes have already been addressed to some extent earlier; they are not much different than shallow infiltration processes except

perhaps we don't have nearly the thermodynamics going on nor are we close to pneumatic pressure, wind effects or things like that. What was discussed earlier today, there's a matrix-type liquid flow. This is where most of the modeling forecast's been done. Some specialized modeling has looked at matrix fracture flow which Ed Kwicklis just presented.

One aspect that hasn't yet been integrated, to my knowledge, to any extent, this is vapor transport problem which involves the future processes in convection -- these are all the types of processes that I can visualize in the most simplistic form that would define or describe to some extent how liquid and vapor move through Yucca Mountain.

This next section will just briefly look at some of the features associated perhaps with convective gas flow. I want to go through three overheads here and then present some data from a monitoring program that we're over two years into right now, and that data will illustrate what we've been able to measure and also perhaps before we have to change gears a little bit, just maybe how important some of this stuff is.

Pneumatic pressure is the primary driver in convective gas flow. There are clear barometric influences that are driven by diurnal pressure changes, seasonal pressure changes, and storm-related events that are occur almost on a frequency of 7 to 10 days. What drives this

system is a pressure dampening process which can, in fact has been demonstrated to occur across the upper paintbrush tuff. When there's a lot of moisture in the rock, pressures tend to damp across that. That can set up a gradient effect to the deeper rock that does not -- one lags or -- yeah -- lags that pressure pulse coming in so that the flow can in fact move up or down. We're going to see some of this activity in the shallow bore holes that we have.

Topographic influences -- and Ed Weeks has gone into considerable research in this area in the open bore hole testing program. The upper crest of Solitario Canyon system has been well written up. Gas flow at UZ-6 and -6S. There's also this interreach depression process that could be going on. We don't know yet for sure. There was some indication that there was some movement, a natural convection process is going on at UZ-16. There are buoyancy effects which are primarily driven by temperature, high temperature, light gasses at deep depths and vapor can rise naturally.

Equilibration time, once we establish an instrumentation or pressure will probably be on -- equilibration meaning when do we have a representative measurement of pressure and not rely so much on the equilibration of the senses itself. It's fairly rapid. It's a few days or weeks for that type of measurement.

Temperature parameter primarily drives conducted heat lower from geothermal gradient to discharge of heat through the unsaturated section. Liquid floods itself can influence that. It could have an effect on what the thermochronic properties of that material are. The more water in the system, the greater the heat capacity that system is, you're not -- probably going to see very steep thermal grades.

I did some recent work at looking at what John Sassas has done years back, trying to reflect back on what's probably happening at UZ-14. That entire canyon has a thermal low grade, which is probably, in my view -- and perhaps because it could in fact be indicating to us that we have lots of water in that paintbrush tuff. And that water sitting down there is eating up the heat flow coming into the mountain. We need to do more work along those lines.

I looked at G-1 in particular. Very interesting coincidence of events. The bore hole was completed in September and they measured the thermo profile in September. A year later they came back in and did the same thing. Maximum thermal disturbances occurred in the saturated section. Minor thermal disturbances occurred in unsaturated sections. So that might be a priori evidence to try and get a handle on this problem of where did the water at UZ-14 come from. It wasn't all lost at one horizon. I think

that's just an indication of where we might use that information.

What goes on -- I have an advective heat transfer process; it can occur as liquid or it can occur as gas. We believe we can measure advective heat transfer and I will show you that data from the HR bore holes. There are also latent heat and vaporization processes that can serve as heat sources or heat sinks. We're not sure yet whether we can get down to this level of measurement to look at the activity, the thermo dynamic activity at deep depths. Equilibration time would be on the order of a few months given the way that we're drilling these holes now.

The last type of measurement that we take is the water potential measurement. It's used to define both the liquid and the vapor flow system. We use thermocouple sychrometers here; we measure it in the vapor phase. We do not make an attempt to try and measure in the liquid phase. It's not practical to do so in very, very deep environments. We use this information and Ed Kwicklis kind of alluded to it a little bit; he's already given you some examples where you can use this information to discriminate possible wild flow mechanisms. We use it for both vertical and wild flow descriptions of flux in the rock. The vapor component of it is directly related to the measurement itself because we measure the relative humidity or the vapor concentration of

the gas. This sets up the fusion gradients.

Equilibration time we've observed from G-tunnel work, from work UZ-1 and from work of the HR bore holes from anywhere from a few months, dynamic activity, lots of things going on, lots of gas exchange, lots of heat flow, to very slow. Processes that might take several years to get to a stable equilibrium.

I emphasize here that stability or equilibrium itself is not necessarily important to achieve. What is important is to see how quickly things can recover. The measurement that we're making now is extremely sensitive to any pressure disturbances and any temperature disturbances.

Now I'm going to jump to some monitoring data that we collected. While you're on your trip tomorrow if you do stop at the laboratory I will be there, and I will be able to show you this ongoing experiment. These are the sychrometric records from four instrument stations and a bore hole we instrumented in October of 1991. The stations -- the purpose of this work was to characterize the sensors. How long -- how accurately can we read them, how long would they last, did they drift, what is it that we're going to need to achieve success in deep bore hole testing programs?

Three stations, one located at 40 feet, that being Station A, and Station B being 30 feet, Station C being 20 feet, and Station D being 10 feet. The record with the most

activity is Station D; it's only 10 feet deep. This rise that you see in water potential here is due to the winter precipitation of '91, '92. We moved from a very dry state, somewhere around -70 bars or greater, all the way up to about a -10 bar suction. Then it fell off through the summer; it dropped way off. What you see here is the winter rise; this starts to occur around September and this is vapor movement. You're not really seeing a change in the moisture content in the material itself. What you're seeing is condensation of vapor; in the wintertime we have the maximum amount of pressure activity occurring. The movement of apparent water potential from this level to this level up here has nothing to do with infiltration. It's warm vapors moving upstairs and getting cool and condensing.

All this activity you see here is the drydown effect would go off-scale, occurring in the summertime; it would pick up another winter precipitation event that occurred '92-'92, and we move from almost an initial state. You can see a trend in this data. You see a trend. And we're right back up; we're coming back down. Now we're in the winter cycle, going into winter cycle again, and we're seeing vapor moving up and condensing.

This station equilibrated rather rapidly but there's a lot of dynamic activity going on. Station B -- let me drop Station C. We see equilibrium of Station C at

this point right here, then it falls off. What you're seeing here is the response of the psychrometer to tiny temperature changes. There should be a roll affected here. What you see here is the precipitation that occurred back in here infiltrating down from this level, Station C being 20 feet deep. Then we go through the summer cycle, things drying down, and what do we have over here? We probably are seeing now the precipitation coming in from the winter precipitation of '92-'93.

You go a little bit deeper, Station B -- it gets a little confusing because I always want to number my stations first thing so I'm sure it's there, rather than the other way around. Anyway, Station B achieved equilibrium a little bit later, rolled in, correlates quite well with the temperature profile. Now we start to see Station B pick up precipitation that occurred back in here. Rising up, drying down a little bit, and we're 4,000 -- let's see -- 19,000 hours; we're about 4,000 cycles at this point.

Station A equilibrated right over here. This is the best we can guesstimate. This drop that you see in here is a gas sampling test that we ran to make sure all of our sychrometers were running correctly. But we believe we achieved equilibrium at this point.

Now, I'm going to take another data package and look at one singular station where it got all the fake

variables plotted, Station A being 40 feet deep. This is not a very large temperature altitude; about .3 degrees Celsius over the course of a year. Here's your pneumatic pressure system; as you can see in the wintertime, very, very high dampdown and then climbs back up through the summer and then when you get back into the winter you see the highest frequency movement occur.

As I pointed out, here's the equilibrium position here; here's the temperature moving back up. There's a nice little thermal trend in here that's probably not related to disturbance of the bore hole. The bore hole was drilled with an outer rig and instrumented almost immediately. I believe this trend is telling us that we've had an infiltration, a pulse come through the system. We've changed the thermo dynamics of the system now and the temperatures are moving up.

So if you superimpose another temperature wave on all this you probably see something like that. This is the yearly frequency of the temperature and there's another -- if we get another wet year again, it'd probably go up again. This difference in amplitude is fairly tiny. This is like .03 degrees Celsius between here and here.

This is the gas sampling test we pump for 21 hours. You can see that we didn't return to equilibrium immediately, but it took us about 30 days till our system

settled back down. Similar type record at 30 feet depth, temperature amplitudes are much greater. We also see the slight trend in shift in the cold spots and the hot spots. There's original equilibration, and this is water influx coming into the system. Pressures are -- I didn't go -- there's a lot you can do with this data. It would take a long time to go through all the fine features. I just want to give you a sense of where I think we can measure in the deep bore holes.

I am going to show you some information right at this point here, and this is where the temperature rolls over and we have minimum influences of heat conduction going on.

That's that 900 hour record where the top temperature peaked out. This record illustrates the barometric pumping process going on. The temperature top to bottom here is .03 celsius, so full scale temperature, .03. These temperature disturbances that you see here are on the order of three-thousandths of a degree celsius. They are responding one to one with every barometric pumping weather front coming in and out, in and out. Water potential is still trying to equilibrate, but you can see that it is also responding to this barometric sort of pumping effect. This is the depth of 30 feet. We could do the same thing at 40 feet. The records repeat themselves.

What we pick up in our instrumentation programs, we pick up the diurnal pressure changes, 30 feet. We clearly got the weather front coming in. Here is your diurnal's again. Now, we are picking up the temperature changes in diurnal. If you were to expand this again, you will see that you are seeing changes in measured water potential. This is over 900 hours of time. The bore hole had been operational for over 13 months at this stage.

I am going to switch gears now and take a look at 16. As I pointed out earlier, some of our siting criteria. We picked 16 inside of WASH, actually confluent at two drainage, this being Well Back Ridge. We decided to put the first one here. These are traces coming off of an area photo of what the fault structure might look like. We don't know for sure where the fault is. We will start right here and find out what happens.

What I tried to show here is, this is a potential for concentrated recharge. Alan pointed out earlier that we might not be seeing too much flow in the thick alluvial section here. It's about 27 feet thick. We may be losing a lot of that. All the data so far that we have gotten supports that.

The multiple bore hole testing idea would put a hole here, perhaps, and maybe move one over here into the active drainage and maybe one over in here. For right now,

this is where we are. The other two bore holes we plan to drill at Ghost Dance Fault, we want to get right on the fault to start with and see if we can run the bore hole all the way down the fault.

Here is the 16, summary of our preliminary findings. The Imbricate Fault that we intersected was almost vertical. We had excellent slip and slides to make that determination. We are looking at 85 degree dip on the fault plane. Fracture density because of the site that we picked at Topopah Springs, is much greater than earlier estimates that range from 50 to 250 per cubic meter. That's to be expected. We are in a tensional fault system. We are right into it.

The average that had been used previously was like 125 versus 50 here, from Montazer and Wilson. We encountered water and fractures in the prow pass unit, and I want to get into that a little bit. There hasn't been a lot of discussion about this water encounter so far today. It was a non-saturated matrix environment.

I need to back up and review a little bit of the history of what happened when we hit that water at 16. We took the bore hole down in five foot core sections. At 1,600 feet we drilled five feet of dry, five feet of dry -- when I say dry, I mean relative. It's not seeping water. We hit a fracture at 1614. It released water to the bore

hole immediately. I asked them to drill five more feet, to make sure we had enough water here to sample.

The water released instantaneously. This is quite different than the water occurrences at 14. That was a very slow leak to the bore hole. This was a flash event. The water just came right out and filled the bore hole up. We got some water samples here. We didn't get a water level measurement because we didn't have the equipment. We are estimating that it possibly occurred at this point, though it could have been higher. It could have been at this later established piece of metric level, at 1605 feet.

Two days later we continued the operation. We reamed this section out, and there's lots of water in there. The water came up as part of the reaming operating. Then, when we got below this level here we reamed again, but the reaming materials, the cuttings came in dry. Then, we did five, five foot core runs and we didn't have any water. A day later there was a little bit of water standing in the bore hole. Interpretation is, it's leaking from this zone up here that we first tapped.

I think it's important to recognize that the flashing bed of that water versus possible interpretations of where it might have come from, I am tending to think now that the water is actually going to be derived from higher up in the section, likely the Calico Hills. Al Yang has

some very interesting chemical data that will establish the character of that water with respect to water table water. For everything that we could see when we went through this process, it doesn't look like the water came from the water table.

Moving on to the next day, we found a little bit of water, enough to tag a water level. It didn't mean anything. The rest of the section was dry, reamed and cored dry, and no water. We got down at this level, at 1650, two five foot core runs and found a little bit of water here and bailed a little bit of water. Then, we drilled the core out and it was dry. Then, we hit saturated core at this point. From there on down, five, ten, 15, 20, the entire section was saturated. Here, we bailed out 200 gallons of water. You can see what's happening to the water levels here, they drop off.

When we hit the water at this point here, the water level came right up to here, 1605. Basically, other than taking this 200 gallons out, it stabilized throughout the period. It's pretty stable at 1,605 right now. That's a little bit of a back drop to what happened when that water was encountered.

Here's some information. I am going to go over this pretty rapidly, because you have seen a lot of this already today. Alan pointed out the five curie neutron

moisture meter device that's being used. It's an excellent tool. I think we are going to get some really good capabilities here to extend our knowledge into bore hole environments, where we didn't get that data earlier. Phil Nelson and Alan, in particular, are doing a lot of work trying to correlate this to matrix hydrologic properties.

The traces that were seen, you see a very marked change in the saturation at Calico Hills at this point. We will see that later. A drop off at the Prow Pass, it's a very sharp mark. Up in here we think it's very dry. You can see the strong correlation of these traces to fracture densities correlated back to whether we are in a lithophysal or non-lithophysal unit. The non-lithophysal unit gives you much more fracturing. Water contents tend to be higher in that type of material. You get into the lithophysal and the fractures drop off, and water saturations tend to drop off too.

Lots of information packaged into one slick little log. I think that once we get correlated values back on that we can go back to lot of other holes and re-establish what maybe saturation profiles look like and things like that.

More information on that hole. There are several of these overheads that just basically correlate information. What we found out with fractures in this bore

hole, they are predominantly are vertical. This attempt to show medium dips of fracture says that over half the fractures let's say were greater than 88 degrees, and all the rest of them distributed on the other side.

There are special types of fractures that especially occurred in the lower Topopah here that contain bugs, or secondary permeability porosity features. I don't know what the full significance of that is yet to what's going on. I don't have this record complete, although the data is available in the medium dip of fractures.

MR. HINZE: About three minutes, Joe.

MR. ROUSSEAU: This is the current porosity profile. You have all seen this, so I won't repeat that. The volumetric water contents, correlation between voracity, high volumetric water contents. You have seen all of that earlier.

I want to get to some information that became available this morning. What we are showing here is the fracture density and water potential in bars. Now, this data suffers from the fact that the measurements weren't actually made close enough in time to when the core was sampled. We have been able to recover some of that information that I am going to show you on the next trace. Everyone doesn't have this, but I have passed this around to the people at the table. You may have two versions of this,

but I am going to use this one.

When you look at the water potentials, there are two measurements of water potentials here. The ones shown in red were done from cychrometer samples stored in jars. The ones done over here were done from calculations used in saturation measurements and moisture retention curves. What we are seeing in the Calico Hills is an almost 100 percent saturated material.

This line that you see down here in green traces what the water potential profile should look like with no flow. This profile is corrected for gravity head. At this point, being the elevation that you are, you should have about a minus 50 bars. If you were to trace this down you would have a very smooth, theoretically, very smooth water potential profile.

Here is what it might look at .1 millimeter of flux and .05 millimeters of flux. There's a fairly significant break right here. What I have not been able to establish but I think -- and we will see some interesting chemical data coming in here -- at this point, at 1,150 feet where the basal vitrophyre was encountered, small trends in chlorine 35 were picked up by June Frabrica at that point. I asked her to look at that when she did her first measurements. I don't know what the significance is of that is at this time.

High tritium pick up at this point here. What I am suggesting is that perhaps the water we saw at UZ-16 came from a fracture that is basically tapping the Calico Hills here and draining water out of the Calico Hills. Fracture did not recover water from downstairs until after we got to saturated section. It did not do that. It drained its water. That's why I think it's quite possible that we have seen fairly recent water, perhaps connected to the fault system, that was encountered at 1,150. There are some preliminary indicators right now chemistry-wise, that would indicate that.

Clearly, we need to confirm it. I think we can get the confirmation from the additional bore holes that we had intended to drill at UZ-16. I know that I have run out of time, and I know that people have to move on. I don't have enough time to finish it. I can stop here.

MR. HINZE: Thank you, for the comprehensive discussion. Unless there's a pressing question we will wait until Al Yang finishes his material. Al, can we call upon you then, to discuss with us some of the hydro chemical characteristics.

MR. YANG: I am the Project Chief of Hydro Chemistry, UZ Hydro Chemistry. I am going to talk about some data we collected from Yucca Mountain UZ bore holes.

The objectives --

MR. HINZE: Al, could you make certain that you are speaking into the microphone. We do want to make certain that we hear you.

MR. YANG: The objectives to understanding gas transport mechanisms, direction in the travel time at saturation zone, then for the pore water we try to extract some pore water that has no contamination and represents the initial preparation water. Then, to provide the independence evidence of the water flow direction, water ages in unsaturated zone. Then, to determine the extent of water interactions in the Yucca Mountain.

The method we used, this is for the gas phase. We have a gas phase chemical investigation from the bore hole. We collect the gas sample, transport it, prepare it in the lab for analysis, and then analyze the gas sample. Then, make some interpretations, and we need more further collection of the sample and go back here and cycle this. For the analysis of this mostly by carbon 14 gas counting, tritium by liquid saturations, stabilizer by mass spectrometer, tracer gas by GC.

Then, some of those preparation of the gas sample in the lab is, we collect the carbon CO2 sample by the molecule sieve, trapping the molecule sieve and release it. Some of the water is trapped in the core traps.

Some collection the sample, that already has a

tube going down hole, so we have carbon dioxide can be collected from those pumping up the gas to the surface. We have the hexafluoride as a tracer gas to see the air contamination. Water vapor we collect and we measure for the O-18 analysis.

For the aqueous phase it's the same thing. You collect the core sample, analyze the water and interpretation, go cycle again. We know we have loss of the water using the protocol. I think Ernie talked this morning, transport of seal core to the damper and analyze in the damper. Extract pore water by the compressions, that's what Ernie talked to this morning. Analyze the water by carbon 14. The small sample you need to use in the tandem accelerator. It's a very small sensitive accelerator, and we only few pieces. There's one at Livermore, Woods Hole, and I think one at Princeton.

We have to send out for these analyses. In-house we can run the stabilizer and send out to Reston, and chemistry by ICP and IC. Ion Chromatograph and iron copper plasma, using those for the chemistries.

This is how we extract the water out. We modify some of those compression cells. This is a cell. We have the rock sample in here with the actual pressure, this confined pressure from the side and squeeze the water out and it comes through the syringe, so there is no contact

with the air. The water is just flowing through the syringe and stays in the syringe.

There is some gas coming out from these rocks too, so the beginning is the gas coming out and later on is the water. This is how we are using this water, measuring the Ph conductivity and do all the chemical analysis on these waters.

The data that I am going to talk about is from UZ-1 is from here. Joe Rousseau has been talking about that. That's only for the gas sample because we don't get any coal from this hole. All the rest is cuttings. What we can do on this hole is only the gas. UZ-4 and UZ-5 is around here, on the permi wash. Those only got the coal. We didn't have it. Casing down there, we couldn't get any gas sample. Only the water sample in UZ-4 and UZ-5, and I have some data from UZ-16 in here. These are the water portion I will talk about, and in gas phase we are talking about UZ-1.

What kind of isotopic we are going to measure, hydrogen. Tritium is a radioactive and has a half life of 12.35 years, so you can use this to measure the tritium activity in the waters. The carbon 14 has a stable isotopic of 13 per ratio. We are using this to determine the source of the carbon or where it comes from. The carbon 14 is radioactive with half life of 5730 years, so we can measure up to 40,000 years on the ages.

Oxygen isotopic, because of the oxygen, 18 to 16, this is too small to measure. There is abundance in the nature, so we are using this 18 to 16 to trace the source of the water and where it comes from.

This is the gas, UZ-1, as I told you, UZ-1 gas data. We correct for the CO2 gas pump from the in situ. UZ-1 hole has a 15 zones. We have a sumping tube going down each zone and pumping those gas up to analyze CO2 concentrations. You can see we stop about ten years data so far now, from 1983. You see the air/CO2 concentration is about 0.03 percent in here. You can see at the very beginning, because of the drilling going through the hole, a lot of this is air, drilling air. That's all we saw here.

As the time goes we pump in this hole and clean up all of this, and the data get tossed more in situ concentration now. You can see going up to 0.1 percent by volumes on the CO2 concentrations and 1987 up to here. Here, we see all the air is going up so we are sure that we are dealing with in situ gas and not contaminated gas. We trace that by the SF6. We measure the SF6 and take this data in here, and this is the percent CO2 now. High concentration near the surface that's from the root respirations. A lot of CO2 come out from these root, from the plants growing there. Some of them fractured out a bit at the very bottom. You have increase in the CO2

concentrations as year goes by.

Now, why this concentration was so high compared with this area. CO2 is moving down from the surface down, concentrations should go like this, keep on going down. Now, you have a high concentration near the bottom. We traced that back to the G-1 drilling. During that we lost about a million gallons of the drilling. That, you find in the G-1 drilling near the bottom, that water.

I think these are from those organics, decay of how many years increase in this. Right now, I think advantageous to us to using the CO2 high concentrations to monitoring it for the next several years, how fast it's moving up from this site coming up. I think that's important information, like CO2 radioactive carbon 14 coming up from the nuclear waste. This may be a good source to study on that. Monitoring this, as the time goes by now.

This is the one that you are dealing with the CO2 carbon dioxide. You need to know the source, where this carbon comes from. This is the form at near the surface, root respirations. Most of the 1312 ratio in the CO2 gas is about here. You can see, it has a depth going to about 380 meters. It doesn't change that much.

This bring up the morning, I think that BIER IV is asking about, the gas phase and the liquid phase was 30 phase interaction between those, of the isotopic ratio. It

seems to be that the calcite is in the Yucca Mountains. If calcite is about here, the ratio is about here, 5 to 8. If this is in tact with that, this ratio started to come toward this way. We didn't see that.

It seems to be there's not much interaction going on between gas phase and water or any phase of the calcite to exchange it. We think the carbon 14 aging may be good, because calcite is one million years old or ten or 50,000 years old. The carbon 14 is pretty consistent for the last four or five years. You can see the trends -- maybe I need to explain, what is percent more, what it means. In the carbons during the 1950 in the tritium in the air, that's concentration of the carbon 14 defined as 100 percent. The reason we have a higher than 400 percent is nuclear tests in the air. In 1954 and in 1963 produced a lot of carbon 14 there, then they determined in 1950 there is 100 percent of the carbon 14 concentration in the air. That air is about 100 percent carbon 14.

This is why it's higher than that, due to the nuclear tests. They produced a lot more carbon 14 in the air. If 100 percent of this starts to migrate down, it's slower than in the Topopah Spring unit here. Topopah Spring is more steep. What that means, this range gives you -- the horizontal bar -- gives you the times. This does give you the distance. The gas travels from this point down here

at faster rate and from here to here at a slower rate. This is the time longer time, we show distance.

I think it makes sense near the surface here, as we go through the fracture flow -- Alan Flint said this morning, surface fracture has been sealed by the carbonates. It may be taking longer in the Topopah Spring Units because it's more open. Gas can transport faster, and maybe it's faster rate of transport.

We have modeled this data, carbon 14 data, with the diffusion models. I think we have that in here. You can see the steady state diffusion and decay were pretty well from here with the data. We have observed in the calculations, it seems to by the diffusion that the transport of the gas since it's by diffusion concentration gradient, and slowly diffusion is through this. If this is the case, this morning one of the Committee members raised the questions, if the air is breathing at the Yucca Mountain are you going to effect any of those things.

It seems to me that if the diffusion goes slowly diffusing it and breathing is one effect in here, once it -- the hole stands. When it's open -- we saw most of the hole at Yucca Mountain is breathing. There is air coming out. Once it is -- it doesn't effect for those gas transport. If it's a transport it won't be in the diffusion, something like this. This is only one hole. We

need to check on other hole. This is simply answer to the question this morning about breathing effect on this chemistry.

Now, I am going to talk, this is the gas phase. I am going to talk about the liquid phase now. Now, I am starting going to talk about tritium. In order to make you familiar with what the tritium units, I had definition put in here. Tritium units, what does tritium unit means. It's the concentration unit of tritium in water.

The one atom of the tritium in ten to 18 atom of hydrogen, that's what you define as one tritium unit. In the water it's equivalent to about 3.20 pico curie of the water. Next, before you look at this data here what that means, let me explain it again. Before 1950 tritium is produced in the air constantly by the constant bombardment of the atmosphere, and they are producing the tritium.

Since the formation of the earth the tritium was formed every second. What the concentration in that has been measured, it's about ten tritium units. As the time goes down to the underground, it started to decay. After 12 years it becomes five. Another 12 years, it becomes 2.5 and just decay to about 100 years, and then you don't see it.

Now, since 1954 there is a nuclear test in the air, and Soviet and U.S. explore a lot of this. There is a lot of tritium formed in the air. Lot of people using this

high tritium concentration as a tracer to measure the water. That gives you, if the tritium concentration is higher than ten or something like that -- since 1954 or 1953. This data will give you some idea if it's the recent water or the old water. If you look at this data, if it's less than ten, it's maybe before 1950. It depends on how many tritium units that maybe decay, maybe 100 years.

If you see some higher right now at the test site on the air on the rain water, it's about 30 to 40 tritium units. That's what we see right now. In the past it's higher, especially since 1963. Now you can see from UZ-4 that has been mentioned quite a few times, near the surface about here about 20 to 30, then you decay to near zero at this depth, about ten meter. Then, there's a fracture on the UZ-4 around here and then high moisture content on the bedded tuff. Then, you see the high tritium again. High tritium units. This high tritium units is more than water.

There, I get to zero the old water about 100 years or beyond the 100 years old, then come in here with the young water. How they get there. It cannot be vertical preparation. It has to be some sample of something.

The UZ-5, the next one, it stills show the same thing, the very high moisture content, very high tritium. This is not only in one hole. Another hole -- he told you about the carbon 14 ages. You can see here where the carbon

14 age at the top of the Topopah Spring on the UZ-5, is 49,000 years. Then, if you look at the UZ-4 not far away from here, near the bedded tuff near the top it's 1,000 years with the short distance of not that much age difference. It cannot be vertical. It has to be horizontal flow coming from someplace else, such a large change in the ages.

Again, on the UZ-16, we see the same thing. This is on the bedded units, Tbd. Tbd is a bedded unit. We see the very high tritium units. Not any one hole, many holes, and all the same thing consistent with a high tritium. This is in the Topopah Spring units, we see the few area of the high tritium. This is about 20 or 25. Recent water is in here.

This one, there's a high fracture around this area. It's very surprising, in the Calico Hills, other data show that it's very old. I will show it to you, Calico Hills water is very old. We see some of the high tritium in here. Is this true or not? Now, we need further investigation on this. Is that possible. Other data I show very old water. If you have high tritium concentration - you don't need much -- you could get that data in years. It's not the whole body of water that's young. A little bit of the high tritium concentration goes through the fracture or something and drops into there, you can create that.

We still have to further investigate on these things. It's very low concentration about here and high tritium below that unit. This is occurring all over the Yucca Mountain. So far we see it from UZ-4 and UZ-5 and UZ-16.

MR. HINZE: Can you briefly say how you are going to investigate the origin of that?

MR. YANG: The origin?

MR. HINZE: Yes, the origin of that, the young water.

MR. YANG: It's coming from the -- sometimes comes from the fracture. That's why we still don't know. Only one hole. We can trace that flow path and we know how they get there. Right now the impression is, either from the exposed. If the bedded unit is exposed maybe the rain coming down or through the fractures, rapid flow coming in and the bedded units and coming here. That's all I can say at this stages.

This is the chlorine 36. They show the same thing. This is by the Fabrica-Martin, his focus 93 paper. UZ-16 on the high concentration near the surface, and then coming to almost stagnate and up again on these bedded units. Then, going down again near the Calico Hills you come up again. This has been occurring, the same thing as tritium, the same thing as chlorine 36. The same

concentration below the units, other units. This has been proved again and again with all of this.

This is the oxygen build up stable isotopes. If you are not familiar let me explain what this means. Usually under the cold climates precipitation is very depleted. That's minus here. If it is during the summer or warm climate, precipitation water is up here. If you see -- you can see from here, this is Calico Hills.

A lot of the Calico Hills unit is all very depleted. What that tells us is, Calico Hills water is the last ice age water, 18,000 years ago. I still don't have that carbon 14 age yet. This data tells me that it's old. Either you don't get this -- you can see that most water in the Topopah Springs here, all around this ranges here. This is very depleted. It makes sense. Calico Hills has a long time that the water sits there for a long time. This is also supported, this is 0-18.

Let me go through this too. Joe Rousseau has explained, some of this is perched water. Below that, we have groundwater. Joe Rousseau is explaining, is this the same water. Is it perched water or the groundwater. My data shows exactly the same signal. That perched water is actually comes from the same as the groundwater.

I don't know when it's there. Maybe it sits in there. The chemistry tells me this is not chemistry. This

is oxygen 18 is the data -- tell me they are the same things.

This is for the Delta-D. It's, again, the same thing. These are the perched water and these are the groundwater. They show the same signal. It doesn't make any difference, all of this. Still, the Calico Hills is very old, near the minus 117 from the Calico Hill. Near the surface more modern water is higher in warm climate and all this in here. We still have some data missing in here.

One more thing that I would like to say is, here is the groundwater in here. This is Calico Hills old waters. How they get this to here. If this is drained from this, this signal should be the same about here. This is somehow going to someplace else and it's somewhat at fast pass coming out and coming out here. That's what the BIER IV is talking about. There's a dry area around here this morning, about bedded and it's very not saturated. It seems to me that the water doesn't come through here, and somewhere from someplace it's coming up here. Seems that every unit is by itself.

This is the plot, the Delta-D, 0-18 plot. This is the precipitation, the water. During the summer all the data fall in here, during the winter it falls in here. This is Yucca Mountain precipitation line. Why the slope is lower, because of the evaporations when the rain falls

through the air. The dry in the Yucca Mountain area, the water evaporates. When that water evaporates the lighter ones evaporate first and then the heavier ones. That's why this side toward this site gets heavier and this one toward down gets heavier. That's the Yucca Mountain.

These are the pore water from UZ-16. It seems to be permil to this Yucca Mountain line. The Calico Hill units is very low in here, so that's permil water. If you put this line through here but away from the precipitation line, what does that tells you. When the rain water is falling on the Yucca Mountain surface it's infiltrated and going to that deep -- it should be following on this line. The source of water should following on this line. They deviate from that line, due to evaporation before in that top few meters or so, they evaporate or they run off. They evaporate and make it heavier. Then, they form in this.

This tells you the history of the water before penetrations. They have some evaporations going on before they evaporate. If no evaporation, this dot should fall all in here. That's what the isotope can tell you.

I don't have that many carbon 14 data. I am going to tell you how I approach on the carbon 14. The source of the carbonates by carbolic acid, this is the root respiration near the surface. You have a CO2 form from the root respiration and have a rain water coming down, you have

a calcite near the surface, they react from the bicarbonates. It is the bicarbonate that we are dating on the carbon 14, to see how old the water is.

This is the initial activity. Either the calcite is very old -- carbon 14 concern is zero percent, it's dead. No carbon 14 in there. This is the root respiration, 100 percent. The carbon 14 signal usually says this is zero, for the plant it's minus 25. By analyzing this carbon ratio you can tell what the source of this is. It comes from the carbonate.

Another way of forming the bicarbonate is from the silicate rocks. The silicate rock, you still can't form bicarbonates. You can date in on this water. The silicate don't have any carbon like a calcite. If this is CO2, 100 percent, you get 100 percent, 13, 13, 25. By analyzing this you can tell what the source of carbon comes from, what kind of reaction is going on at Yucca Mountain to forming this water. If this water is 15 percent, this is the very beginning. This already gives you a 5,000 years old. Does that tell you it's actually 5,000 years old, no. This is just formed at the beginning due to the chemical reaction. You have a 50 to 50 percent resolution by this.

One carbon from here, one carbon from here, you are forming these two carbon. The age is already 50 percent old. You have to take this into consideration when you are

dealing with the ages, carbon 14 ages.

Besides that, you have a CO2 gas exchange. Any exchange going on can figure carbon 14 ages. CO2 bicarbonate can be exchanged with the carbonate in situ. All the changes can occur -- you have to take into this all these considerations.

There is a model. Right now, about six or seven or eight models being used for dating all this. You can put those chemical reaction and exchange taking into account, and you do all these exchanges and calculate how old the age is. This approach, we are going to take correction for the carbon 14 age once we get those carbon 14 data back. We will analyze the 1312 ratio and see what their number is. Are they silicate solution or calcite solutions. We can correct for the carbon 14 ages.

Now, this is for the chemistry. Again, why the Calico Hills is old. You can see, this is sodium concentration is so high. Usually the very young water is the calcium bicarbonate near the surface. As the water moves through the ground it gets older and older and becomes a sodium carbonate or sodium chloride waters.

You can see sodium chloride near the surface. Near the Calico Hills is a lot concentrated. This is the calcium, and it gets so low and high in sodium. From the calcium near the calcium bicarbonate water to become sodium

and next, sodium waters. This is for the carbonates. You can see, again, carbonate is a lot higher. Carbonate then starts to get lower.

This is the same thing, again. I told you about this is the perched water on the UZ-16, and this is on the groundwater. The chemistry is the same thing. This chemistry of this perched water here doesn't fit with all this water here. What I am saying is, the perched water is the same as the groundwater as the perched water. My answer as it is now is, no.

The same thing in here, you can see all this three part is all the same thing. The chemistry shows that, stabilizer shows that, it's the same water as the groundwater. Again, all these is the same chemistry. All the chemistries show the same water. The chloride is about somewhat high. We have some of those precipitation chemistry this morning. There was a question about how some of the chloride is about here, some of the high chloride.

In summary, the gas phase carbon 14 during the UZ indicates faster transport of CO2 in Topopah Spring unit than in the Tiva Canyon unit. The gas forming is from the gas diffusion. Tritium from UZ-4, indicates preferential flow path. The same thing show up in the chlorine 36 data. High tritium in Calico Hills needs to be further investigated. That's what I mean. It's maybe true, maybe

very slow getting here, some flow fracture getting here. We have to from other source, verify that point. It's important. It could be contaminations. If the contamination is in the lab or anywhere else, we have to solve that out. That's what we need to further investigate on that.

Pore water chemistry from UZ indicate calcium bicarbonate type young water near the top 20 feet and sodium carbonate type old water in the Calico Hill unit. Before I even get the carbon 14 ages I can tell that Calico Hills is old. That fits to the theme of what we think.

The stabilizer data from UZ-16 indicate Calico Hills unit water is very light in both oxygen incitation on the paleowater. UZ-16 pore water stabilize data on deuterium versus oxygen diagram, indicates all data to the right side of the Yucca Mountain precipitation line. This is what I explain water evaporation.

MR. HINZE: Thank you very much, Al. You stayed on time. We very much appreciate that.

MR. SACKETT: Do you use an enrichment technique for tritium?

MR. YANG: No. Right now here, mostly what we are looking at is any water contaminations. For the enrichment, that is many you want to see ages. You want to see the age, 100 years old or how many years old, you need to go through

enrichment. It's expensive and takes a long time.

MR. SACKETT: What is the protection limit, one tritium unit?

MR. YANG: Yes. They can go up to 0.1 tritium units. Take a long time, about three weeks, to do it. The cost is about -- this is why we have in-house running it. It costs about $500.00 for one sample. We have no sense to get that. Right now we are trying to see water in there, 100 years or what. We must indicate in the carbon 14, is this 10,000 years or more than 10,000 years or less. That's what the importance is.

The dating is mostly concerned in the carbon 14. I tried to get a good age correction for the carbon 14.

MR. STEINDLER: Are we looking at a single set of samples, or are we looking at repetitive samples?

MR. YANG: Especially in the Topopah Spring, when you squeeze the water out only that much, we can't do too much about it. We have the combination of the ten. For each one piece of core takes about two days to squeeze that water. You can imagine. To get about 30 or 40 water maybe takes a month just to get that data. It's very expensive data in here that we are talking about.

MR. STEINDLER: I guess I wasn't asking about the expense. I was asking for what are your statistics? Are you are talking about one set of samples that you have just

shown us here?

MR. YANG: What do you mean, one set? From one squeezing?

MR. STEINDLER: Yes.

MR. YANG: No. Some of them, yes. With the Calico Hill a lot of water in there, yes. One squeezing we can get one data. If not, then we have to combine two or three pieces of the core squeeze and come back and get one data.

MR. HINZE: Darrell.

MR. LEAP: Thank you. I am Darrell Leap. I have a couple of questions. Number one, you say you squeeze the water out of the core?

MR. YANG: Yes.

MR. LEAP: Do you think there's any problem with isotopic fractionations doing that?

MR. YANG: No. We have that data puolished already. We have a squeeze water compared with the distilled water. We cannot get all the water out even by squeezing. We have about ten percent and sometimes five percent moisture left. The rest of the water we do by distillations. The distillat: n water, that's pure water. There's no calcium or chemistry in there. We are using that for oxygen isotopic, tritium and all this analysis. We compare that distillation with the squeezed water, and

that's what is published in the papers.

MR. LEAP: The second question that I have is, how do you think this very old water depth got in there if it's not coming in vertically? It must have come in at some former time.

MR. YANG: Right.

MR. LEAP: Do you think it could have come in vertically then, or do you think it has come in horizontally? Do you have any feeling for that?

MR. YANG: I don't know. It's maybe from the fracture sitting there for long times. I think this is about 18,000 years old. We know the ice age started about 10,000 years ago to about 24,000 years ago for the last ice age. That's a long time to even gage through the metrics.

MR. LEAP: Do you think that they could be a possibility to indicate that perhaps with increased precipitation in some future time that we could completely change the flow paths of Yucca Mountain?

MR. YANG: No. Some of the rain storms -- there's a big rain storm maybe running into there. We have some data like that. During the 1984 there was very big storms. On the isotopic data we didn't show that moisture signal inside infiltrating, we didn't see that. It's likely over line flow.

MR. SACKETT: What are present day Delta-D and Del

18-0 for precipitation?

MR. YANG: You can tell if it is the summer it is quite different. In the summer ranges from about minus 0-18 or Delta-D.

MR. SACKETT: Stick with 0-18.

MR. YANG: Well, 0-18, about minus five, sometimes minus two. Sometimes it's about near one. Those are the ranges. In the water --

MR. SACKETT: In the winter time?

MR. YANG: In the winter time it's about 100 -- minus 13 to about minus 11 or even minus 14 during the winter.

MR. SACKETT: That's about what your paleowaters are, right?

MR. YANG: No. The paleowater is -- that's about minus 15. We are talking about minus 11 and that's minus 15. That's why it's very cold ice ages.

MR. HINZE: You had a response to Al's comments?

MR. FLINT: I just wanted to make one point of what Al Yang was talking about. It may be an explanation for this water in the Calico Hills versus the groundwater. We think that a major part of the recharge in the saturated zone system comes from the Mesas to the north. Water coming in the Mesas going to the saturated zone and then moving laterally under Yucca Mountain and coming up in the desert

south of Yucca Mountain, may be the reason why those chemistries are different.

That water may indeed not have anything to do with downward flow or very little downward flow of the unsaturated zone. Most likely it's attached to the saturated system which is somewhat of a separate system.

MR. HINZE: Al, you made a comment that some of this younger water, this steeper younger water, may have something to do with measurement uncertainties or sampling. At what point will we reach the state where we are going to have assurance that the younger water is not contamination?

MR. YANG: That's why we don't go by the tritium alone. We go by the chemistry, compare the chemistry, compare the stabilizer. We are approaching mindful to prove that point. Right now you show me tritium is young, but that's a conflict. It's not unlikely. A small amount still show majority is old, the small young water that can show up in the tritium. The chlorine 36, we can use and see how they compare.

With the multiple approach to prove that point, that's the approach that we take. Chemistry, stabilizer -- whatever you name it -- we try to use in those.

MR. HINZE: Thank you.

MR. POMEROY: Alan, your second bullet on your summary, the statement that essentially says the tritium

data and the chlorine 36 data are indicative of a preferentia flow pathway. There are no qualifiers, but are there any other alternatives that you can think of for that?

MR. YANG: No. By the way, I didn't mention that. Chlorine 36 and the tritium peak doesn't match because that water vapor tritium is in the water vapor itself. It can be vaporized by beta transport in the dry area. It's been proven at the New Mexico, tritium peak moves farther away from chloride peaks.

The chloride only moves with the water. It cannot evaporate. It's non-volatile. There is some difference between the two. I didn't point that out. That's where the peak doesn't -- you don't exactly match on the peak movements in those waters.

Besides those things, other things -- I don't know -- that's the basic tool that we can use now. Chlorine 36, there's other ones that in the liquid phase, I think maybe this is the two that we use. The accelerator they have developed a technique on those for chlorine 36 with the small samples.

MR. HINZE: Mike.

MR. CHORNACK: To answer your question a little more directly, there is always a possibility of some sort of getting to outside contamination, especially for the tritium. That is another possible source. To try to

investigate this further, we are fortunate in that we have taken suites of samples in all these, and we are going to go back and try to squeeze some more water out of the core and have the core samples in the near vicinity of this zone analyzed again to see if we get similar readings for the tritium in these zones.

MR. POMEROY: We look forward to that.

MR. YANG: Yes. We have one side by side to read them again, to see how they look.

MR. HINZE: Bill.

MR. FORD: Bill Ford, NRC. I was just wondering -- I haven't listened to the last two talks -- this information here, does this agree with Alan Flint's earlier explanation of water contents in the Calico Hills unit can be largely explained by downward movement in the matrix with water equilibriums, with water in equilibrium with the matrix potential?

In other words, do I hear more than one conceptual model being expressed here?

MR. YANG: No. As I say, I have seen a lot of data between 600 feet to about 200 feet still missing. I tried to see how that data comes down to Calico Hills. If Calico Hills going at this and all this other stuff in here, there has to be someplace coming out to the Calico Hills. It has nothing to do with the matrix flow. If the matrix

flow is coming there it maybe long time ago, something has stopped for long times. Is that possibility, it's unlikely.

I have to get more data between 600 and 200 feet for the top of Calico Hills and see how that point -- if the point is gradually toward that, then maybe have the matrix flow going off. If it's very sudden changes going like this and all of a sudden change on this one, something is there. I am not even sure the matrix flow even is coming down here. Maybe it goes sideways or goes someplace else.

MR. HINZE: I think we can pick up some of these questions at the round table at the end meeting. Obviously, this is a very important topic that there is considerable interest in.

I would like to call on you, Mike Chornack, if I might. I understand you are going to give us an abbreviated version of the plans for the ESF study.

MR. CHORNACK: This is going to be real fast. It's sort of an abbreviated talk I gave to the NWTRB. Again, the title says it's UZ testing in the ESF. I am not sure if this is a relief or not, but there will be no data in this presentation. We have not collected any data. It's primarily trying to outline our testing strategy.

Just briefly, the outline that I am going to talk about in the ESF, the purpose and objectives of the study. I will give a brief description of the tests that we have

planned, and then a summary.

In my first talk I sort of alluded to the ESF studies. It's basically broken into -- we like to look at it as two phases, the construction phase test and construction phase or main test level test. You see, there's a whole series of tests planned of four or five principal investigators. As of now, all the study plans are written for the construction phase test. The last three, the fracture test, percolation test and bulk permeability test are in their final phases of being completed.

The purpose of our UZ testing in the ESF is to provide hydrologic parameter input for the resolution of design and performance issues, also to provide an understanding of the impacts of ramp and drip construction on the in situ hydrologic characteristics in the unsaturated zone. And, to contribute to an understanding of the in situ hydrologic characteristics of the unsaturated zone.

The objectives of the study are to determine the in situ unsaturated zone hydrologic conditions from core and fluid samples from as many bore holes as we have access to in the ESF, bore hole geophysical logging, TV logs, and in situ bore hole testing and bore hole monitoring. Also, to determine the spatial distribution of present day water flow within the unsaturated zone, and to characterize gas and vapor flow in the unsaturated zone.

Also, to provide hydrologic data for calculations of unsaturated zone groundwater travel time, provide hydrologic data for predictions of radionuclide releases to the accessible environment, both in the gaseous and aqueous phase, and to provide hydrologic property data to design analyses of the underground facilities, repository seals and the waste packages.

I will just go in real briefly to the test description and some objectives. The first test is the radial bore hole test. This is one of the first tests that we will be conducting in the starter tunnel. As you know right now, we have completed construction of our 200 foot starter tunnel, and we are in the process of constructing our first test alcove in that tunnel.

The first test will be the radial bore hole test. It consists of four test activities to be conducted in the two ramps in the ESF. The first is the air permeability and isotopic testing within hydrogeologic units. The second is air injection testing across hydrogeologic contacts. The third is long term monitoring of selective bore holes. After the long term monitoring in other selective bore holes that we have done the long term monitoring, we will do water injection testing at the contact sites.

The specific objectives for the radial bore hole tests are to quantify gas permeability and isotrophy of the

hydrogeologic units within the unsaturated zone, to estimate tortuosity and effective porosity of drain flow paths within the unsaturated zone, to quantify the boundary effects at the hydrogeologic unit contacts, and to compare pneumatic and hydraulic results especially at the hydrogeologic unit contacts.

The excavation effects test. This test won't be conducted in fiscal year 1994 but hopefully we might get to do this test is fiscal year 1995, depending on the rate of construction of the ESF and some of the accessory drifts.

Just a brief description of the testing activities. The tests will be conducted from alcoves on both sides of a planned excavation. What we will do is, basically, we will mine alcoves on both sides of where we intend to do a mine excavation forward. We will drill bore holes from these alcoves in front of to where the opening is to be mined and place various monitoring instruments, and then we will look at the air permeability before and after the excavation to see how the excavation has changed these characteristics in the unsaturated zone. We will also monitor in situ stress and mechanical properties measures. These monitoring instruments will be in place before to get pre-construction data, and during and after construction also.

The specific test objectives for the excavation

effects test are to estimate the magnitude and extent of modification of the hydrologic properties in the Topopah Spring welded unit caused by the excavation of the ESF.

This test was talked about earlier, our perched water test. We sort of look at this as a contingency test, in that we won't conduct the test unless we hit perched water. This is one of the tests that has a potential of actually allowing us to say stop the tunnel boring machine, we need to investigate this appearance of perched water.

The test will be conducted if perched water is encountered. In the event that perched water is encountered in the ESF we will conduct hydraulic tests, and chemical sampling will be initiated as soon as the area in the ESF is accessible. If there are large flow rates occurring flowing into the mine opening we will conduct flow rate measurements, and then also in these large flow rate areas. If we encounter a smaller flow rate, smaller areas where flow into the ESF or the excavation is not as great we will drill bore holes into the perched water zones for sampling, testing and monitoring.

The specific objectives of the perched water tests are to detect the occurrence of any perched water, estimate the hydraulic properties of perched water zones, and determine the implications of existence of perched water zones on water flux, flow paths and groundwater travel time

in the unsaturated zone.

This is another test that we are going to be conducting in fiscal year 1994 in the first alcove in the starter tunnel, the hydro chemistry sampling test. The testing activities will consist of collecting hydro chemistry gas samples from bore holes drilled either specifically for this test or we will try to collect gas samples from any bore holes drilled in the ESF.

So, this is sort of a test of opportunity, where we will use other bore holes to do gas sampling from. We also intend to drill short, one to two meter diameter bore holes as close as possible behind the TBM, and to collect gas samples that we hope will be representative of pre-mining conditions.

Eventually, we would like to also drill some long bore holes, approximately 45 meters in length if possible. We will drill from alcoves at selected locations for the collection of gas samples and core samples, to basically squeeze water and gas out of them.

The specific objectives of the hydro chemistry test are to collect and preserve core samples for extraction of unaltered water and gas, collect in situ water, water vapor and gas samples from bore holes in the ESF, obtain hydro chemical and isotopic data for interpretation of transport mechanisms, flow directions and travel time of

water and gas in the unsaturated zone, and also determine the geochemical evolution of unsaturated zone water using hydro chemical and isotopic techniques.

MR. STEINDLER: Excuse me.

MR. CHORNACK: Yes, sir.

MR. STEINDLER: In the slide before this one, you are indicating that you are going to try and chase shortly after the --

MR. CHORNACK: Yes.

MR. STEINDLER: Do you have any information as to whether that sort of thing has ever been successful in the other applications?

MR. CHORNACK: I really don't, no. Successful, in what regard?

MR. STEINDLER: Over here, in Chicago or in other areas, whether you can get --

MR. CHORNACK: I am not sure.

MR. YANG: I think it is like a -- we have some experience with the vertical bore hole right now.

MR. STEINDLER: With a boring machine?

MR. YANG: Yes.

MR. STEINDLER: That's 25 feet in diameter?

MR. YANG: No. I am talking about the surface base bore hole.

MR. STEINDLER: That's not what I am talking

about. You are chasing a very complex and smelly machine.

MR. CHORNACK: Yes.

MR. STEINDLER: So to speak.

MR. CHORNACK: What we will do is, we will try to if need be, we could increase possibly the depth that we drill the bore holes in, to try to possibly see where we get out of the zone of influence of the excavation caused by the tunnel bore machine and possibly can get some pristine in situ gas samples from that.

MR. HAYES: The study we are going to do now in the alcove, isn't part of that to test how far into the formation the impacts go, to give us some idea of our potential --

MR. CHORNACK: Exactly. We will do hydro chemistry gas sampling from some long bore holes, possibly 30 meter bore holes. What we will do is, we will evacuate the bore hole until we get -- let me digress a little bit.

What we do is, when we drill the bore holes we drill using air as a circulating fluid, but we put a tracer gas into the circulating fluid. Then what we do is, we go back to the bore holes and pump them until we get background levels of our tracer gas, and then we are assuming we removed all contamination from the bore hole. We assume that we are getting pristine rock gas samples out of the bore holes.

Whether we can accomplish this by doing these short bore holes, surely after passing the tunnel boring machine, we are not sure.

MR. HOXIE: Dwight Hoxie, with U.S. Geological Survey. It seems to me the TBM is going to be driven by electricity. It ought to be relatively clean, especially compared to a drill and blast method which is probably very dirty in terms of injecting.

MR. STEINDLER: Do you have any idea how many that thing uses?

MR. HOXIE: I think it uses a lot.

MR. CHORNACK: Thank you, Dwight. Hydrologic property in major faults, this is another test that won't be started until we start the tunnel boring machine operation, which is scheduled for late 1994 or early fiscal year 1995. The first fault we encounter in tests will probably be the Bow Ridge fault.

The testing activities associated with this study are, we will conduct single and cross-hole pneumatic tests, and will be conducted from two alcoves at each fault testing location. Basically, we will have two alcoves and we will drill bore holes into the fault and fault disturb zone once that a bore hole is parallel so that we can test across the fault zone, and one set of bore holes through the fault zone itself or perpendicular to the fault so we can do actual

testing actually within the fault zone itself and the fault disturb zone.

Then what we will do is, we will do cross-hole testing to characterize the permeability and isotope within the fault disturb zone and fault zone. Cross-hole tracer tests will be used to estimate tortuosity and fractures associated with the fault zone and fault disturb zone. We also do cross-hole hydraulic testing, and we will provide the opportunity to compare pneumatic and hydraulic test results and sort of give us a conversion factor, hopefully, so we can use some of our air permeability data to estimate some of the hydraulic properties of these zones.

Later, the bore holes will be instrumented for long term monitoring of the fault zones to see if we can detect any pressure pulses or movement of water along these major faults over periods of time, possibly as long as five years.

Specific objectives are to measure pneumatic and hydraulic permeability, porosity and isotropy of major faults and associated fault zones, to monitor for vertical gas flow, water vapor and water in the major faults, and to estimate the tortuosity and effect of porosity of major faults.

Those ones I have previously discussed, these are what we call our construction phase test. Now, we are into

the post-construction or main level tests. The study plans for these -- the chapter of study plan for these activities are in the final stages of completion now.

The first one is the in tact fracture test. This test will consist of collecting fractures that are oriented perpendicular and parallel to the core axis that will be collected at numerous locations. What we are going to try to do is, we are going to try to go to areas where we have faults and try to collect basically an in situ fracture by first drilling in fractures that are located perpendicular to the core axis, we will pile a rock bore hole and put an anchoring device through the fracture. Then, we will come back with a larger core bed and over core the rock bolt. By this, we hope to bring out a fracture that has the in situ fracture characteristics of basically an undisturbed fracture, that we can take back to the laboratory and test.

For fractures that are parallel to the core axis what we will do is go in with our larger core bed, core down along the fracture, and before the fracture is removed we have a method to in place metal bands around the core itself, again, to preserve the in situ characteristics of the fracture before we remove it and take it back to the laboratory for testing.

When we get these in tact fractures back to the laboratory we will conduct -- gas and water will be injected

into the fractures. These fractures will be subjected to varying confining pressures. By this way, we hope to vary the aperture opening in some of the fractures.

Some of the specific test objectives are to evaluate fluid flow and chemical transport properties and mechanisms in relatively undisturbed and variably stressed fractures, to investigate permeability under in situ or lithostatic pressuring conditions that can be determined for single fractures. We can also develop water retention curves for fractures with differing aperture widths. We will do this by varying the confining pressure on the fractures tested in the laboratory. We can also provide fracture property data input for unsaturated zone flow models.

The percolation tests. I am not sure if Ed mentioned this. We had a large block experiment that we conducted in the laboratory. This is basically our in situ version of our large block experiment.

The testing activity will consist of large, approximately two meter, cube isolated blocks will be excavated within selected hydrostatigraphic units. When I say excavated, I don't mean we are going to remove them from the in situ position. Basically, in the main test level we will go down and excavate a drift or test alcove where we can go in and basically mine out this large block of rock

but not the base of it, leave it in place. By doing so, we will be able to instrument the block with various types of hydrologic monitoring instruments, TBR problems, long fractures, things of this nature.

There will be a trace of transport under controlled fluid conditions. Tracer tagged water will be introduced on the surface of the block, either though a sand bed or some sort of trickle system or sprinkler system. We can monitor the outflow or the effluent from the block can be collected and analyzed to determine transport behavior through the block.

The test objectives are to observe fluid flow and solid transport processes through variably saturated, fractured, welded tuff under controlled, relatively undisturbed conditions.

The last test is the bulk permeability tert. This was initially conceived of to be a large chamber that would be sealed off. We basically do very large scale air injection tests into this large sealed chamber. We went back and re-thought that, and we thought that a configuration of bore holes, basically three sixty meter long bore holes grew in a frustum configuration which is basically an expanding array of three bore holes that starts at a certain distance apart at the apex and radiate laterally outward.

By doing this we thought we could get some scaling effects into the test also. We could test fractures that are near by testing the front of the bore holes and expanding out at the end of the full sixty meter length we would be testing across a larger distance.

Basically what we would do is, we would conduct a single and cross hole air injection and water injection testing using packers and down hole sensors. The test locations will be spatially located to characterize the homogeneity of the Topopah Spring unit, the main test level.

Some of the specific activities of the bulk permeability tests are to assess the fluid transport properties in a relatively large volume of minimally disturbed tuff, and also determine bulk permeability values for use in unsaturated zone flow models.

Just a brief update as to where we stand in the UZ studies in the starter tunnel. As you all know, the starter tunnel is completed, the full 200 foot depth. We are mining the first alcove in the starter tunnel, in which we will conduct the radial bore holes tests and the UZ hydro chemistry test. We also plan to do some gaseous phase circulation studies in these bore holes also.

We have conducted some initial prototype sampling of gas samples from these short hammer drilled bore holes. Again, the starter tunnel was mined using drill and blast

methods, whereas most of the excavations will be using mechanical mining methods. I don't think we have any results back from these gas samples but we have been collecting gas samples from this alcove that has been mined.

MR. HINZE: Can we close this off?

MR. CHORNACK: Summary. The results will be used in the resolution of YMP performance and design issues concerned with fluid flow within the unsaturated zone. Principal application will be assessment of groundwater and gas travel times. It will also be used for design analysis related to the underground repository facility. Also, issues concerned with the waste package containment and barrier system, we will use information resulting from this study.

Thank you.

MR. HINZE: Thank you, very much. I am sure that there are questions, but these are questions that can be taken up during the field trip tomorrow. It was important that we do go through this today.

We will take a ten minute break, and we will come back in ten minutes. We will start on modeling then.

[Brief recess.]

MR. HINZE: Can we resume, please. The next speaker will be Bo Bodvarsson, from LBL. We are going to hear something about the three dimensional model. Bo, are

we ready?

MR. BODVARSSON: Yes. My name is Bo Bodvarsson, Lawrence Berkeley Lab. I am working with the people at USGS on the three dimensional site scale model. These are some of the people that work with me at USGS. My co-principal investigator is Ed Kwicklis. We have various investigators from USGS that contribute data, and also work with me on the 3-D model.

The presentation outline, that's why I need the second viewgraph. These are the kinds of things that I want to go through. First, the objectives of the study, general approach. The approach we use in the modeling, the results to date, what we are doing now, where we are going, and why we think this work is reasonably credible.

Why a model? Why do we need the model? We need the model to integrate all the available data from the unsaturated zone at Yucca Mountain. We need estimates of moisture flow, heat flow and gas flow within the mountain. We need a model to guide us in site characterization, to let us know when we have enough data and when more is needed, where we should drill the wells, where we have complex one, two or three dimensional flow patterns. We need to predict conditions in all new bore holes as well as in ESF. If we don't predict beforehand, we never have credibility with the model. It is just another tool.

What is a model? What do I call the model? Here is a little schematic to explain what a model is. You don't have this in your packet. This was developed very recently, as a response to me not being very clear in our dry run.

I am trying to explain here model codes in computers. Here we have Yucca Mountain. We somehow want to represent this Yucca Mountain with some kind of a model. We can't take into account all the details, so we drew this by dividing the mountain into boxes like in a numerical modeling exercise. Then, we have all these units like the Topopah, Calico Hills and paint brush and Tiva Canyon and all these units that they put in the model with all the parameters like permeability, porosities and all these things that Alan Flint has talked about and all these other guys.

Then, we take all these boxes and put them in the computer -- this happens to be an IBM-6000. This is a good computer. This is one that we use. Then, we have a code. This is our numerical model. We use TUFF. I don't think you can see it, that's why I made it so small. You can see it if you --

[Laughter.]

MR. BODVARSSON: You see that statement there? That statement says if the CPU time -- that means the computer time -- used times the dollar amount per CPU

exceeds fiscal year 1994 funding, stop.

[Laughter.]

MR. BODVARSSON: That's probably the most important statement in the code. You put it in the computer, and then the computer spits out all these numbers, a lot of numbers. People all talk about let's have the code do this and do this as fast as we can. The main problem is, to reach steady state in our model takes five hours. To analyze all these thousands and thousands of numbers it takes weeks and weeks. Really, the computational time is really not that important. It's more the time it takes you to understand what comes out of the computer.

What I am going to talk about today is this part. This is what I call my model. This is the input and the output. This is what I am trying to understand. I am not talking about the computer code nor that box here, nor the real thing.

Alan Flint has shown you several times our model. I am just doing this gradually here. This is on a large scale. If you go to the smaller scale you go to this area, here. How did we decide on these boundaries. These are boundaries aligned with some major faults like the Solitario Canyon fault, like the Bow Ridge fault to the east, the Yucca Wash fault which is not known but we think there might be a fault here. Then, we put the boundary as far south as

we possibly can, to alleviate boundary effects. This is our main area for the unsaturated zone. We wanted to, of course, enclose the repository region here. Here, we have the major faults.

General approach, going to this one, here. How do we go about doing this. Let's first look at the general approach and then important hydrogeologic issues, and model development steps. The general approach. This comes right from our study plan, mine and Ed Kwicklis'. This is what we have here, the site scale model. All the data collection and analysis coming from Alan Flint, Joe Rousseau, Al Yang, and all these important data is integrated into conceptual model which feeds into our model with the appropriate numerical codes. This is basically the site scale model that I showed you in the last slides.

This is a three dimensional, very complex model. It considers water flow, gas flow, temperatures. We need a lot of set models to test out, for example, different hypotheses. We want to know how accurate do we have to represent the distribution of infiltration. We don't want to test that on a big, three dimensional model. We want to test it on a little model first and then apply that to the three dimensional model. There's a lot of hypothesis testing we do here to feed into the site scale model. You go through a lot of peer review such as we have here. This is

one of the peer reviews that we had.

Then, we decide we need more data in the western part of the block or the eastern part. We feed back and we talk to Alan Flint and the others, and say we need desperately more saturation data, infiltration data, give it to us as quickly as you can. Then, that feeds back down.

At the same time we show them our modeling results, and if they say they don't make sense to us based on what I have seen in the Mountain, we try to adjust our model. Uncertainty analysis, Ed Kwicklis talked about this before. All of this feeds into performance assessment by periodically feeding this to performance assessment people like Jerry's people, Bill Nelson's people and those people. We probably should have more interaction but we are working hard on it.

Some modeling issues, important issues. I believe whenever you start to look at the complex problems you have to look at the issues. Here are some of the complicated issues, uncertainty, flux determination. Alan Flint will be the first to tell you that this is certainly not the precise science. We have densely fractured units, millions of fractures. This is one of the more uncertain things that we have. I think this is one of the most important uncertainty of the Mountain right now is, what do the major faults do. Matrix fracture flow, thermal effects, lateral flow,

capillary barriers.

Let's go to our steps. We don't want to develop this model all at once. It's a very complicated model, so we have taken it in steps. By developing a moisture flow model first, and then gradient and gas flow components. Along with all of this, we want to calibrate the model against all the data. We want to predict the variables of all new allocations similar to what Alan Flint showed you this morning. Also, what happens in the exploratory studies possibilities.

We want to periodically use the model for sensitivity studies, to say in this area I have enough data or do I need more. Finally, we want to continuously use that model for hypothesis testing.

What data are essential. Data needs and contribution from other studies, hydrogeological maps are important, hydrological parameters. I will go through those. You have seen this in a different form before. This is the 3-D site scale model. Here, you have all the people that talked and other people too, that feed data to this model.

We spend considerable amount of time with Mike Chornack, Rick Spangler and many other people, to develop detailed maps of the hydrogeological units. This happens to be the Topopah Spring Unit. You see the variability in

thickness. Right where the repository unit is you have the maximum thickness. Then, it dips very rapidly in all directions.

I am not going to talk about the other data needs because a lot of this data you have already seen before by some of the other investigators. I want to tell you about how we approach this from a numerical point of view. How do we grid the model. How do we decide on the boxes, the horizontal grid, the vertical grid, how to incorporate faults and fractures, how we do make sure this is flexible enough that we can repeat it. When we have changes in the grid we have to be able to do it. We need to develop new simulation technique if we find the ones we are using are not accurate enough or not fast enough.

I am going to go very quickly and briefly through this. If you have questions, please don't hesitate to ask.

This is the horizontal grid that we decided on. It's based on many, many different things and considerations. First of all, we wanted to have the grid blocks both for existing bore holes as well as future bore holes in the center of the grid lock so that we can predict them and can match the data from what the model says.

Secondly, we want to have grid blocks aligned to the major faults, so that we can put set models around here if we need to represent the faults more accurately. Third,

we based this grid on infiltration data that Alan Flint gave to us. There are many different other reasons for this grid assignment.

Vertical grid. This shows one cross section, just showing a typical vertical grid. What we wanted to be sure to represent with this grid is, the layering of the units -- this happened to be the bedded units here -- accurately represent the offsets close to the fault. This is the Ghost Dance Fault. Accurately represent transition close to the major unit, so that you have finer elements closer to the unit. Also, we wanted to make sure that this is computer generated so that we can regenerate it if we need to find a grid.

MR. DAVIS: I have a question. The boundaries are treated as no flow?

MR. BODVARSSON: The boundaries presently are treated as no flow. We can treat them as any other boundary that we like.

Finally, I cannot emphasize this enough. We spent a lot of time developing this three dimensional grid. Most of the time is spent on generating computer codes to generate the grid. We wanted to be flexible enough, again. If we have to do it again, wee don't want to do it over a nine month period. I believe that if we do this grid over it will take a few weeks to do it. If we have to modify it,

it will take much less time.

Now, results to date. What have we learned so far. I can only go over this very quickly. I wanted to give you the approach so that you know all the backgrounds to the model. If you have any questions about the results, please ask.

We started by doing a lot of two dimensional simulations. We looked at the effects of the major faults. We did a sensitivity study to make sure that the grid was fine enough, that it was not giving us erroneous results. Then, we have done three dimensional simulations. I will talk mostly about three dimensional simulations because they are the most interesting.

First though, in order to understand this a little bit, let's start with the two dimensional cross section that goes across the pork chop right around here.

MR. HINZE: Do you keep the grids the same all the way down.

MR. BODVARSSON: Yes.

MR. HINZE: Is that a vertical grid?

MR. BODVARSSON: This horizontal grid is the same all the way down. The vertical spacing varies a lot.

MR. HINZE: Yes.

MR. BODVARSSON: To just give you a little feeling here, this is the two dimensional cross section model. This

happens to be a infiltration rate at the top of about 1.1 millimeter per year which is similar to the value that Alan Flint got from his one dimensional model of UZ-16. Is that right, Alan, something like that?

This just gives you an idea of what happens. Water is going down here on the top. It flows down through the Tiva unit pretty vertically. You have a lot of lateral flow component here in the bedded unit, depending strongly on what you assume for the faults. I can't go into a lot of details with you for what we assume for the faults, but there are generally three assumptions that you can make about the faults. We don't know what the faults do.

One, is that because of the capillary characteristic is a wide fracture, the water doesn't want to go in there. It wants to stay in the little pores in the matrix block. That's one possible model for the fault. The second model is that the faults are full of the material, filling material that Alan Flint said, that might be a higher permeability than the surrounding matrix block. Maybe the characteristic curves are still for small pores but the permeability is higher, something like that.

The third one is that the fault actually is highly indeterminate because of core material in the fault so it flows down. All simulations, since we don't know this, my approach is to do all the simulations with all three

assumptions and then see the sensitivity of it, until we know something more about the faults.

MR. POMEROY: Before you go on, have you done a comparison with some of the 2-D results that other people have gotten, and can you get similar results to the results that have come through the 2-D models? In other words, have you calibrated between the 2-D and 3-D model?

MR. BODVARSSON: Yes.

MR. POMEROY: And, you get similar results?

MR. BODVARSSON: Yes. In some areas we get similar results. It all depends on if you have two dimensional flow reaching or three dimensional flow reaching. Some areas on the mountain, you cannot compare 2-D and 3-D results because the flow is so complex three dimensional flow. Other areas you can, yes.

Here, you see the saturations also. You see the flows here, saturations, 80 to 90 percent in Topopah and the Tiva and much lower in the bedded units. Capillary pressures, this is not so important or not so interesting. Generally, they vary from mostly below ten bars except in some regions in the Calico Hills areas. Because of the lateral flow you get much more tension, like 20 bars or higher, based on these 2-D results.

Now, let's look at 3-D results. I will try to show that in a reasonable manner. I will first show you

four cross sections, a picture with four cross sections. Three of them go like this, one here, one here, and one here. One goes along here. You are going to see the saturation.

Here, you see the same model. Actually, this is mislabeled. This should be Solitario Canyon fault. This should be Bow Ridge fault here. Yucca Wash border table. Do you see the three cross sections there, and then one along here. You see the dryness of the fault. In this case we assume that the faults come from the big fractures, so the water doesn't really want to go into the faults. They are really very dry regions. The rest of the simulation, I am going to show you, you can assume that. That means they are treated as barriers to the flow, if this is the right representation of the fault.

You see also, the bedded unit. You see the flow factors here, and you see the lower saturation of the Calico Hills region, higher in the Topopah and the Tiva and lower in the bedded units.

Next, I am going to show you planes. What we want to see is if we have uniform infiltration. We want to see if it goes uniformly all the way down or if there's a lot of lateral flow. Here is for a uniform infiltration rate, here is the normalized infiltration rate. That means the vertical flow in a plane -- and this happens to be the top

of the Paint Brush Unit -- normalized by infiltration rate on top, in percentages.

If you have 100 percent, that means the same amount is going down through this unit what came through the top. Do you understand that?

MR. HINZE: No.

MR. BODVARSSON: This is just the vertical flow at any location in the three dimensional plane, divided by what we put on top. If it is more than 100 percent that means that water somehow concentrated in that region. If it's less, it evaporates from that region. Right here above the Paint Brush unit everything is uniform, all around 100 percent. There has been no flow. That means pretty much the flow through the Tiva seems to be vertical.

Below the Paint Brush unit on top of the Topopah, you start to see significant variations because the Paint Brush unit causes a lot of lateral flow. Here, you see for example, close to the Ghost Dance Fault that there's tilting right here. A lot of lateral flow. Here, we have more than 125 percent flow. That means a lot of vertical flow here and less here. This is getting dryer and dryer. The same here close to the Bow Ridge fault, where we have this big tilting in the beds.

MR. HINZE: Do these diagrams illustrate results that are comparable with observed data?

MR. BODVARSSON: Yes. They are comparable to the observed data. I will come to that in just a minute.

Here, you have at the bottom of the Topopah, you see still more of this lateral flow component. The flow is piling up close to the fault, which we assume water does not want to go into these faults. Finally, at the water table, this really is the amount of water that goes into the water table. This is from the Calico Hills into the water table. Again, more lateral flow above the Calico Hills, very significant lateral flow. Even though we have uniform infiltration rate on the top it's extremely non-uniform when it gets to the water table. There are preferential pathways, just due to the tilting.

Your question was very good with regard to how does this compare to actual data. You don't have this viewgraph either. I am sorry about that. I just put it in recently. This is UZ-14 prediction with a uniform model. Right around here you are supposed to have the perched water. This uniform infiltration rate doesn't show the perched water. What we decided to do was to go to a non-uniform infiltration rate.

The approach that we use is similar to what Ed Kwicklis talked about, Alan talked about, what if infiltration is concentrated in the washes. The embedded unit may be exposed in the washers and they are highly

permeable, so maybe a lot of the water goes into the washes. This shows similar viewgraphs of concentrated water into the washes.

This is where the concentrated water is. Here, we have almost no infiltration. On the average, it's still .1 millimeter per year. The total amount of water we put on top of the mountain is exactly the same, but it's just not concentrated in the washes. We want to see if this improves our matches with UZ-14. This is the top of the Paint Brush unit. When you go further down you get the lateral flow, you get very much dispersion of the water. It's spreading out even though it starts up in the washes. It's starting too spread out in the top of the Topopah.

I am going to skip this one to the water table, because I want to be on time like Alan. Alan was on time, right?

MR. HINZE: Yes, the only one.

MR. BODVARSSON: The only one.

MR. HINZE: Right, so you have a challenge.

MR. BODVARSSON: Here is at the water table, again. There is still more dispersed, and here you have strong component of lateral flow. Taking a look at what this how and how does this effect UZ-14 -- let me see, I put it out of sequence here. We will find it momentarily, if we have it. If we don't have it, we won't find it momentarily.

What happens with that is, when we put it in the washes it was almost saturated exactly where the perched water zone was. What we have to do to match the perched zone in 14, we have to reduce the permeability below it by one order magnitude. Then, we got the perched water. It's not just sufficient to concentrate it in the washes. Maybe if it concentrated a little bit more it would be sufficient. We still had to reduce the permeability of that unit below it.

Current work, what are we doing now. I am sorry that I have to go through this so quickly. I wanted to be like Alan.

[Laughter.]

MR. HINZE: Do you have the characteristics of these cells in an analytical function so they are easily changed?

MR. BODVARSSON: Yes. We use the formulation that Ed Kwicklis talked about. We use the data that Alan Flint collected and Joe collected, so we can easily change if that's necessary.

MR. DAVIS: Are the only comparisons with "reality" using 14, or is it every --

MR. BODVARSSON: It's all bore hole. We don't have so much -- the main data we can calibrate the model to are saturations and capillary pressures.

MR. DAVIS: What about the data we just heard about?

MR. BODVARSSON: That comes a little bit later, when we calibrate it against that data. Some of the data is very uncertain, because we don't know about if the tritium is correct or not.

MR. DAVIS: Do I have a model for the entire 3-D model, or do I just have it well by well and some kind of qualitative thought?

MR. BODVARSSON: Like I said, the main data we have to compare to is saturation and capillary pressure data or moisture retention. We have very little of those data. Almost all the other bore holes don't have reasonable data.

Now, I want to talk about current work. Actually, this is current work, what are we doing now. What we are doing now, we are completing a report on this first phase of the model, moisture flow. We are completing another one on the decoupling of the tuff, because we decouple the gas phase and thermal and moisture in order -- when we do only moisture calculation we don't want to carry all the governing equations.

We have completed the report on grid effects. We are perfc.ming the three dimension simulation as I told you about here. The main purpose of this is to determine where one dimensional, two dimensional, three dimensional flows

occur at Yucca Mountain. Then, we say where you have this complex flow we need more drill holes or some more information about those. Then, we are completing the simulation about matching the behavior of UZ-14.

Where do we want to go. We are incorporating the gradient and gas flow. It's right now in the model. We don't use it all of those when we match for UZ-14 because we don't have such detailed information. We will very shortly.

We are developing a new grid, to incorporate the ESF. It's very important to have ESF in the model. We actually -- Mike believes that we should have had ESF in the model before we started the ESF, to be able to predict what happened in the ESF but we did not.

We are doing continuous model sensitivity to find out when we have enough data. This, of course, is a very good statement. Periodic release of model data to perform assessment or retardation thermal loading studies, et cetera.

MR. POMEROY: Going back to Bill Hinze's question for just a minute. In assigning parameter values to the individual cells, you have some parameter values derived from vertical bore holes. Are you linearly extrapolating between bore holes to assign values to parameter values?

MR. BODVARSSON: What we do is, we take the data

we have is from individual bore holes. We have the transact data that Alan Flint collected at different regions. In areas where we don't have data we just have to extrapolate and interpret.

MR. POMEROY: You use linear extrapolations?

MR. BODVARSSON: Generally, yes. When you realize it, we have very little data as we speak, from Yucca Mountain. You know what. Credibility of the study, we have our quarterly meetings that Ed Kwicklis organizes, where w talk about our results of our model and the data collectors talk about their modeling as well as data collections. We try to make sure that everything is consistent.

We publish every year in international high level radioactive waste conference to give an update of this modeling activity. We have periodic internal review that USGS reviews, all the way down to you guys. Not to mean that this may be the most important one. This maybe should be here. Then, we do this very rigorously through the quality assurance program, certainly.

To summarize, the 3-D site scale model is operational. For example, we run to steady state with different infiltrations on top in about five hours of computational time, which is very rapid for 6,000 grid locks and 30,000 connections. The major purpose of the model is to integrate the available data and to guide in the site

characterization process, so far as I am concerned. The model is under continuous development with current incorporation of gas flow in the ESF. This is where we stand now.

MR. HINZE: Thank you, very much. You missed by 28 seconds, but it was a good try.

[Laughter.]

MR. BODVARSSON: Alan is still the only one.

MR. HINZE: That's right. Bo's very informative discussion is open for discussion.

MR. LEAP: I am Darrell Leap. I want to ask you to clarify a little bit on this using the model to determine whether or not you have enough data or not. Is this basically a sensitivity analysis that you will be using? As you get more data you plug it in to see how sensitive the model is to response, and then you keep adding to it; is that correct?

MR. BODVARSSON: That is one component of it. You know, what I think is probably at the present time most important that we are learning about the model is again, what I said before is, where in the mountain do we have a simple one dimensional flow. Where do we have a little more complex, two dimensional flow with lateral flow and basically vertical flow, and where do we have very complex three dimensional flow due to the faults or due to the

bedding and whatever.

What I hope to have by the international high level radioactive waste conference is a map of the mountain that says zone one, zone two, zone three. My view is, based on this data -- you know we have limited data -- is that where we think we are mostly one dimensional flow, as a first estimate, we probably don't have to put as many wells there and probably have sufficient data there. Where we have much more complex, three dimensional flow, is where we really need to concentrate our effort.

We may be proven wrong down the line because we don't have enough data, but I think that's the best approach that we can use at this time.

MR. DAVIS: Doesn't that presuppose that the model is right?

MR. BODVARSSON: Yes, but that's the best we have right now.

MR. DAVIS: I would test the 1-D as well as the other with bore holes.

MR. BODVARSSON: Yes, that's true. I am sure there are going to be other bore holes where the 1-D is. For example, Joe Rousseau showed a lot of bore holes where the 1-D is basically. I cannot stress enough one thing, because this is dear to my heart.

With a model like this you have to predict

everything you see in the mountain. Otherwise, you don't have credibility in the end. Five years from now if we start to predict the wells or the ESF and things like that, we will never have credibility with the model because we have never demonstrated that the model is good. If we predict each well and if we start converging to what each new well tells us, that the model is getting better and better, in the end we have to have a lot of confidence.

MR. DAVIS: At what point do you change from calibration to prediction in that?

MR. BODVARSSON: We always have calibration and prediction. What I am saying is, let's say we predict the next well and we are --

MR. DAVIS: Say you are off by 30 percent.

MR. BODVARSSON: We are off by 30 percent. Then, we calibrate the model against the new data from that well. Then, we go to the next one and maybe five wells down the line, we are off by 20 percent. We recalibrate. We go five wells down the line from there, you are off by ten percent. That's what we hope to see.

MR. DAVIS: So, when are you done?

MR. BODVARSSON: That's what I don't know. I think when we are done is --

MR. DAVIS: Given spatial variability, it's a very likely outcome that it jumps back up to 15 or 20 percent and

doesn't nicely decay.

MR. BODVARSSON: I am not certain about that. I really am not. You may be right. I think the only way is to find out. I don't see any other approach, do you?

MR. DAVIS: I don't know, because I don't know how this is tied into the performance assessment model which says how much is enough before I can make a regulatory decision. Those may be different questions.

MR. BODVARSSON: We work together very closely.

MR. DAVIS: I guess the next talk is supposed to tie this all together. Maybe we will understand what that statement means.

MR. LEAP: I would like to follow up, too. When you are talking about the one dimensional versus the two dimensional versus three dimensional flow, are you -- I am a little unclear on this. Are you trying to predict that with your model, or do you assume that you are going to have to know that through field testing first and then plug that conceptual model into your numerical model?

Here, we don't know which comes first, the chicken or the egg.

MR. BODVARSSON: What comes first is the data. Right now, we have almost all the data possible in this model. Then, we use the model based on all the data that we have to look at the flows to see the one dimensional, two

dimensional and three dimensional flow.

MR. LEAP: It's data driven then.

MR. BODVARSSON: Data driven. Then, we get the model.

MR. DAVIS: What are the range of conceptual models that you can test without really changing the structure of the model? Let's say that the state has a totally different conceptual model. How many -- geometry is what you are fixed with, isn't it? The rest, you could test.

MR. BODVARSSON: Yes. The geometry is fixed by the geology. I don't think the state will have a lot different geology than what we have because we know what is there in the mountain. What we change very easily is any kind of pattern or infiltration on the top. We can have any kind of permeability distribution in any blocks below. If we want a very fine grid somewhere that we have additional data, we can do that with a sub-grid very easily too.

MR. DAVIS: Functional relationship between matrix and fracture flow is changeable?

MR. BODVARSSON: Yes. What we assume in this one is what is called the equilibrium condition at the top of the curve. We can change those curves. Bill is eager to say something.

MR. NELSON: I am not sure that I am eager. Your

point is well taken, on the conceptual models as this moves along. Then there is a really kind of a simplified approach to look at all the conceptualizations. One starts with the very complete, we can't be any more complete than what our peer review range gives us. Then, there is a sequence of testing that comes back and utilizes this to look at what level of detail or how we do indeed bound the alternate conceptual models.

I might say on the unsaturated zone, I wouldn't say it's complete but there's 126 alternate conceptual models that might be looked at. One very quickly comes down and goes into a hypothesis testing and sensitivity in order to pick between then.

MR. DAVIS: The question is, out of the 126 how many can be tested with the current framework, without him having to go back and re-grid up the entire mountain.

MR. NELSON: We would expect that quite a number of them can't. We haven't been through this -- and I would be less than honest if I were to tell you that we knew it every step. We sense, just as you do, that those alternate conceptual models have got to be looked at. The ones that we settle with have to be things that will bound us appropriately for those.

MR. BODVARSSON: Let me put this a little differently. I don't know if there are 126 or if there are

15, or if there are 500 conceptual models. I know there are a lot of different conceptual possible models. Now, for example, if you tell me that the Ghost Dance Fault characteristics are much different than what we assume in the model, that you cannot really handle it with different properties, then I would have to go back and redefine my grid in the Ghost Dance fault to continue with the model.

If you tell me that infiltration patterns are different, I can do that with the existing one. It's like you said, it's mostly the geometrical ties, as a first order approximation.

MR. HINZE: This has been very helpful.

MR. MOELLER: I have a quick one. You mentioned that it would be very beneficial or would have been beneficial if you had your model at a stage to have predicted the impact of the ESF. When will you be at that stage?

MR. BODVARSSON: That's a very good question. That's a very good question. I believe that this should be the number one priority, is to put the ESF as soon as possible in the model. It's because, like I said, losing the first -- this is just my opinion. A lot of people here might disagree with me, but this is my opinion, that we should have had it and should have predicted from the start. That's my opinion, but it might be totally incorrect.

I am hoping in six months or so to have the ESF in the model and have two models. I am not going to throw away this model because the ESF is a very complicating factor. The ESF doesn't follow the levels or the offsets or anything. It's like a totally different geometry. You have to design it very carefully, because you want to be right from the start.

I am going to look at two dimensional problems first, to make sure that we design that grid correctly. It's going to take a significant amount of time. The problem that I have is, putting emphasis on the ESF -- everybody has limited funding -- with the very limited funding that we have, we have to put something on the back burner. I don't know if I answered you. I probably didn't.

MR. HINZE: I thought you said the number one unknown was the faults and their characteristics.

MR. BODVARSSON: Yes.

MR. HINZE: That certainly must be a very high priority for you then.

MR. BODVARSSON: It's a very high priority for me to get some data from people like Joe Rousseau, who have plans to go and study faults. That's a very high priority. It's something I would like to see, because I would be very interested in that data myself. In the meantime, since I don't know, the only thing that I can do is to consider

different conceptual models for the faults and then look at my results, and go from there. That's a very important point.

MR. BOAK: If Bo can get the ESF in his model in six months he will have it in his model before the ESF enters his test block in the mountain.

MR. BODVARSSON: That's a very good point.

MR. HINZE: With that, let's move on. Thank you, very much for a well illustrated and documented discussion. Claudia, you can be number two here. Claudia Newberry is going to be discussing unsaturated zone data collection and all the rest.

MS. NEWBERRY: My name is Claudia Newberry, and I am here from the Department of Energy in the Technical Analysis Branch of the Regulatory and Site Evaluation Division. I have been with DOE for about five years now. My Branch Chief, Jerry Boak, is in the front row. All those hard questions you have this morning, he will answer.

Going back to this morning, if you remember, April Gil was up here. She provided you with an overview of the regulatory requirements that drive the collection, interpretation and development of the hydrologic information. If you flip back to that presentation, you might notice that only certain sections of 10 CFR 60 deal expressly with the unsaturated zone program. All the other

sections that April talked about were developed for both the saturated and unsaturated zone programs.

A lot of the conditions that she described actually require input from more than just the hydrologic program, but also things like tectonics, geochemistry, climate, so that we are only talking about a very small part of the program as input to the larger process models and performance assessment calculations. As I go through this, please remember that while the unsaturated zone program is a very important part of the equation it is only one factor. When we get into the process models, bear in mind that there are other factors that are feeding into it.

You have heard a lot today on data collection. You heard Alan Flint and Joe Rousseau and now Yang, talk about the different data collection activities and interpretations. One of the things that I hope you noticed and I know you did because you mentioned it is that there are a lot of modeling activities involved with the data collection part of the program. Alan talked about the one, two and three dimensional models that he's using in terms of refining his data collection activities.

The very detailed models of the various aspects of the unsaturated zone program are combined in the site models that were described by Bo just now and by Ed Kwicklis. The activities that Bo and Ed do feed into the process level

models but are actually a part of performance assessment. When we talk about the performance assessment part of the program, we are talking about process models that combine the unsaturated zone flow with transport with geochemistry absorption, things that now begin to look at more than just one part of the equation but two or three different parts of the equation. Those process models are then abstracted into the total system performance assessment models.

Performance assessment is traditionally shown as a pyramid, and this is as close as you will see a pyramid in my program. At the top of the pyramid are the total system models. These are the most abstract models. These are the complementary cumulative distribution curves. I can say it, it I really can't explain exactly how they work. The intermediate part of that pyramid are the process level models. Those are the flow and transport models, and those address one or more complex processes and have a lot more data involved in them.

At the bottom we have the site models, and those are the ones that are the most complex in terms of the actual data that is put into them and the more detailed in terms of the stratigraphic extent.

MR. DAVIS: Can you go back?

MS. NEWBERRY: I can go back.

MR. DAVIS: There's a couple of things to explain

to me. How does the process model differ from the site model? The site models have the processes in them. What is the difference between the second and third bullet.

MS. NEWBERRY: The site models are where you are looking at the actual stratigraphy. What Bo was describing as his three dimensional site model is the beginning and almost the transition into the process models. When he takes his three dimensional grid and applies TOUGH to it, the TOUGH software code, then he is beginning to look at the processes.

MR. DAVIS: The site model is just a geometric model then, of what the --

MS. NEWBERRY: Let me get into this a little bit more. Maybe it will come clear. This is the pyramid with the levels of abstraction at the top. What we actually do is quite the opposite. We start at the bottom and work up. First, we use the lowest level data and models to create tests and modify the process level models. The inputs that Alan Flint had to Bo's model to his site scale model are abstracted and put into a process model.

Those are again abstracted for the performance models, and finally we do a total system performance model.

MR. DAVIS: It's your definition of process model, that I am have a problem with.

MS. NEWBERRY: Jerry, can you help me with the

process model.

MR. DAVIS: Let's say Bo's model 3-D has all the hydrology and then let's say total system performance that Sandia has -- I know what that one looks like -- is there something in between here that I don't know about?

MR. BOAK: Bo showed something that he developed that had stratigraphy and physical properties assigned to it. That was a site model. He then implemented that into a code which connects events that might occur in there as a process.

MR. DAVIS: The site model is really a description of the geometries.

MR. BOAK: A description of the geometry and the physical properties assigned to those geometric units.

MR. DAVIS: That's the site model.

MR. BOAK: That's the site model. The three dimensional model is a process model that uses that data to run processes that operate in that three dimensional site model.

MS. NEWBERRY: We start with a lot of information and abstract down to very little actual data that's going into the performance models, but a lot of complex processes.

MR. DAVIS: The first and second didn't go downward at all. He took geometry and added process to it. Now, I am going to go down to simple performance assessment

somehow which you will explain, right?

MS. NEWBERRY: I hope. This is an example of how performance assessment models can be refined based on the improved understanding from the site information. As Ed Kwicklis talked about, this particular saturation curve has a high value here at the cap rock at the Topopah Spring. That's a very narrow unit, but it seems to be very critical to looking at vertical flow.

In the process of looking at the total system type of performance we have to incorporate a very thin but laterally extensive layer into the whole process of how we describe vertical flow through the system.

There are three key defining elements of performance assessment in most basic definitions. It's a systematic process that identifies and models features, events and processes that could effect the safe performance and environmental acceptability of a radioactive waste repository. That definition isn't just true for performance assessment.

When we look at the whole site characterization program we are looking at features, events and processes. When we are looking at the site program up here at the top, we are primarily concerned with the features, what are the saturations, what are the matrix properties, what are the fracture properties, what are the stratigraphic extent of

these units, what do the faults look like. We are looking at the features.

When we move into the process models as the name would imply, we are beginning to look at the processes that are involved. We are looking at UZ zone flow and transport, and now we are starting to combine information. We are looking at what happens when we add heat, what happens when there is vapor flow, what happens when we come in contact with various geochemical conditions, what happens with sorption.

Now, we still care about the features. The events are important but our major area of concern is the processes involved. When we get down to the very bottom or top, as you may prefer of the performance assessment program, now we are concerned about the events. We have defined our features, we know what the processes are at the site, now let's add some events to it and see what happens.

While features, events and processes are how we describe performance assessment, in reality it's true across the whole program. It's just a matter of emphasis.

We have talked all day today basically about data collection and the models that are associated with data collection activities. These are what we are calling the process models now. These are the flow and transport models that we are looking at to help describe the unsaturated zone

system. This past year we did a review of the various unsaturated zone flow and transport capabilities available to the project, and two codes were recommended for some enhancement.

One is the TOUGH 2 code that Bo has been talking about in terms of looking at the three dimensional site scale model. The other one is the FEHM code that was developed by Los Alamos National Laboratories. They both have their strengths and they have some variations in what they can and cannot model.

What we have done here, as Bill mentioned, the 123 different conceptualizations that could occur or that you could use in modeling the unsaturated zone. We have taken -- and this is in your handout and probably more readable there -- three different cases. We have shown them against 68 different pieces of information parameters that are required if we are going to model those activities. Again, I didn't write down all those 68 parameters, I just kind of lumped them so we could make this a little more readable.

You can see as we go from a very simple -- Richard's equation -- isothermal system that is strictly porous media. We have very few real data. As we move across the matrix and look at gas flow non-isothermal, we need more information. When we move to a multi-phase system we have two cases here. One, we are using TOUGH which is a

porous media realization and the other one is the FEHM code which can take into account fractures.

You will look at the amount of data that is now required from the site haracterization program to run these models and show whether or not these processes are important.

MR. DAVIS: Can I have a little bit more background on the FEHM code versus TOUGH's handling of fractures? We just heard a talk that said it handled fractures. What's the difference.

MS. NEWBERRY: Bill Nelson.

MR. DAVIS: With respect to 3-D fractures, if there is a difference.

MR. NELSON: There is no difference. There are different nuances that they do -- if my memory serves me right they both take it in dual porosity with a pseudo steady -- both of them are struggling. Actually, TOUGH 2 has some advantages at the moment on the dual permeability with transients. It's pretty hard. Some has some advantages and some have others.

MR. DAVIS: What's the reason they have two of them now. I guess I am confused.

MR. NELSON: The reason for that really is, is that -- I don't want to take too much time here. This idea of validation, validation is a continuing process. We sense

that validation is reasonably achievable. We are going to keep working on it. The verification aspect back here, you are comparing with analytic solutions. Unfortunately, our analytic solutions are not complete enough to really test them.

To really test we felt that we needed -- it would be used in a benchmarking sense, to see what we were doing with the rough and tumble.

MR. DAVIS: Will the benchmarking be done prior to the decision for the final code.

MR. NELSON: I am not sure that -- I think it's premature to decide that.

MR. BODVARSSON: My understanding is that USGS are trying to develop a three dimensional model of the flow system, the gas flow, the moisture flow to be able to guide this in the site characterization. This is our purpose.

MR. DAVIS: The TOUGH code --

Mr. BODVARSSON: The code is immaterial, as far as I am concerned. I happen to prefer TOUGH, because I used that for many years and am very familiar with TOUGH. I can make it do a lot of things that I am happy about in this program. The Los Alamos is responsible for the retardation studies. They are more comfortable with the code development themselves, the FEHM code, which is a fine development code.

They periodically will get our information and our data and put it in their code to get some kind of a flow field to do the retardation studies. I think it's immaterial to compare those codes or say one code is better than the other code.

MR. DAVIS: That's not my purpose.

MR. BODVARSSON: There seems to be a preference in Los Alamos wants to use that code. What Bill said, it's also -- it gives me confidences. When we compute our three dimensional moisture flow and give all the parameters to Los Alamos, when George Civilaski computes that in his own model without going through the calibration and predictive, if he gets similar results to mine I am very happy.

MR. DAVIS: The question really is, you are both using the same conceptual models.

MR. BODVARSSON: Yes, that's the main thing, as far as I am concerned.

MR. DAVIS: You are using the same physics.

MR. BODVARSSON: As far as I know, yes.

MR. DAVIS: Thank you.

MR. NELSON: When you get this many combinations you have little nuances. Functionally, they can be the same.

MR. DAVIS: It's hard to belabor this. As far as use in the program, who got site characterization, Los

Alamos or both?

MR. NELSON: Both.

MR. DAVIS: Thank you.

MS. NEWBERRY: The important thing from the slide was the amount of information that is required from the site characterization program.

What we did learn was that we think that discreet fracture flow is a primary enhancement that we want to make to the code. FRACMAN developed by Golder Associates, is being modified to work with FEHM. It can be modified to work with TOUGH.

I do want to emphasize that the site models are needed to create the unsaturated flow and transport models for Yucca Mountain when we start using these process level codes. It depends on Bo's mesh or the mesh that George Civilaski develops for the FEHM code, which is a little different. It depends on the meshes and it depends on the inputs that you put in those meshes.

MR. DAVIS: Is that a different code?

MS. NEWBERRY: It's a different code, that's going to be used with the FEHM code and possibly with the TOUGH code, to give us a discreet fracture component to the models.

MR. NELSON: This is part of the approach that is being used to bound things in connection with the fracture

systems. There's another set of presentations that can be done that would do this. We are using a basis of a discretely fractured system as a basis for testing alternate conceptualizations based on a continuum representation.

MR. DAVIS: It helps. I guess there is still a lot of questions raised. Maybe she will answer them. I will let her continue.

MS. NEWBERRY: This is a wiring diagram that shows where site characterization fits into finally coming down to resolutions of the regulatory requirements. Somewhere in here, I will get it in focus. You can see that the site characterization activities will feed both the unsaturated and saturated zone models, and those have to be combined with information with waste properties and facility design before we can come up with a full groundwater flow model, before we can develop scenarios, before we can develop a waste package environment model, a waste form model.

Those in turn feed down to the higher level models, the radionuclide transport model, the total system model. Finally, we get down to where we have sufficient information, that we can actually address the regulatory requirements.

Groundwater travel time keeps coming up, and here it is. We formed a groundwater travel time issue resolution working group to examine the technical aspects of

groundwater flow at Yucca Mountain. One of our objectives is to develop an approach for demonstrating compliance with natural barriers performance requirements. We have a draft action plan. I will quote out of it a little bit, because I think it pretty much describes where we are in terms of groundwater travel time.

The definitions of groundwater travel time in 10 CFR Part 60 and in 10 CFR Part 960 are different. The definitions are, however, similar in that they are both concerned with pre-waste emplacement groundwater travel time as a single value parameter. The arrival of contaminants in groundwater at the accessible environment could, however, only occur after waste emplacement and should in fact be thought of as a multi-dimensional parameter distributed in time, space and concentrations.

As a consequence, groundwater travel time is currently described in NRC's rule and DOE's guidelines as not an appropriate or useful measure of site performance. That's what we feel. When we go to the NRC in March for a technical exchange, we would like -- this says 1995, but we are not that far behind. It's only in 1994. We would like to discuss this with them, and reach some sort of an understanding over what groundwater travel time is and how it should be defined.

Also, I would like to point out that the State of

Nevada in a letter to NRC, advised that it needs to examine groundwater travel time and the definition of a disturbed zone in parallel, in context of our evaluation of the extended dry repository concept. In other words, we need to consider heat, and heat is only a part of the repository system after waste emplacement. Groundwater travel time can only be effectively defined in terms of a post-waste emplacement calculation.

You will have a report sometime in late FY '95. It takes us a lot longer to write than it does to talk.

MR. HINZE: That is '95?

MS. NEWBERRY: That is really '95. Yes.

MR. HINZE: Okay.

MR. STEINDLER: A small nit. Are you planning to have, prior to your March -- next March meeting, some exchange of written information with the NRC staff, so that the conversation can be fruitful when you finally get to the March meeting?

MS. NEWBERRY: Les, are we planning on any writing? No. We are going to surprise them.

MR. STEINDLER: Good luck.

[Laughter.]

MS. NEWBERRY: Okay. We have talked about process models. Groundwater travel time is really a pretty advanced process model.

We are also concerned about some of the engineered barrier system -- subsystem models. I think Mike mentioned that the hydrology program is an input to the engineered barrier system models. Right now we have two that are currently being used on the program and are being enhanced. One is the YMIM, which was developed by Lawrence Livermore Labs. That is a multiple process effects on container performance and release model, and the AREST code from Pacific Northwest Laboratories, which is another engineered system model.

That is subsystem performance assessment, then comes total system performance assessment. This is of course the most abstracted level of modeling on the program. We have two total system level models that are being used. One is the total system analyzer from Sandia National Laboratories, and the other one is the Repository Integration Program that was developed by Golder & Associates.

The TSA was used in the total system performance assessment in 1991. RIP was used in a code comparison in 1993. Both codes were used in the 1993 total system performance assessment. In that particular performance assessment, we looked at thermal perturbations to the site.

One of the results from TSPA -- total system performance assessment, 1991, was an indication of a very

definite relationship between releases and the flux through the unsaturated zone. There was a clear relationship between flux and how much we could release from the repository. So, that information was fed back to the site program as an indication that we need much more detailed information on the flux in the unsaturated zone. It is a critical parameter to understanding performance. Again, this was without a thermal perturbation to the site.

MR. LEAP: Let me ask a question.

MS. NEWBERRY: Sure.

MR. LEAP: What is a normalized release?

MS. NEWBERRY: Normalized release? Jerry?

MR. BOAK: A normalized release is the release of radionuclides -- of the individual radionuclides, divided by the release limits permitted in table one, the 40 CFR 191, and added together, with the sum normalized release that forms one axis of the complementary cumulative distribution function under the 40 CFR 191, the pre-existing regulations governing waste disposal.

MR. DAVIS: So, if all of my calculations are less than one, why do I need to tell anybody to go do any work? Because one is the limit of any probability.

MR. BOAK: That is a good question.

MS. NEWBERRY: Yes.

MR. DAVIS: Very good question.

MS. NEWBERRY: Can we all go home now?

[Laughter.]

MR. DAVIS: If Alan Flint hadn't said he didn't trust any of your models, then I would say we could go home now.

[Laughter.]

MS. NEWBERRY: It is all his fault.

Okay. Where are we going with the future of total system performance assessments? In the near-term, we are going to use them for program decisions on site suitability evaluations, the underground facility and engineered system designs, and prioritizing and evaluating the test program. As we go through these total system performance assessments every two years, we should be looking at the sensitivities of the total system performance to the different aspects of the site and feeding that back to the testing program.

Longer term, of course, the total system performance assessments have to feed into the advanced conceptual design and the license application design, the site recommendation report, the environmental impact statement, and all of the safety and analysis and license application work.

MR. HINZE: This is in a two-year cycle?

MS. NEWBERRY: You do them every two years, right Jerry, or have been? You have done them twice now.

MR. BOAK: I think that is the usual answer we give.

MS. NEWBERRY: Okay. In summary, the site performance -- site data and performance assessment are linked through the site program, data interpretation and modeling. The site data and models are used to refine the process level performance assessment models, the TOUGH, the FEHM. And the process level models are tested and abstracted to provide the initial and boundary conditions and the input data for the system-level models.

And, again, where we are in the performance assessment program -- we actually do have total system performance assessment models. They exist. They are being enhanced. They are being used. We have subsystem level models. We have process level models. And the primary objective of the performance assessment part of the program is to update and test codes based on the site data and models, to test the models and provide feedback to the site and design programs.

Do you have any questions?

MR. STEINDLER: I wonder if I might ask whether you have defined for yourself the set of criteria that will tell you whether or not the particular model has been adequately or sufficiently validated? How do you know success when you see it?

MS. NEWBERRY: Well, I have been told that the only thing you can do is invalidate a model. You can't validate it. But, when you are looking at the process models -- well, let me back up a little bit. What we would like to do with a lot of our modeling activities is do some predictive models, so that when they go to drill bore-holes, we can predict what we expect to see at those locations. If we are correct, percentage wise, we become increasingly correct with more and more bore-holes that are drilled, then we should have increased confidence in the models.

As far as the long-term models are concerned, the process models, it is very difficult to actually develop any real validation process, because you can't go out and test it. You have to look at natural analogs, and see if what you predict is actually occurring in the analog situations.

MR. STEINDLER: I think I understand the problem. The question I have for you is what do you propose as a solution to the problem? Are you simply going to let the clock run out until you have to have a license application in on the desk of the commissioners and then say, well, that's as far as we are going to go? I mean, that is one way to assess how far you need to go or how much work you need to do.

MS. NEWBERRY: Well, again, I guess I have to ask you which types of models you are talking about -- the site

models, the process models, the total system models --

MR. STEINDLER: Yes.

MS. NEWBERRY: -- or all? And, again, in terms of site models, I think that you can come very close to verifying the model based on predictions of what you would expect to see and if you are right -- if Alan is --

MR. STEINDLER: What do you mean by right?

MS. NEWBERRY: Okay. When we did -- drilled UZ-16, Alan Flint came in with a prediction of saturations. He was very close, in some cases, and he was a little bit off in some others. Sorry. But, he was actually pretty good. So, his model must be pretty close to correct for that location. Now, we are drilling --

MR. STEINDLER: Just an assumption.

MS. NEWBERRY: For that particular location.

MR. STEINDLER: It still is an interesting assumption.

MS. NEWBERRY: Okay. Now, if we continue our drilling program, and we ask Alan to come up with a prediction of what he expects to see in SD-12, which is not even started yet, and, again, he predicts saturation curves correctly for that location, we have increased confidence in his model. If we go ahead and drill another hole and he has a prediction and, again, he is correct, we have increased confidence in his model. If we get to the point where we

are pretty confident of his model, but we can never show it as totally correct, unless at some point -- well, we can't -- at some point we have to say we have confidence in that model, and we will take it forward.

MR. STEINDLER: Yes. I just -- my question --

MS. NEWBERRY: That is why I am saying the only thing you can do is disprove it; you can't prove it.

MR. STEINDLER: I see. All right. I will quit here.

MR. HINZE: A few more questions. Go ahead.

MR. LEAP: So, basically then what you are saying is that the greatest confidence is going to be in the interpolation within the mountain, rather than extrapolation to some time outside -- to distance outside the mountain some time in the future. So, basically then you are just saying that basically it comes down to just faith, doesn't it -- faith in your model, and faith in what you have done so far? And you say that that is the best we can do, and --

MS. NEWBERRY: Well, again, I was talking about in that case about what I call the site models, okay -- the features. When we start talking about the processes, you can compare what we expect to see at the site with natural analogs. We have people who are working in New Zealand, in the thermal fields to look at the thermal effects on the

rock of high-temperature liquids. Now, that can give us an indication of what would happen if we added heat to our site.

MR. LEAP: How do you think the natural analogs in other parts of the world are close enough to Yucca Mountain? Has anybody done anything to verify how closely these analogs fit the Yucca Mountain situation physically?

MR. BOAK: Yes, they have. The New Zealand analog was selected because of its similarities to Yucca Mountain, and because of the ability to look at an active geothermal field, in other words, a place where heat was being put into rocks remarkably similar to Yucca Mountain. The mineralogy is similar, and there is a wide range of conditions that we have the opportunity to look at.

So, if we are looking at our geochemical models, we think that things like EQ-36 -- to look at whether that is really a good representation of what the thermal dynamics of the process is that would occur in a repository if one were at Yucca Mountain. We think it is a quite good analog to test the ranges of possibilities -- the range of parameter space that we need to understand in order to evaluate Yucca Mountain. It is not always as easy to find a good analog for other sorts of processes we would like to evaluate and the validity of analogs obviously ranges widely. We are not really sure whether we will be able to

do that -- to test that for everything.

But, I think the other aspect of a kind of analog process is to look at Yucca Mountain as an analog for itself, in that it has been through a heating event during the time shortly after the rocks at Yucca Mountain were erupted, and so it has shown a lot of chemical variations, mineralogic and petrologic variations, and even hydrologic variations that we may be able to pick up traces of in the major trace and isotopic geochemical signatures.

MR. HINZE: Alan Flint.

MR. FLINT: Yes. I just want to make a statement or two about what was going on with this modeling business. One thing is that we are going to have to develop cumulative competence. As was said earlier, there might be 128 conceptual models. You can take all 128 of those, mine being just one of those 128, and maybe half of them predict the same thing that I predicted just as well. Then you can look at those half that predicted it and you can look and see if the system fails according to regulations, if one of those other models was the case.

If you have a drain pipe, all of the water runs down the drain pipe, hits the canisters. It all comes back to the drain pipe and continues on down. You violate the standards, yet you predict the profile that I saw, if you are 50 feet or a hundred feet or 200 feet away. So, you

have to look at a series of models. They can make the same prediction because there may be many different combinations that would give you the same answer. But, what you need is a set of models then -- that this 50 predicts this one particular location. If everything looks the same over the site, you run into some problems. What you need is divergence of information. You need the perched water model. Then all of a sudden you take my model plus the other 50 that predicted the same thing I saw, you go to UZ-14, and you find that 25 of those could predict the two occurrences.

Now you have started to eliminate certain things about the system. Then you add the geochemistry data, and you maybe eliminate more of those, until you start to develop a system that can see these different things that you see at the site in different locations. But, you are just going to have to develop this confidence -- this cumulative confidence where a lot of different people looking at these answer the same questions the same way and start to feel comfortable with it and how your probability of violating the standard or running into these problems occurs when you start to eliminate some of these possible conceptualizations that you put into the site.

But, you need to do this at different locations, under different conditions, because you might have several

models that will give you the same exact prediction. Mine was just one that worked at UZ-16. It actually may have worked at UZ-14. We haven't gotten the data back yet from that. Then we are going to start to look for -- then use our models and predict something -- take 25 and you predict certain things. You can see it with only 10 of the models, and then you see it for real. You develop confidence. That is the only way you can do it I think is to develop that confidence.

MR. HINZE: Paul?

MR. DAVIS: Two questions. Who is doing the rest of those models? I thought I just heard that site characterization was being driven by one conceptual model. And then, second, how do all of those still relate to this total systems model? And that quantum leap I still do not understand. Sorry.

MR. FLINT: I don't understand it either, but I will -- the first part of your question I can --

MR. DAVIS: The first question is who is doing the rest of that modeling that alters the conceptual models in a systematic way?

MR. FLINT: Bo is doing several of those. We are not doing all 126 because we are pretty confident that the 126 don't all need to be done. One of those is pure matrix flow. We know there is fracture flow going on, so we know

we incorporate the fractures. There we get rid of anything that is pure matrix flow. We know there is a geothermal gradient, so we get rid of isothermal conditions, and we go to thermal conditions. We know there is vapor flow. You see, a lot of those things we put on a big list. And you would look at the list and you would say well, that is ridiculous to have all of those, but we have to have them on the list so we can show that we looked at all of those, and we can start to reduce that down.

I run some models, Ed runs some models, Bo runs some models -- all different combinations of things at different parts of the site. But, we are doing that for a site model that then has to be consistent with what we see in the mountain. We have to constrain ourselves by some reality which I think we can do. The work that Rick Strimler is doing is giving us a wonderful geometry to work within.

But, you are right, in the end, we are only going to have a calibrated model based on each of the following bore-holes. If we get to the last bore-hole, and we still haven't gotten it right, that is the best we have. And we have to look at the uncertainty of all of these other models that are possible. And, if all of the uncertainty of all of the other models can cause failure of the system, then there is a potential that a failure of the system will occur, or

we cannot predict that it won't occur. That is when we say the site is not a suitable site.

But, in the end, if after four or five bore-holes, we start to develop this uncertainty, let's say we are off by 30 percent on every single one -- make that your uncertainty, put it in your total system performance assessment model -- if you can't get failure with that uncertainty that you have, then you have developed confidence, and that is when the NRC is stuck with the task of deciding whether or not the site is a suitable site.

We would say, well, as scientific organizations, we feel comfortable that this is a good, reasonable range of uncertainty. And then somebody in the Regulatory Commission has to make the decision whether that is an acceptable risk or uncertainty and our believability.

We are doing some of those models now. In fact, we have done the more complicated models. We have gotten rid of the simple models, because the simple models are represented in the complicated models, in a sense.

MR. DAVIS: I only heard one. The way I thought I heard the talks going was that you were doing detailed modeling and everyone else is doing detailed modeling that fed into one model, Bo's model -- not that you were doing parallel modeling of different concepts to compare with reality and drive the program.

MR. FLINT: We are doing different models.

MR. DAVIS: Which is true?

MR. FLINT: We are doing lots of submodels. We are doing lab scale, small field scale, larger-scale modeling. And Bo's one model is a model that has a lot of those different components in it. And lots of conceptual models are tested in his model. He is using the one geometry. His geometry is fixed for the moment. It can be changed. You can go to uniform infiltration rate. That is one of the 128 conceptual models.

MR. DAVIS: I understand.

MR. FLINT: Infiltration and washes, that is another one. And, WIPP fractures, that is another one, with isothermal condition or non-isothermal. He has done it with non-isothermal. He puts isothermal -- or I mean, he puts thermal conditions in, that changes it. See, he can keep adding all of those things to the one geometry and test many of those -- the most important ones -- that we think are important. So, we do have a series of sub-models.

MR. DAVIS: And there will be a systematic approach then that does the multiple conceptual models to derive site characterization?.

MR. FLINT: Yes. I believe so.

MR. DAVIS: It will happen?

MR. FLINT: And that is in there.

MR. DAVIS: The second question. Now, I t[illegible] that with the supposed uncertainty you said. How does that translate into uncertainty in simple, total systems performance assessment models?

MR. FLINT: Jerry?

MR. BOAK: Ask that again.

MR. DAVIS: Let's say we have a description that I lived with here that said we have some 30 percent uncertainty in something, and we can't get better than that, but now I have this process of going from a complex site model to some supposedly simpler -- I have been told simpler, total systems performance assessment model; what is the transformation of uncertainty between those?

MR. BOAK: I guess I would say that when you abstract a process model to incorporate it into a higher level subsystem or system model, what you are abstracting are the critical features. There cannot be 82 sensitive parameters to a model. Statically that would fall apart. None of them would be very sensitive.

So, some features will predominate in the sensitivity and, therefore, the uncertainties can be captured by bounding evaluations or by detailed uncertainty analyses to say, look, we put this in. We covered five orders of magnitude, which is more than the natural range of occurring materials and, in fact, it doesn't make a damn bit

of difference in terms of how the site performs.

At that point then, it is reasonable to remove that feature. On the other hand, it behooves us to understand that particular parameter well enough to know that we are not missing something in saying good-bye to it.

MR. DAVIS: But, that is done on a detailed level, because that is the only place I can make that judgment.

MR. BOAK: That's right. That is done on a detailed level, and not at the system level.

MR. DAVIS: So, at the detailed level, I really do the uncertainty analysis?

MR. BOAK: Yes.

MR. DAVIS: I have to?

MR. BOAK: Yes.

MR. DAVIS: Okay. Why do I use the other one at all then?

MR. BOAK: You don't do an uncertainty analysis on total system releases or on dose to populations over whatever timeframe.

MR. DAVIS: But, why not, if I have already done the work?

MR. BOAK: You don't get to that. You don't have a --

MR. DAVIS: I know. Exactly.

MR. BOAK: -- sophisticated enough. We have to do

this --

MR. DAVIS: Well, I have velocities. Let's say that Bo would give me a range of velocities as a function of space and time. Couldn't those directly be used by total systems performance assessment without a new model?

MR. BOAK: But, that is a simplification, using only the velocities.

MR. DAVIS: It is into the output.

MR. BOAK: It is a substantial simplification.

MR. DAVIS: No. I am just saying --

MR. BOAK: To do it for the three-dimensional model for a thousand realizations is likely to even slow down most computers.

MR. DAVIS: Fine. But, I don't see how I captured his uncertainty, unless I did the --

MR. BOAK: His uncertainty in the velocities?

MR. DAVIS: Unless I did the full uncertainty analysis at the complex level of modeling, I don't know how I would transfer that to a stochastic -- I hate to use the word, Alan -- model at the total systems level that captures the same sort of uncertainty. I still don't even know what I am doing that process, to be honest. I have no idea why you think you need another one. Because, if I look at the two models today, I can say that the total systems performance assessment, with these multiple columns, is damn

near as complicated as the one he is doing, it just has some more processes in it in the repository. I am not sure why -- why I do the simplification step.

MR. BOAK: I don't think Alan agrees with that.

MR. DAVIS: Why would I do the simplification?

MR. BOAK: A realization in the TSPA.

MR. HINZE: Dave maybe has an answer. He has got his hand up. Let's see if we can get one more remark in here. Let's see. Do clarify this.

MR. VAN LUIK: Well, I don't know if I can clarify it or not. I think what Jerry is saying is correct. We are depending on the site people to come up with a model that reflects the conditions that are found at the site. Where performance assessment takes off is one, demonstrating that it correctly abstracts that information into the base case for the total system assessments and, second, then we have to, as you saw in the bottom of the hour glass, we have to put in the events. Now the events are the leaps of faith that were mentioned a minute ago. Will there be some kind of a natural perturbation of the system or are the Sierra Nevada going to collapse and allow lots of rain to come into Nevada?

These are the kinds of things that we have to bound in some way that will satisfy the regulators. So, our first job -- and I think the last to the last viewgraph was

saying our first job right now is we have demonstrated that we have a total system capability. We have demonstrated a mid-level capability, and now our job is to take the process-level models, incorporate the new information from site, do the sensitivity studies, so we can document and defend the roll-up for the higher level models. But, that is only for the undisturbed case. Now, we are going to add heat, and we are going to add events which may or may not ever occur, and evaluate those probabilistically. I think that is where some of the faith comes in.

But, the basic idea is that the undisturbed case model has to be defensible and the roll-up from the process level has to be defensible. After that, it is going to be a debate between those who can think of better scenarios than us.

MR. DAVIS: Right. Maybe we can talk later. But, my problem would be -- if I took Bo's model and added events and heat in the repository, I don't have any problem understanding that transformation. It is the process of abstraction that I keep hearing about going from complex to simple abstraction that I don't understand. Maybe we can talk about it later.

MR. VAN LUIK: Yes. That is a whole other topic. We probably shouldn't be in this site program discussion. I am sure that we will have other exchanges on TSPA and why we

chose the philosophy of using rolled-up models, rather than stringing process level models together.

MR. HINZE: Thank you very much. You did clarify it for us to some degree, in any event. Thank you very much Claudia.

At this point we have ended the formal presentations from DOE. Joe, in his review, has opted for handling that in any roundtable, that is why I made that statement.

So, at this point, what I will do is -- Marty, I believe you have arranged to go before Linda Lehman, is that correct?

MR. MIFFLIN: Yes.

MR. HINZE: So, at this point, we will call on Marty to discuss fracture matrix flow in the unsaturated zone at Yucca Mountain. Marty Mifflin.

MR. MIFFLIN: Well, after hearing some of the talks, I think that I can go very fast. I am tired, and I think everybody else is tired. You have seen some of this before. I will just make a few points. I am Marty Mifflin, with Mifflin & Associates. I support the State of Nevada and Nye County.

What I am going to try to do is deal with the importance of the fracture flow and at least touch on some of the conditions under which fracture flow should be

expected. I heard somebody mention millions of fractures. Actually, there are billions of fractures under the original approximately 2,000-acre repository block. This was made up quite some time ago to try to get across the idea that the predictability of this type of a site, when you have to deal with the fractured nature becomes a question as to -- from -- how you deal with point data, versus extrapolating between point data, and also the possible importance of fracture flow versus matrix flow.

Now, this is a model of the site that was in the SCP -- a conceptual idea of what the hydrology might be or might not be. It was put out as kind of a working hypothesis. It is probably not too far from at least the basic overall types of conditions that might be found.

The data there that shows the density of fractures came from the various early cores and there is much better data now, although I don't know whether the fractures have been counted in the core. But, in some of the cores I imagine the densities might even be higher than what we see here. But, the point is is even in the bedded units, there are fractures. And the question is how -- it will be very important as to determining how those fractures behave or what is the range of possibilities in fracturing in both the Paintbrush and the Calico Hills.

This was also old data, but it gives kind of an

idea of what types of saturations are -- were found in the early core work and, of course, there is even a greater variability now with some of the work that Alan and others have been doing. The point here for this slide though is to give some idea of the porosity of the system right there in the center and how it varies with respect to the welded units versus some of the bedded units, and also the fact that, when you get down in the 80 and the 90 percent saturation, you are basically getting up close to full saturation.

Now, this is a really -- even though there is better data now, I think that this particular simple-minded depiction develops an important departure point for conceptual models of what goes on in a fractured system as you vary flux or recharge. And, of course, generally speaking, everybody wants to deal in average flux; but, in reality, as Alan has pointed out very well in some of his work, that the -- on a localized basis, in time and space, we are talking about not averages, but we are talking about the way water may ent-- into the mountain in short-term recharge pulses and, in some parts of it, at least, it may be kind of ephemeral flow and fractures, and in other places, we are talking about matrix flow, depending on the actual saturated hydraulic conductivity of some of the units.

Here, I went through an exercise on early data. Unfortunately, early data had wide ranges in values that were reported. But, I went through an exercise and said, okay, if we have .5 millimeters per year, for example, would we have fracture flow or would we have matrix flow. In other words, the way I use the saturated hydraulic conductivity is I said, okay, at about a hundred percent gradient, can the surface area accept that re-charge rate, assuming it got into the ground, in any given unit? If it can't -- if matrix flow can't keep up with it, it will go to fractures. So, what you see on there, M/F, or F, or M is whether or not, at those various postulated rates of recharge of a year's period of time -- in other words, it is distributed over time -- that you would either have matrix or fracture flow. Of course, the availability of recharge is not necessarily distributed over the year, until you get down at depth.

So that, at least at the surface, one would see that, if you had the availability of say, in a short period of time, you would be almost always dealing with fracture flow up in say the Tiva Canyon, if localized availability infiltration, and so on. But, when you get down in the Paintbrush, the bedded unit, the chances are, based on those hydraulic conductivities, chances are you would be at least in an environment where all of it could be matrix flow. It

doesn't mean it would be, but all of it could be at those rates, and so on.

So, I think that that type of simple-minded conceptual model creates the type of problem that has been discussed here in more sophisticated terms, where, you know, you have a range of conceptual models of the actual physics of the system and how you back out in confidence that you have got the right approach.

Well, if you think about those say current climate situations, and the idea that one of the postulated benefits of the site being located in an arid climate, one has to ask, okay, what happens if it gets a little wetter -- if there is more effective moisture? Clearly, this is an issue with respect to how much is matrix flow and how much is fracture flow and, indeed, what are the distributed or localized recharge rates, in terms of performance of the site, with a slight change in climate to more effective moisture?

So, we back off and say, well, what percent of time say over the radioactive life of the repository, if we forget about standards for a moment -- and I think it is important to think not only over the period of the radioactive life, and also over the 10,000-year period. So, if we just ask the first general question, it is something like 65 to 85 percent of the time in the last 2.4 million

years has been, at least on a worldwide basis, a cooler or wetter, glacial-type of climate. That is what the record shows. So, that at least catches our attention.

But, as you go into the actual detailed level of understanding, we go down through -- I have tried to make some points here and what it does is it creates -- what we really know creates a level of uncertainty about projecting over the next 10,000 years of the regulatory period.

We find that climate change, on a worldwide basis, that the records showing going to say wetter climates, are not necessarily synchronous, and that is even true within the great basin. Part of the problem may well be just our control on dating. But, part of the problem is that the complexity of the feedback and actual climates is such that we are not quite at the point where we can predict on, at least in a regional sense, what a given change in world climate would do on a local basis.

So, my conclusion at least is that -- the bottom point is that we would have to have a better understanding than we have right at the current time to try to get at the -- being able to predict, on the basis of some recognized and proven forcing function, such as the Milankovitch Theory, as to whether or not we are going to have a pluvial climate within the containment licensing period.

If we then go to a conservative approach, if we

say we can't predict, or we can't predict with much certainty, then one would ask, well, what would be the change -- say a maximized change if we went to a full pluvial climate that shows up in the record in the Great Basin. I am sticking out -- I put up there on purpose "opinion," because we don't even know what the recharge rate of the site is now. And, even if my opinion of about 10 times greater effective moisture were correct, we don't have a departure point to multiply by 10. So, we have some problems right from the start. However, my own opinion is that it may not even be a simple function that we get down so dry and then you shouldn't multiply it by 10, you should multiply it by 20 or 30 or five.

So, I went ahead and assumed that there is probably about a millimeter minimum of distributed recharge. And, if that is the case, we would expect, on a distributed basis, something like a range from 10 to 30 millimeters, and you would have some zones that were much higher, and some zones that were much lower. And perhaps -- in the case of Yucca Mountain, some areas that are well-defended by heavy caliches, et cetera, or regardless of whether it is fractured. Tiva Canyon may not have a whole lot of recharge, but under washes it may be quite greatly increased.

It you go back to that earlier five -- 10 -- if we

go back to this one, we see that we are up here. We are getting up into where we would have fractured flow in most of the units, as soon as we get up to say 10 millimeters. However, in the bedded units, it is possible we still would have basically a matrix flow, depending on the characteristics of the fractures, through those bedded units.

Well, the other scenario where I would expect considerable fracture flow is under some thermal loading scenarios. And this is a nice kind of a summary of thermal loading scenarios that Larry Ramspott put out a while back. Basically, you have the so-called reference thermal load, or the site characterization plan thermal load with the 57 kilowatts per acre, 10 year-old core.

Then you have the idea of some type of the so-called cold type of loading, where you would try to keep it basically below the boiling point, and then you have the dry-out scenario, where you would have a high enough thermal load to try to keep the boiling envelope around for 10,000 years or so.

I tried to go through a mental exercise of what might be expected with the cold load. You have to have a much larger site. You are going into -- going on all three or four sides of the repository block. I think you would have locally marked increases in contact with the waste

package. I think that gas phase releases might be reduced, primarily because you would increase saturation in perching and so forth, above the repository on the bedded units, which may indeed inhibit gas circulation. I am convinced, if any of the waste packages failed, you would have a much higher travel times, far more fracture flow below the repository level.

We are dealing with the type of situation where, depending on what the engineered barrier was, would probably determine just how successful this type of a cold load scenario would look in say performance assessment models. We may get into the problem of groundwater travel time in this type of scenario as well.

I made up a sketch of what I think the site would look like, in a very crude way, with the cold load. The repository would be -- there would have to be areas of the repository beyond this cost section to handle the postulated waste.

The upper unit there -- I kind of diagrammatic -- or the Paintbrush Tuff I diagrammatically have suggested that that would be at a fairly high level of saturation. It might be totally saturated. There would be some perched water on top of it. I showed diagrammatically that some places in the welded tuff in the Topopah Springs, there probably would be localized perching. There could be

localized even ephemeral perching. There would probably be a lot more ephemeral fracture flow through the welded units. There would be maybe -- as the postulated evidence for the failure of the water table, there would be several hundred feet of difference in the position of the water table. It would be a little higher than the current one, which you see dotted there.

So, basically, this would be a scenario where I think that the welded units would be basically -- remain unsaturated, but there would be much more fracture flow involved. And my own feeling is that the repository horizon would not flood, at least where there is a database in-hand for the present time. Although, UZ-14 is raising some questions because the perching is not that far from the repository horizon at the north edge of the block.

If we go to the site characterization plan loading scenario, then -- and we had plenty of pluvial climb -- in other words the wettest that is in the geologic record for the Great Basin and for Yucca Mountain area, I think that here, some of these points would be reasonable projections.

The thermal aspects, with the 96 degrees C envelope -- some of these things that Buscheck has modeled and demonstrated through his various and sundry modeling efforts, and others have done similar things -- suggests that obviously we would have a boiling -- above boiling

zone, and we would have some type of a localized saturation halo caused by condensation.

I think that one of the problems -- and I think it is easier to show -- is that this scenario is that -- because cooldown comes so early in the 10,000-year period, that one sees some things that are very unfavorable. What I have shown here is where it is double-hatched as a postulated thermal envelope. It is basically -- it is above 96 degrees C. It is the area that at least partially would dry out. It mobilizes based on -- assuming that it is a conductive type of envelope -- that it mobilizes if you have almost a complete dry-out int it from the matrix water something in the neighborhood of 10 or so thousand acre feet of water and that goes out -- and presumably because it may be relatively trapped under the Paintbrush Tuff bedded unit, that most of that would condense and remain partially above and partially below. Some of it will perch on the Calico Hills bedded units.

Then presumably -- most of that is in fractures, and it will drain back as fast as the cooldown occurs. And added to the cumulative recharge over a period of time of several hundred years would, depending on what recharge is in a pluvial climate, and it should be high enough that it would fill up that mountain pretty good.

So, basically, all of that shaded area is my

concept of what gets -- sets up conditions for fracture flow, and a lot of it. So, it is not a very favorable scenario, at least as I understand it and as I think some of the modeling and the analysis have demonstrated would be probable.

And the dry-out looks good, at least in an overview sense in some ways, but not so good probably when you take a more in-depth look at it, from the standpoint of how much -- of where you might get some releases at land service. The part that is very difficult to predict, particularly with a pluvial climate, is just how much hydrothermal action you get at land service. You have got basically an infinite supply over the 10,000 years, if you have a plenipluvial climate. You have a good supply of water. So you have got the heat and the thermal envelopes would go far enough, right up to the Paintbrush Tuff, and whip right down close to the water table. So, you have got a situation where, not only do you have the buoyancy effect of the water derived from the water table, you also have a problem that you are accumulating a lot of water above it, and so you have got a damn good water supply.

And so there are problems with determining whether the whole system leaks or not enough so that you would have distributed hydrothermal activity in localized vents. And also, there is the question of how long the waste packages

would hold up.

I couldn't figure out how to draw that, so I took one of Tom Buscheck's. But, one of the aspects of it would be a much smaller repository, if you load the waste in in a higher density. But, on the other hand, basically, what this modeling shows is that you have got this condensation zone that gets right up there toward land service. And, if you have any of the really open fracture conduits, then one would anticipate, with the pluvial climate -- and this is not showing any recharge -- that you have a good water supply. And you have at least set the stage for hydrothermal activity on a localized basis, all because of fractures. That may well be open enough to allow the circulation.

One other element of the question about climate change and thermal loads is the time that is involved here. An undesirable aspect with going with the dry-out scenario is that you are keeping it hot for -- you know, above boiling for a long period of time. Well, it gives you a much longer period of time then to be unlucky enough for a climate change. So, on the right there you see that, in this particular modeling scenario, which is basically one of the dry-out scenarios, is that you are above boiling for most of the -- almost all of the 10,000-year period of containment. Also, that gives you a 10,000 year time period

for a climate change to occur. So, that is another aspect of the whole thing.

In summary, the main point I was trying to get across is that, if one considers the importance of fracture flow, in terms of the idea of actually having a repository there, rather than just pre-existing conditions, than the importance and the difficulty of dealing with an accurate depiction of what that fracture flow does, based on the basic saturated hydraulic conductivities of those units, becomes extremely complex, and that feeds back into some of the questions I have heard on the modeling.

We have a real problem with respect to predictability. Even though, I agree with Alan, the way you get at the better models is exactly the approach he is putting forth. You have a hard enough time modeling the existing conditions without trying to superimpose a greater availability of water on the thing. It becomes very difficult then to actually calibrate the model.

That's all I have.

MR. HINZE: Thank you very much, Marty. Unless there is a pressing question, I am going to thank you, and we will move on to Linda Lehman's presentation about an alternative conceptual model. Any questions can be developed after those two.

MS. LEHMAN: Maybe I will hold this. Thank you

for the opportunity to speak with you today. I am going to try to talk about some alternative conceptual models and their potential affects on performance assessment.

First, I would like to acknowledge my co-author, Tim Brown, and also thank the State of Nevada for funding this research, and also to thank the ACNW for providing funding for me to be here today.

First, I would like to talk about some model assumptions which impact performance assessment. This is just very descriptive. Then I will talk about a modeling exercise we did during Intraval, which examines the effects of alternative conceptual models on flux.

And then I want to discuss a little bit about the need for an analysis of bias and a fair evaluation of alternative conceptual models.

We heard earlier that there is probably 128 alternative concepts, but I am not going to get into all of those today. I just wanted to briefly mention some of these. We have heard a lot about matrix versus fracture flow, dimensionality, distribution and amounts of infiltration. Some of the other assumptions that can greatly influence the outcome of a performance assessment are what I call equilibrium assumptions. This is sort of your pressure distributions and things that control your matrix fracture interactions -- whether or not the column is

in equilibrium with the water table -- whether your infiltration is transient or steady state -- boundary and initial conditions, such as the use of no-flow boundaries, wet versus dry fractures, and then parameter models. These are models which are modeled, as opposed to measured parameters. These would be things like infiltration, conductivity, water retention properties and porosity.

Just a simple example of matrix versus fracture flow. In the literature we find saturations of 10 to the minus 10 for matrix, which would lead to a relatively slow transport of radionuclides through the matrix, versus published data of 10 to the minus two meters per second for fractures, which would obviously lead to very rapid transport.

Dimensionality. We have been through this, so I don't want to spend too much time. But, one dimensional flow versus two or three dimensional aspects -- whether or not the flow can move laterally, or if it is just vertical.

A subject near and dear to my heart, distributions and amount of infiltration -- whether or not the infiltration is distributed uniformly across the top of the mountain, or whether it is indeed focused into certain areas. I will go more into these last three things in our conceptual model analysis.

This is just an example of matrix fracture

interaction. If there is little interaction within the matrix, large amounts of water can move through the fracture, with just small amounts moving into the matrix. On the other hand, if you had large fracture matrix interactions, your flow might not make it very far down the fracture, and you would have large imbibition into the matrix.

Several people talked about steady infiltration versus transient type of infiltration signals. We also did s me looking at that in our model, but I probably won't dwell on that today.

Boundary conditions at faults. Another problem that I see is whether or not these fault zones are no-flow boundaries or whether in fact they can be a flux boundary or pressure boundaries, allowing infiltration to come in through the side, as opposed to only one-dimensional, basically through the top.

The magnitude of infiltration also is troublesome to me. This is taken from the TSPS, 1991 exercise. I believe this was presented to this Committee about a year ago. As you can see, most of the percolation flux that is considered is very very low. When we get out to numbers that are five millimeters or more per year, the probability of that being utilized becomes very very small, and especially for larger fluxes, which may be possible, as I

will try to show you. The probability of them really being considered I believe fairly is pretty small, as you can see.

What we found through our work is that conceptual model error, or error due to the improper use of a conceptual model can be quite large.

So, now I am going to present the second part of my talk, which is the modeling exercise that we did through Intraval. I am just going to be very brief with it. But, I want to show you the effect on flux of the different models, considering distribution of infiltration, dimensionality, and fracture versus matrix flow.

Alan presented his results of this Intraval work, the UZ-16 data. Basically, the unsaturated zone working group of Intraval had an exercise called the Yucca Mountain exercise. And here the problem definition was to take data from three shallow bore-holes, UZN-53, 54 and 55, shallow meaning 120 -- 100 to 120 meters deep -- calibrate against water contents, and then, secondly, do a blind prediction, based on your best calibration, and predict what the water content profile would be in UZ-16 which, at that time, had not been drilled.

Now, the intent, as you have heard, is to find what is the representative flux through Yucca Mountain. This is the $64,000 question. So, many of the people in the group felt that what they would like to see is find the best

flux -- I mean the flux which best matched the water content profile. Well, we knew that this probably was not a good exercise to do that because the results would not be unique. It would not be a unique solution. However, it was really our first opportunity to get a hold of any site data. I reported to you before that some of our data requests were 10 years old. So, we wanted to take the opportunity to use this data. So, we did the exercise, but chose to look at the -- what kinds of flux -- what range of flux would be possible, using some -- what we felt very simple models.

The location of the bore-holes you have probably seen -- the three shallow holes in a line here, and then UZ-16 right at the top.

This is a schematic of our one-dimensional model. We did try many iterations with this, varying the number of layers, but we actually got the best results with a simple four-layer model. When we did these runs, we tried to hold the parameters that we were given within the ranges that were given, and then we varied the ones that we did not have data for.

So, doing that, we did not feel that we could get a good match to the data. Now, the bars are the calibration data. We have averaged them. I believe these were like over every five meters. This is like the 95 percent confidence interval in the data, or two standard deviations.

EVENING SESSION

(6:00 p.m.)

MS. LEHMAN: As you can see, we did not do a very good job of matching this. In this bedded unit here, we were much too low in our water contents, and we were much too high in the deeper units. So, then we tried as best we could, using a two-dimensional model, to see if we could wet-up this unit. But, the types and ranges of flux that we were considering here was of course limited by the dimensionality to about .01 to .2 millimeters per year.

In this simulation, this is an example of our two-dimensional model. We allowed infiltration to come in through the side, hoping to wet up these units. We had infiltration through the top and through the side. Through the side we changed from .1 millimeters per year up to 1 millimeter per year. However, we didn't do much better with our two dimensional model either, as far as calibration.

Again, we were too wet here, too dry here, too wet. So, we thought that perhaps there was some other mechanism, either three dimensions, or fracture flow that could be controlling.

So, with that, we tried to do a very simple fracture model. And here we used site data, the actual spacings of the fractures, and the average aperture for the fracture. We used only published data. You will notice

here, we used symmetry, so this is actually a fracture half-width, and a half-width of the fracture itself -- half-width of the spacing and the fracture.

You will notice in this bedded unit that there -- the fracture does not extend down through the whole section. It ends at this bedded unit, because work had been published that said there was no fracturing in that unit. So, using the published data, that is what we did.

Our results were much better in this case. Instantly we saw a better result. Now, we did eventually, to get our last calibrations, put an evaporative term in the top to bring this down. However, all of the water that went in went in through the fracture. And, as you can see, we feel like we did a fairly good job here of matching. We were a little wet on some of the runs. But, all of these runs were done at five millimeters per year.

So, since Alan showed you his results, I am going to show you my results. We also thought our results were pretty good. This was the prediction against UZ-16 data. The dark line, or course, is our prediction, versus the actual data which we summed here, probably over -- I think this was every 10 meters. I can't remember exactly. However, we did not match in the lower units. We were much to dry in the lower unit. We were a little wet here in some of these upper units. We did not model this part at all in

our model. We just assumed the water table to be there.

Now, another model that we used was not a flow model, but it is called a depression-focused recharge model. And this was to look at the range of flux that would be possible through focusing effect. This model was developed by John Nieber at the University of Minnesota, in the Agricultural Engineering Department. What it does is it models the catchment basin. We modeled the Solitario Canyon catchment area, so that area would be plugged into here, in these outside rings. The permeabilities we used were published for the various units that outcrop. And then, for the focusing area, we used the extent of alluvium in the bottom of the canyon, and we took the area of that.

This also uses a climate simulator to determine the rainfall distributions. For that, we used data from Topopah Station, which is about 70 miles northwest of Yucca Mountain. But, it did have a 20-year period of record. So, this climate simulator preserves all of the statistics of the actual 20 years, and then simulates daily rainfall over the basin. And what it does is it takes into account infiltration and run-off and slope. It will calculate how much water can actually go through that depression and become recharge -- become depercolation or recharge, considering evaporation and all that.

Much to our surprise when we got the results, we

found that range to be between 12 centimeters and 30 centimeters per year. So, we were very surprised, because this is about five orders of magnitude higher than anyone had even considered possible there.

Of course, this isn't a definitive study. It was simply a first-cut, back to the envelope calculation to see what was possible, because we wanted to know what could go into a focused model. And certainly, this is an area that needs a whole lot more work, and we hope that DOE will look at these numbers and challenge them and go out in the field and let's see some of these numbers.

To date, almost all of the infiltration numbers have been done through inverse modeling calculations, as you have heard Alan say earlier. Most of them that have survived over the years for the performance assessments have been derived from one dimensional matrix flow models. So, that is why you see such low fluxes used.

Now, we concluded from this exercise that we needed more data to determine whose model was best. I will get into those types of data in a moment. But, as Alan said, any performance assessment or any validation process which separates out alternative models to be used in a performance assessment should have several components. One is that it should be iterative and it should build confidence over time. We have heard this theme many times

today. It also needs to look carefully at sources of bias in the codes.

Now, we looked briefly at the TSPA modeling and the new RIP model. I feel that there is a large opportunity for bias toward matrix flow in these codes, especially within RIP. Now, I don't disagree with the concept of having this type of model, however, when you evaluate these models, you really need to look at it very closely for sources of bias. One type of thing that is contained within RIP is that the matrix conductivity has to be fulfilled through the matrix before any flux will go into the fractures. And, as you saw through that distribution, there is not many times that you would have enough flux to go into the fracture. So, while it says that it is including fracture flow, it may not be doing it as often as you would like it to be. So, it just takes close examination. So, that is why I am hoping very much for a fair analysis of these conceptual models.

Now, also, any process that sorts out these models I believe should use both what I am calling confirmatory data and consistency-type data. By confirmatory data I mean things like water potential, things like tritium, or anything that will tie-down the time history of the model. For example, I was unaware of Al Yang's work today. To me, that was certainly telling that there is fracture flow

operating there, as opposed to matrix flow. So, then I could throw out perhaps some of my matrix flow models and be more assured that I had matched this confirmatory type of data.

Let's go on. I talked about that one.

The next one is what I am calling consistency data. That is simply supporting data that would be utilized to qualify of disqualify a model. Some examples of this would be temperature data. We really believe that temperature needs to be taken into account, not only in the unsaturated zone, but in the saturated zone as well. Here is a picture, which was from Bill Dudley's -- one of Bill Dudley's reports, which shows the distribution of temperature at the water table. As you can see here, we have a very hot area, 38 degrees over here, and a very cold area, which runs, coincidentally, with the Ghost Dance Fault, right down the center of Yucca Mountain. So, it would appear to me that we have a channel or at least cold water moving from the north down through the center of the repository.

One thing I would like to see examined and hopefully will be examined -- and I have heard encouraging words today that we were going to have some comprehensive examinations of these fault properties. Certainly, if the fault is transmitting in the saturated zone, we ought to

have a clue that it could also possibly transmit through the unsaturated zone, not necessarily, but we should at least look at it. Okay.

In the end, only the model or models which agree with the confirmatory data and are most consistent with all other information that are available, should be preferred or validated.

One other thing I wanted to mention was we do have other information on the saturated zone that may be useful in looking at fluxes through the unsaturated zone. I believe I presented this to you several years ago. It was the oscillations of the water table, the frequency of oscillations. And they are different on the west side of the mountain than the east side, which indicates that there is some compartmentalized aquifer situation there. That could be also utilized as consistency data.

So, in conclusion, the choice of conceptual model has a very large impact on certain parameters. I showed you a range of flux of at least five orders of magnitude that we got.

A methodology must be developed for the fair treatment of these alternative conceptual models. I hope this is being done. I saw a lot of talk about it today, but I am not certain exactly, and would like to see in writing how they propose to go about that.

Also, I feel that we have to have an analysis of bias conducted on the way these alternative concepts are treated in the performance assessment. That is it.

MR. HINZE: Thank you very much, Linda.

MR. POMEROY: Linda, a quick question with regard to the Intraval experiment or study. You did a study -- Alan presumably also did his study. Were there any other studies, and were the results as consistent as both yours and Alan's were?

MS. LEHMAN: Yes. The Center modeled the -- they did a one-dimensional model with 25 or so layers, like Alan's. And then Sandia -- Tom Robie did a stochastic model, but his did not match up at all well with the data. So, the end result from the Intraval, was they did a comparison and they decided that no one model could be chosen over the others.

MR. POMEROY: Thank you.

MR. HINZE: Further questions? Darrell.

MR. LEAP: Linda, do you feel that the areas for possible focus -- all of the areas for possible focused recharge, you call it, have been delineated and elucidated? If not, what would you think would be the necessary work that would have to be done to make sure you have got all of these pinned down? I know this is a very general question.

MS. LEHMAN: No. I really don't believe that they have been nailed down. It is my opinion that the higher reaches of the wash are probably areas of focusing. I don't feel that a lot of testing has taken place there. I think in the upper 40-mile wash they are starting to see some rapid infiltration. But, the whole west side of the mountain has not yet been looked at. I am not certain that the placement of the wells are specific enough. Because obviously it is a very specific thing, and your well placement is absolutely critical.

You saw the results of the Apache Leap work where they had focusing right down the Queen Creek, but yet just a few feet to the other side, they didn't see that. So, I think it is absolutely critical and, like I said, I am not certain that these placements are correct -- that I would choose anyway.

MR. HINZE: With that, thank you very much, Linda. We will move on then to the last scheduled speaker, Dave Kreamer. Dave. Dave is with UNLV and was involved with the ESSF review. You will review some of that with us I believe.

MR. KREAMER: Perhaps.

MR. HINZE: Was your exam for your students today easy, or was it --

MR. KREAMER: The exam is going on right now.

MR. HINZE: Right now. Okay. Well, we are happy we brought you away from that.

MR. KREAMER: You have hung in there a long time. I want you to know that I appreciate it. A couple of apologies up-front. First of all, I would like to apologize that I don't have pink overheads. Secondly, I do not have a hardcopy for you. I don't think it will be necessary. Also, I have shortened my talk quite a bit because of the late hour. So, I will just move on.

My name is Dave Kreamer. I direct the Water Resources Management Graduate Program at UNLV. I have been involved in the early site suitability evaluation peer review, the hydrology section of that, and I have also been a member of the EPA's Science Advisory Board Subcommittee on Gaseous Movement in High-Level Waste Repositories, with regard to C-14 movement.

I would like to talk to you about two things today, first of all about the peer review for the early site suitability evaluation. Secondly, I would like to talk a little bit about chemistry and a little bit about trace element analysis -- something that perhaps is rather new and promising.

In the first regard, in the early site suitability evaluation, let me first explain to you what that was. About two years ago, there was a document, the early site

suitability evaluation. The purpose of that document, of course, was to establish if we should go on with more work, or if there were any features right now in the suitability of the site that determined that we should not continue with the evaluation of the site.

A report was made by the research team and it was peer-reviewed by outside peer reviewers who weren't involved in the process before. I was one of those. I was responsible for the hydrology section. Although several people from other sections, climatology and other sections commented on the hydrology section as a critical factor. I will summarize some of the comments in that early site-suitability report for you very quickly.

First, there is a great deal of uncertainty. That is nothing new after all the discussions we have had. At that point, two years ago, there was more uncertainty. We hadn't been underground as much. We had less site-specific data. A lot of our information basically was due to modeling efforts.

So, in that regard, the ESSE document itself that we were reviewing had such statements as follows: "Confidence in the model is limited by lack of site-specific data. The models are based on many simplifying assumptions that should be verified using site-specific information and the analyses have been conducted, however, with a limited

hydrologic data set using models that may not correctly approximate dominant conditions."

So, with that back-drop, it was evaluated. And, lo and behold, some of the peer reviewers agreed.

One other thing about the early site suitability evaluation. There were several levels of acceptability or unacceptability that went into the report. The site could either have, in each category of climate or hydrology -- could either have a very high degree of acceptability, a low degree of acceptability, or it could be unacceptable in that category. Many of the categories had a high degree of acceptability. The hydrology section was chosen by the ESSE Team as having a low degree of acceptability because of the uncertainty associated with it.

In the peer review, some comments, my own comment, and that of Dr. Hodges -- that, without site-specific information, the realistic bounds couldn't be established on the models and predictive approximations have to be grounded in appropriate defendable assumptions. What we have seen today is that in the last two years we have gone a long way toward meeting some of those criteria with the field testing.

In addition, to be more specific on some of the unsaturated zone comments, some selected recommendations in the peer review had to do with the need for more information

in gaseous movement. Since that time the EPA Science Advisory Board Subcommittee has met and made recommendations to the Chief Administrator of EPA on gaseous movement in high-level waste sites, with regard to C-14 particularly, but not excluding other gaseous compounds.

Other recommendations that I made included increased look at fracture coatings, for two reasons. Just before the early site suitability report, there was a team of scientists put together by DOE that did an unsaturated zone review, headed by Al Frieze. On this team were Van Ganucten, Everett, and many other fine scientists. They recommended that, in order for the models to be acceptable, some things had to be established more adequately -- that the pressure equivalency across the matrix fracture interface should be better determined -- that we should very carefully approach the acceptance of overlap and continua in some of our models between matrix and fracture flow.

So, one of the recommendations was we look at fracture coatings, not only because of that interface problem, but also because the fracture coatings might change with time and, in changing with time, the permeability might change with time and, therefore, affect our modeling of the future events.

Preferential flow paths, of course, are a crucial issue. In my mind, they are probably the most important

issue. We are gathering data. The issue of whether this data is truly representative of all the sites and the potential fast fracture flow is still questionable.

Then, also the identification of horizontal moisture layers was also recommended at that time in holes that could be TV-logged. Many of them hadn't been logged for years and years. The idea of a very quick TV-logging of some of the holes that hadn't been logged and that were available for logging quickly, with the improvement of techniques over TV-logging in the last few years, it was recommended as a very quick way of seeing if seeps had developed. And other things -- other specific things were recommended. But, the whole idea was to understand the uncertainty as far as the hydrologic distribution in the system.

Some bottomline on the ESSE. There is a favorable condition three in the legislation -- that the hydrogeologic system will eventually be readily characterized and modeled with reasonable certainty. One of the conclusions of the peer review team, and not only myself, but others, was that this may or may not be realized. Again, this is two years ago, based on the information that was available at that time.

Also, it is possible that the site will not be able to be characterized without a significant uncertainty.

If that is the case, then some clarification as to what acceptable uncertainty would be necessary to move forward. It is something that needed to be defined two years ago, and might even need to be defined today.

Finally, a couple of things. Currently -- or currently as of two years ago -- there was not enough defensible information to reject or accept the site. It was premature to state the likelihood of suitability. The site was acceptable at a low-level of acceptability for continued evaluation as far as the hydrology goes.

Also, I would be sort of remiss if I didn't mention that -- to all the peer reviewers, they found that the project personnel were diligent, working hard, and very helpful. I have personal thanks to Dwight Hoxey and Jean Yonker and several other people.

I would like to switch now and talk about, as Monty Python says, "and now for something completely different." I think sometimes when we get hung-up in site characterization, we think about things in the same way. This is certainly not that. This is what I think is a new approach - looking at trace elements. It is an unproven technique, and I want to stress that it is entirely preliminary. I think it does have some promise, and I wanted to present it today.

I am going to present it in terms of saturated

flow. But, I think that the correlation with unsaturated flow is obvious. I wanted to show you some data from Death Valley National Monument. Essentially, around the State of Nevada, a team headed by Dr. Clause Detzenbach of UNLV, and several other people -- we have looked at several springs all around the state and we have looked at the trace element analysis. These are trace elements that are sometimes in the parts pre trillion range, minute things that usually aren't looked at in water because they are so hard to measure. They have been looked at in sea water. They have been looked at in various acidic systems. But, trace elements, such as the rare earth and other minor transition metals, normally are not looked at in water analyses and pH ranges of six to eight. We began to look at these things in the Death Valley area.

The springs that I want to tell you about -- and we have done more than this, but I want to be sort of cautious -- I am going to present something that is out in review now for publication. I am going to walk up here so I don't block too many people.

Three springs in Central Death Valley that are thought to come from a carbonate system. The carbonate system -- in two of these springs the water is thought to come up 2,000 feet from the carbonate aquifer below. The third, Nevaras, has a carbonate outcrop at the Bonanza King

formation, a hundred yards away from it. So, these three are thought to be carbonate waters at elevated temperatures.

In the northern part of Death Valley, three springs, one of them alluvial, Mesquite Spring, a low-volume alluvial spring, and then two springs that are thought to come from the tertiary, or do come from the tertiary volcanics. I will refer back to these.

But, I wanted to show you what we gathered. We looked at about 50 trace elements. This is the slide you never show in a talk. I want you to memorize all of those numbers. These are in parts per billion concentrations of trace elements. And, you can see, there are quite a few trace elements in that list. The reason I am showing you this is it poses an obvious problem in how do you deal with that data. Our hypothesis then is that there is some linkage between the trace elements in the rock and the water that comes from the rock. In order to deal with this much data, it would be ludicrous to try and deal with the competing complexities of rare earth geoaqueous chemistry. In other words, there may be competition for ligens -- carbonate ligens. It is impossible to deal with all of this data in a realistic way because of the competition. So, we chose a statistical approach to deal with this massive amount of data, and these are only six springs.

Again, in review of what we found, that different

elements, many of them were in the parts per billion range -- this poses analytical chemistry problems. A lot of our data was thrown out and so we eventually ended up with 42 elements. And even, of those 42, some of them have pretty wide error bars, and we treated those a lot more lightly than the other data.

So, how did we treat all of this data? Well, what we did was we did a variance maximizing rotation on this data. Essentially, what we did is called principal component analysis or factor analysis, where you get the different elements and you try and find the maximum variance in the data set, and you do that once. And then, in the remaining data set, you do it again. What this does is it weights the elements. Each element is weighted then according to this principal component analysis. And you get a certain amount of variance in each of these rotations. Those were the elements you saw very quickly. And, again, I want to move quickly through this. I am not bogged down.

But, essentially, what the Eigen values here show you is in each sequential maximization of variance, how much information you get or how much variance is reduced, so you can see in the first principal component analysis that we got about 50 percent -- over 50 percent of the variance out of the data set. When we did it a second time, we then cumulatively got about 80 percent of the variance out of the

data set. Then, when we did a third principal component analysis, we were up above 90 percent of the variance out of the data set. So, what it is is a data reduction technique that more or less deals with that data and finds commonalities in the data.

So, what did it mean? When we plot principal component one against principal component two, what we find is something like this. If you look, you will see the three carbonate springs come out together. You can see the two springs from the tertiary volcanics together and the alluvial spring separate.

If you were to take the first three principal components and look at those for the trace elements -- and, again, these are trace elements that are all in very minute amounts, what we see is, again, those groupings, with one variation, the variation -- and I apologize for moving. Two carbonate systems where the carbonate aquifer is 2,000 feet separate out; but the carbonate spring -- I said aquifer, I meant springs -- come out here. The one spring where the carbonate aquifer outcrop is 100 yards away is separate in principal component three.

Now, principal component three only has a small percentage of the variance in the data set, so it is not as important as principal component one and two. But, again, you can see that grouping. It looks pretty good.

Now, we have done this in several sites. We have implications in the trace elements that there may be some linkages between Ash Meadows and the carbonate springs. We also have some restrictions in our data. Obviously, any drilling muds or fluids might completely throw off this analysis. So, we have just been able to sample springs to this point. However, the idea of using unusual parameters may be one that can be looked at with regard to unsaturated zone in Yucca Mountain.

I am going to throw this up for just a second. There are traditional analyses that are done for rare earths and rocks. This is a rare earth element normalization on a logarithmic scale. There is some data that we have already found is wrong in this, particularly the Europium anomalies that barium oxide has the same molecular weight and it is a principal contaminant. One of the problems with these analyses is you have some things with equal molecular weight that essentially will give you a wrong number. But, what you might be able to see is in some of the springs that are supposedly alike, if you were to look say at Scotty's and at Grapevine Surprise, which is the real surprise in this, they have the same pattern. It is these two right here. And then the carbonate down below has a very similar pattern in the rare earth element signatures. This is normalized to shale. I don't want to spend time on that.

So, that is just a quick introduction that perhaps there are other ways to look at chemical data in the system. We might be able to glean -- like a detective game, we might be able to understand source and pathway of water a little bit better if some of these other methods were looked at.

I want to close with a quote concerning predictions. This quote is from John Sedgewick, who was a -- General John Sedgewick, who was a Commander for the Union Army in the Civil War. At the Battle of Spotsylvania Courthouse, he was viewing the Confederate Army, the enemy, and he made this quote: "They couldn't hit an elephant from that dis..." That was the last quote that General John Sedgewick made.

[Laughter.]

MR. KREAMER: There are potential bullets at Yucca Mountain with the uncertainty in the distribution of hydrologic flow moving downward. And hopefully some of these tools eventually these unproven at least tools, may have some potential light to shed on the process.

Thank you for your time.

MR. HINZE: Thank you very much, Dave. I hope this isn't the beginning of a Civil War.

I want to now turn to Joe Delacus and see if he wants to make any -- excuse me.

Dave, we have a question here,

MR. DAVIS: On the site suitability evaluation, is that something that will recur? Is that a one-time --

MR. HINZE: Go to the microphone, please, sir.

MR. DAVIS: I'm sorry. Paul Davis.

Will the site suitability be evaluated again?

MR. KREAMER: Not to my knowledge.

Jeramy, do you want to take that?

MR. BOAK: We're currently in the planning stages of another site suitability evaluation and there will certainly be one more at the point at which we make a decision about whether the site is considered suitable or not.

MR. DAVIS: As that at the same point you're presenting CCDF's for final licensing? Is that a different point?

MR. BOAK: The site suitability report, that's roughly synchronous. So, at least two more between now and a potential license application. But there is a suggestion that we'll be doing it repetitively. I wouldn't say that the iteration rate is well determined at this point.

MR. DAVIS: How do you fold in the concern that seems to be expressed on the one viewgraph that you may not be able to characterize this site?

I'm asking one of you. It seems like -- I mean, he's stating that there's a potential risk we'll never solve

the problem, if I read the viewgraph correctly.

MR. KREAMER: As of two years ago, I believe that. I'm not sure if I did the evaluation again that I would make that same conclusion, or at least as strongly. I don't know how that would be reconciled.

Would you like to --

MR. BOAK: The wording of the suitability conditions in 10 CFR 960 is extremely intricate, but if you spend the time to learn why it's in there and talk to some of the lawyers about how one needs to clarify the wording, one of the conditions that would lead to disqualification of the site was a determination that you could not show it's suitable.

MR. HINZE: Thank you.

MR. BOAK: And the uncertainties could in fact be so large that you would decide it was not worth it to make the effort to continue characterizing.

MR. DAVIS: Right. And that's a question as to how do you decide with our money when it's not worth it.

MR. BOAK: I guess I would be inclined to say that at this point that's extremely hard to say. If I had a site which my best estimates showed complied by six orders of magnitude, I wouldn't have a great deal of concern about those few remaining ares of uncertainty, even if they were quite large. If, on the other hand, I lay very close to the

compliance boundary, then far different levels of uncertainty are upsetting.

And I would say that at this point, we don't have enough knowledge to know which position we're likely to be in a ways down the road. I don't think we've got enough data on the site at this point to be eager to start making the judgements about how far. But I think we will see that picture become clearer as we characterize the site.

MR. HINZE: Are there any other comments or questions regarding Dave's presentation?

Thank you again, Dave, and we'll move then --

Joe, you --

MR. DLUGOSZ: Do you want to do this at the roundtable?

MR. HINZE: I thought perhaps if you would like to start off the roundtable with any points that you would like to make in summary for this group. I thought that would be appropriate.

MR. DLUGOSZ: Okay. I guess I don't need a microphone.

What we really tried to do today is establish a framework, a solid foundation on which we're trying to tell a story. And this story is our interpretation and understanding of the hydrologic cycle as it operates the unsaturated zone on Yucca Mountain.

The data, the type of data, both the active as well as the passive data that will be collected, we really haven't done that yet except at a couple of holes on 6 and 6-S, is being done with a precision and accuracy that I feel is unprecedented, as well that it should be.

This data then that we're trying to explain throughout the day, is then incorporated into the models for various calibrations and then we go ahead and we do a predictive iterative cycle. And this cycle is based on prediction, evaluation and then calibration.

I feel in this way we get to the point sometime in the future, whereas when is enough enough. When have we collected the data that's really going to solve the questions that we have.

Now we have a number of open questions, I know. We're not saying we have all the answer at this point in time.

What I would like to do, then, to open up the roundtable is that we have a unique meeting coming up that we did not know about when we put this agenda together, and that's in February, 14th through the 28th, when we have one of our first technical program reviews.

Now, we have all the principals in the audience here, such scientists and engineers here. Could we get some feedback from you as to how maybe we've addressed some of

your concerns today so that we can incorporate that into our presentation when we have our technical program review.

MR. HINZE: A reasonable request.

Thank you, then, Joe. I think I'd like to at this point turn to the consultants and ask them for any observations. I'd like to remind us that at least from the ACNW's viewpoint we started off here with probably three key words: processes, understanding those processes that were taking place in the unsaturated zone. We were interested in the data and the modeling and the quality and the progress that is being made. And finally the uncertainties at the present time and those as we look on to the future.

Please don't restrict yourself to those, but could I turn to you, Paul, first, and make any summary comments? I know you as well a the rest will be thinking about this and giving us your advice at a later time.

MR. DAVIS: Yes. I assume that we'll have written input to you as the final input.

MR. HINZE: Yes. Please.

MR. DAVIS: Just so that you know that my concerns are now to go forward, number one, it certainly is an apparent lack of integration of the work. And that is I felt a shotgun approach to data collection site characterization where speakers got up and all told me they had the exact same objectives. I mean, I could take slide

after slide saying people have the same objectives with various different programs. That may be fine. I don't know who's supposed to integrate that and decide what the priority of work is and decide whether steep boreholes versus shallow work, I have no idea.

When asked, the answer seemed to be that the integration I heard would be by the WBS task leaders or something and that there was no group really doing integration of the work. That concerns me because I don't know the prioritization.

The next question I certainly don't know is the one we've been talking about. How do I know I'm done? I have no feeling from anything that I was told today that anybody knows when they're done. And in fact, I saw very many flow diagrams that were infinite loops. They had no decision place for quitting. They went round and round and round and no final way out. Even the modeling was the same.

I wish I had a feeling for the focus of the program in terms of resolving issues and coming to closure and walking away and saying we're either safe or we're not safe and we're going forward. That would make me feel better if I had that.

I am heartened by the -- at least the words that conceptual model uncertainty will be treated but the actions don't follow it yet.

I would like to see Bo's Model being done in parallel with several conceptual models to drive site characterization instead of what is today only -- and I agree today only -- one conceptual model which may drive site characterization in the wrong way if it's the wrong conceptual model.

So I'd like to see that expanded in a systemized formal way to treat conceptual model uncertainty as we go forward through site characterization and then maybe some of the states' concerns could be folded in and answered at the same time.

Thanks.

MR. HINZE: Thank you very much, Paul.

Darrell?

MR. LEAP: Thank you. I've got a few observations here. I'd like to share my concern also with Paul about the massive integration effort here. There's an enormous amount of data and there are a lot of different people working in a lot of different directions.

I, too, get a feeling that some things are somewhat disjointed and perhaps not being as close to is as some people are, maybe I can't see the connections. But I do think there should be a much better integration of effort and data and talking to each other.

Another thing that concerns me a little bit is the

lack of knowledge of fault hydrology. I know this is being planned. I think this is a very crucial point that has to be addressed because these could be massive conduits, especially in times of increased climactic changes.

And I think on that subject, too, I think the possibility of climactic change is not to be discounted because if the climatologists are correct, they're telling us that there's going to be quite an increase in precipitation in this part of the country.

Now, I know that the last speaker did mention something about the effect of fracture coatings changing with time and therefore changing permeability. But I wonder if anybody's ever looked at the possibility that increasing climatic changes, especially increasing precipitation might have the effect itself in different ways on the permeability of the system, either in the mountain itself or in the pathways in which water would escape from.

For one thing, for example, just as a very real possibility, that if you increase precipitation by several percent, you could increase the soil zones on top of the mountain. You could increase vegetation and the amount of carbon dioxide that's being produced by decaying vegetation; this carbon dioxide being taken down into the subsurface could definitely affect the calcite and the caliche coatings and could very well affect surface permeability.

Another thing, too, as Marty Mifflin pointed out, if the water table should rise by 100 meters, that's 300 feet. That increase in pressure might have an effect on the actual fracture permeability by fracture widening. There's been quite a body of data that's been accumulated on that effect and it's something that probably should be taken into consideration.

I don't know. It's not clear to me at this point just how carefully the models that are being created today, sophisticated as they are, will actually grasp the possibility of changes in permeability and store activity in the case of climactic changes. I'm speaking specifically of increased precipitation. That's something that I think somebody should think about.

I am glad to see, though, that increase in the amount of field data and in situ experimentation being conducted. I think this needs to continue and you need to focus the investigations in some areas where the uncertainty is certainly the most critical. And if there are places of focus free charge, I think these need to be looked at very carefully.

Obviously, I think it's pretty obvious from what I've heard that there's no such thing as uniform infiltration in Yucca Mountain. But again, these are areas that the research is being done so far looks very good.

Some of it, anyway, and I would like to see that continue.

That's all I have right now.

MR. HINZE: Bill?

MR. SACKETT: My expertise is in the area of isotope measurements and if I were to design this program, I would have done things differently. Maybe not better, but differently.

For example, uranium thorium series nuclides are really powerful in trying to understand movement of fluids through the ground.

There are new techniques for carbon 14. Accelerator, mass spectrometry, is the state of the art kind of technique that I don't think is being used here.

And helium 3, tritium ratios are probably better than liquid scintillation counting for determining tritium levels.

In a general, a general thing that bothered me was Apache Leap apparently started 10 years ago and there were three potential sites. And the Yucca Mountain was chosen in '85. So it seemed like Apache Leap just on that basis isn't necessarily a good analog for Yucca Mountain.

But my chronology is not quite what it ought to be. But I have very specific comments about the methodology of isotope measurements that I would do differently.

MR. HINZE: Very good. Thank you.

Do any of my colleagues have any observations that they wish to make?

MR. POMEROY: Bill, could I ask a question, just pose a question to Alan Flint or Larry?

Supposing that the funding levels were somewhat the same and you proceed along the paths you're proceeding along now and pick a time frame, say, 10 years from now. What do you see as the greatest source of uncertainty at that point in time?

I guess I'd like your opinion specifically, Alan.

FLINT: Sure. Larry?

MR. HAYES: Go ahead, Alan.

MR. FLINT: I guess I'm not sure I understand the question. Could you put that in a little different context so I can better understand while I'm trying to figure this out?

MR. POMEROY: Well, I'm not sure I can get it down pat, but supposing the investigations go on for some length of time and you can specify what that time frame is. But at some point 10 years from now you're going to be close to the point where you might be wanting to say either I have enough or I don't have enough. And at that point where -- what factors will be the most uncertain in your mind at that point if you followed the programs as they're laid out right now.

MR. FLINT: Well, I can only address the program that I work on in infiltration.

MR. POMEROY: Yes. I'm sorry. That's all I meant to ask you.

MR. FLINT: I think that if the way things are going, the uncertainties that we have are going to be in the distribution of infiltration. I think that's one of the areas that we will have perhaps our most uncertainty in as well as the properties of these fault systems and how they behave.

I believe that we're making tremendous progress toward understanding the variability of the properties.

Rick Spengler is doing a wonderful job with his 3D site model. We can look at where the Yucca Mountain member and the Pah Canyon member are and we can come up with a good geological model of the site. We're getting good properties. We can distribute those properties in space I think quite well. The variable, the most variable thing we see, I think, is the saturation data.

Why do we have fresh water in one place when it's exactly the same rock in another place and we don't see it. That's because of the variability in the flux rate. And the variability in that flux rate causes that change.

Yucca Mountain in its saturation today is a reflection of what's happened over the last seven hundred

thousand years or more in terms of climate change. So that variability of flux rate is very critical and that's an uncertainty.

The climate change scenarios that we want to work with are also an uncertainty. Our climate program is very important for that perspective. But the way we work at it now is you can take those climate changes that I showed and make one of those and just start a new climate change tomorrow. Go up with what's consistent with past times and see how much of a difference that makes.

But I think that's one of the uncertainties that we have to deal with is the climate change, the distribution of the flux and then how the faults interact. And I think the fault, like I said earlier in my talk, it's how the fault behaves at the surface of Yucca Mountain and how it behaves in the subsurface.

I think they're different, how they behave. I think that the fault does not concentrate recharge in the surface. I think it may concentrate it in the subsurface because you can't get all the water in Yucca Mountain to somehow magically all move to this one fault, but you can do it in the subsurface because of the way the layers dip and the controlling features on the surface.

MR. POMEROY: Thank you.

Larry, do you want to --

MR. HAYES: I'll give a broader perspective to what Alan mentioned because I'm concerned about the entire program and there are some things that are progressing well right now and there are some things that are languishing.

I think my biggest concern as to what is languishing and what is putting us most behind is our lack of new subsurface data in a distributive pattern both vertically and laterally. Our drilling program is doing the best it can with the funding it has. And we have a choice of buying more rigs, drill more and lay off scientists. It's that kind of balancing act.

So I think if you're talking about the next five to 10 years, we need to get our drilling program to give us more information. We need to get more wells in.

You heard a lot today on data to calibrate some of these models. But Bo made the point and I really agree with him. We're calibrating models, making predictions on very limited data.

Now when we go underground with the TBM, that's going to give us a lot of subsurface information, but only in a limited area. We need a broader perspective. If we're going to deal with this issue of climactic change, we need to go out beyond the site.

So it's my concern, those things that aren't perhaps closely tied to getting underground, to doing the

tunneling, things like climate mineral resources, more wells. Those are the things I think that we're going to have most uncertainty about and those are the things that furnish some very basic information so we know whether Bo has a model that has any realism or he's just out there in lala land. He probably is anyhow.

MR. HINZE: One of the observations that I've made during the course of the day is the fact that we have this absolutely credible amount of information on the near surface that Alan and his troops are putting together, and that's just excellent.

And then we have this massive amount of information that we're going to collect at the repository horizon and I say, who cares unless you can really make that meaningful.

I have always been concerned about the lack of follow through with the vertical shafts, because I had a warm fuzzy feeling that derived from the fact that we were looking at the rocks and being able to conduct studies in situ directly above the repository and below the repository.

And if there's anything that I'd like to see the DOE do in this area is to try to look at how they can take all of these great data that they're going to have from the ESF and project that to above and below.

My prejudices and biases, Linda, are known. I

think that I'm certainly interested in using geophysics to make the maximum use of those. But I'm also enough of a geologist to know that we need the direct information in terms of the drilling and we can use some of the geophysics to extrapolate and interpolate. That's what geophysics is all about when it's done well.

So, I was pleased to hear you talk about these things, Larry, and it's given me the opportunity to express my concern about the detailed type of characterization that you're going to have to have to satisfy Bo's or Alan's models. But I also would like to say that I'm following this program for a couple of years. I think there have been tremendous strides made.

I heard Alan give a pitch to the -- I mean, give a talk to the TRB a couple of years ago and I'm reflecting here on how much we've learned since that time. It's really great.

But I'd like to have us get a little more feeling about what that -- about how we can take that deeper.

Other remarks by my colleagues?

You've done all the damage you're going to do? I thought the group should hear that.

I see Jeramy fingering transparencies. That spells a desire. Do I -- is my intuition correct, Jeramy?

MR. BOAK: Yes. Your intuition is correct. I

wanted to say -- I'm Jerry Boak, Chief of the Technical Analysis Branch and I wanted to say a few words about alternative conceptual models and conceptual model uncertainty. It's a subject that's been on my mind because I got invited to prepare a paper on it and I invited Alan to be a co-author and invited Holly Dockery to be a co-author.

A comment made at a performance assessment advisory group, the people who sponsored this workshop -- which I in the end was not able to attend -- by one of our British colleagues kind of troubled me. He said that one could suggest that each of the realizations they had of the geometry of the site where they make stochastic realizations of the geometry, could be considered an alternative conceptual model. And at the time, I suggested this meant that the British has invented computers that could conceive, which was a remarkable achievement.

But I don't think that's an alternative conceptual model. But I'm not sure I can say what is one. In fact, I'm really troubled by Paul's comments because I don't know what it is that he's driving at that is missing.

But that's always been true for the site characterization plan. We've always had a tendency to resort to the Prego defense. You know, it's in there. And ask people, wait a minute. What's missing. But I do know that simply looking at different realizations and looking at

parameters that we know are part of our conceptual model and pushing them to the extreme ends is something we've done as an exercise but we do not consider it an alternative conceptual model.

Joe Wang has done a good deal of work looking at what kind of data we have about the properties of naturally occurring materials with respect to permeability, the air entry pressure. And what he finds is that although for any one group of data, such as the Las Cruces Trench data, the Apache Leap data or Yucca Mountain data, there generally is not a very strong correlation between these two parameters; saturated permeability on the one hand and the alpha parameter or an equivalent calculation of an equivalent capillary radius.

He points out, however, that for the full set of data, there does appear to be a correlation and that it is roughly parallel to a standard equation for a capillary tube, which shows that the saturated permeability is proportional to the square of the radius of that capillary tube.

This makes sense in a physical sense in that the naturally occurring materials tend to show the same trend. They behave like capillary materials. That's a fundamental underlying concept of every hydrologic model I know of, but they do tend to lay below the line very strongly. There are

nearly 900 data on here. I think there are seven on this data set that lay across the line. And they all come from non-welded tuffs from Yucca Mountain.

So there's a fundamental constraint on how we ought to model realistically, how we ought to model materials when we try to model them if we're going to presume the capillary theory is an adequate way to represent it. And all of our models do that, as far as I am aware.

So Joe pointed out that this might be an extremely useful constraint on materials that we had a difficult time measuring properties for especially, as you noticed, for fractures. And in fact, when we did our TSP in 1991 the center point of our distribution for fracture properties was up in here about.

The proposed alternative conceptual model which allowed very high fluxes to go through the mountain that was presented to you earlier and which was published in Brown, et al. in the focus meeting, used fracture properties that covered this entire range, but required fracture properties out here in order to get the high fluxes through the repository horizon.

And in fact, it required that those properties apply most especially at the one point at the contact between the PTn unit and the Topopah Spring. That point in fact is the point at which the match to the UZ-16 data is at

its absolute worst. The saturation is exceedingly high. The measured saturation is remarkably low.

So I would guess -- I would say that although we have a concerted effort to figure out how we can appropriately model the data we have that relate to fracture flow, I don't think we gain any insight by taking the properties and stretching them beyond the realm of physical reality. I don't think we learn anything about how to deal with fractures by doing that kind of modeling.

I think we need to find new ways to address the question of fracture flow. We've tried to do that in some very simple ways in TSP in 1991 and tried to enhance that in our next iteration of total system performance assessment, but I think it still remains an open question. It's one I hope to get a lot of useful information out of the study plans that Ed Kwicklis is working on. I think that probably is the most difficult question we gave to answer because that transition from fracture to matrix flow is certainly the point at which the highest likelihood of radionuclide release starts to occur.

It should be interesting. We should be able to get some bounds on our fluxes if we get down to the Topopah Spring. And as Marty Mifflin pointed out, if the flux through that horizon is anything close to what he thinks is the likely flux through that unit, then it should have a lot

of flowing fractures in it, because as he pointed out the estimate he gave for a flux suggested it was well within the fracture flow area.

So that I would suggest is an extremely good place to look for evidence in an ESF of whether those kind of fluxes are realistic or whether the fluxes that have been assumed in our total system performances are more realistic and whether perhaps some of the very, very high fluxes should in fact be at the very tail of the distribution.

MR. HINZE: Thank you very much.

Are there other comments? Linda?

MS. LEHMAN: Well, Linda Lehman. I just wanted to get some clarification.

MR. HINZE: Is the Reporter catching you?

MS. LEHMAN: I don't know. I guess my question to Jerry is I'm not certain how you calculated that we were out of the range of possibility on the fractures when we used only published data. And maybe you can tell me exactly what you meant.

MR. BOAK: I don't recall the citation from which those properties were taken.

Alan, are you familiar with that? Can you respond to that question? I'm not familiar with the actual alpha values.

Actually, Joe did this study to point out this

particular problem because quite a bit of modeling had been done using that kind of values for fractures. And he was pointing out that that might not actually be a realistic way to do it.

MR. FLINT: Well, I think that there are published data that say what people might conceive fractures to be like. If this was published data, however this was done, whether it was Wang or Simmon -- and I don't believe they used real fractures, measured real properties.

I think what Jerry was doing was looking at the relationship between the water retention curve assumed for the fracture and the permeability assumed for the fracture and found that they were inconsistent. And that's something that we're trying to work on is making them at least theoretically consistent with each other.

They're not independent variables. The aperture and the flow rate is not an independent variable. So that needs to be considered when you do some of the modeling.

MR. HINZE: Thanks, Alan.

Are there more comments? We have a chance for a record here if you wish to go for it. If we go for another half hour we'd set a record.

MR. FLINT: I'd like to make one comment and then I'm going to sort of ask Larry to correct me on the whole thing, so I don't get into much trouble.

But I appreciate the comments you made and the concerns you made about what we're doing and what kind of information we're missing. But you have to realize and remember that one, you didn't ask us to present some of the information you said was missing.

For instance, on some of the isotope data, Sol Peterman has a wonderful data set. He's doing a tremendous amount of work in isotopes and he would have been more than happy to come and explain all of the analysis of the water, of the carbonates, and all of that information.

So you're seeing kind of a small part of the picture. So I think you have to be a little careful, although I appreciate the criticism. I think you have to be a little careful because you're seeing an extremely limited view of what's going on. And we responded to the questions you asked.

And the second point is what we presented today is the fourth priority in the DOE program as it stands now and they run out of money halfway through the third. So you can't expect us to have a lot of the answer and a lot of the information and a lot of studies going on to answer the questions that you think are important.

We think they're important, too. But when you have Bo Bodvarsson trying to run his model by himself for a long time or a with a few other people, we can't do the

kinds of things that we want to do.

We recognize the problems but you also have to recognize that although we say we're not controlled by DOE in what we do -- and that's true -- but if they don't fund the project, we don't do that project. That's another truism that we have to deal with.

But like I said, we are the fourth priority and a lot of what we presented today, and we're doing the best we can with the information, but there's a lot of stuff you didn't hear because -- well, we actually had enough time to get a couple of more talks in.

Larry can sort of comment on that to straighten me out a little bit or whatever, I'd appreciate it.

MR. FLINT: I've given up trying to straighten you out. I think frankly you made some fine comments. They are true. There is not enough money. DOE has set priorities, but we can't throw all the blame on DOE, at least from my perspective, that all the money that maybe Alan and I and others think should be there with site suitability studies is not there.

DOE was under considerable pressure from I think the NRC, from TRB, from others to get underground. Underground was progress.

Now, I have often taken issue with the statement that we'll know whether Yucca Mountain is suitable or not

when we get underground and we make the TBM loop. I still don't know and I still haven't gotten any answers how we can walk through that tunnel, look around and say it's either suitable or not suitable.

Yet I think because of that perception, DOE was put under one heck of a lot of pressure to spend a lot o. their money on getting underground. And I think under the circumstances, the situation is as balanced as it can be.

A big part of the money went to getting underground. We didn't get as much as we wanted for the surface based program. But in the end through negotiations with DOE we did pull some of that money back that originally went to something else and pulled it into the site characterization program.

So I think we're making progress but I agree with Alan, a lot of the things we think are important and want to do, the money simply isn't there.

MR. HINZE: Well, I don't want to speak on behalf of the committee, but I certainly appreciate the comments of Alan and you, too, Larry.

In the beginning of our workshop I mentioned that we were just looking through a small window. And we realize that. And realize that your intellectual curiosity and gut scientific feeling goes beyond what's possible with the funding available.

MR. POMEROY: Bill, can I ask one other?

MR. HINZE: Please.

MR. POMEROY: Can I carry this discussion on with Alan for one more minute? Because something you said intrigued me, Alan, and I'm curious.

One of the things that strikes me, that struck me today again was the tritium data and the chlorine 36 data that Al discussed with regard to possible fast pathways. And I just heard you say, I think, that you had some marvelous data on isotopes.

Do you have any data that's confirmatory to Al's work?

MR, FLINT: I don't have any data. That's something I think you'd have to talk to Sol Peterman about. A few things about what you saw.

One of Al Yang's slides suggested that the water in the Caladra Hills was about 18,000 years old. The numerical modeling that I did, it took 20,000 years from the surface to get to the Caladra Hills. So that's pretty close to the kind of age data that we're looking for in climate change.

In questioning that data, as Al Yang mentioned, he showed -- and I think some of you caught -- 120 tritium units where he said the rainfall is only 30. So you have to start to ask where that comes from if we have some pasta

climate event. And I think someone asked the question -- and i'm not sure Al answered it -- but that was one data point, just one. And as Mike says, we have to do more studies on that particular data point. We have to put all that together.

And right now I don't think we have enough information. I think what June's work is doing, there are some questions about that. I think she's doing a wonderful job. Her first boreholes she's sampled had four times the background of chlorine 36 and we had a problem with contamination which we think we tracked down.

But there are lots of questions about it that we're not sure about. But as Al has said and others have said, we simply have to put all of this information together and we have to draw a consistent picture of how it fits. And if we have to throw that data out and replace it with lower ones if it becomes consistent with all the other borehole information that we have.

We have to start looking at that kind of information.

I don't think you can disqualify a site because of one data point. I think you have to look for a consensus of data points. We're going to drill four more holes there. We're definitely going to be thinking about that point and that chlorine 36 information when we get there. And we

learned a lot from the very first hole that we drilled.

And I think the confirmation is not what we have today. it's what we're going to have later. And I think that's why what Larry said is really true. We've got to keep working on the surfaced based testing because we're never going to get to that part of the mountain with an underground facility. We're going to get it through boreholes spread all over the mountain in the major recharge zones.

I think we're going to miss a lot of stuff by this ESF but I think that's something that just has to be done that way.

MR. POMEROY: I think this committee has strongly expressed its opinion in the past about the importance of surfaced based testing. Unfortunately, I don't think we are your oversight committee and your oversight committee has a different view.

MR. HAYES: I guess I would like to say one more thing in defense of the site characterization program. And I'm not criticizing but I'm trying to put out some facts.

This year we have let's say a $270 million program and maybe we have 2,000 people working on the program. The actual amount of money that has gone directly to site characterization, WBS 1, 2, 3, I think is about $60 million.

The three National Laboratories and Lawrence Berkeley -- the three main laboratories on this program are Sandia, Los Alamos, Lawrence Livermore, then Lawrence Berkeley is providing support to those Labs plus the Survey. And the Survey is the main performer for site characterization, let's say.

Together, the Labs and the Survey has about 300 of those 2,000 people. And I bring those numbers up because it's interesting to me that the site characterization part of the program really is not in any way the big part of the program.

MR. HINZE: A comment here?

MR. JOHNSON: Someone else would rather speak to that lack of integration issue, that would be fine. But I think someone should.

MR. HINZE: Identify yourself?

MR. JOHNSON: I'm Cady Johnson. I work for Woodward-Clyde Federal Services and we're part of the M&O team who is charged in large part with project integration. What I see is we have one of the most long-standing criticisms of the project coming back at us that we come into a meeting like this and don't appear integrated.

And I wonder how much of that is real and how much is maybe due to our inability to communicate the successes we've had in integration.

I could cite the weeks that were spent with Larry Hayes and with the Los Alamos and with the PA community trying to get a summary schedule for this project to show we're really on an integrated footing with the site program providing data in a consolidated form at the times that the PA community might need it.

I could cite the efforts to try and get a coordinated cooperative drilling program going with Nye County and in fact the units of local government and trying to understand their perceptions of the issues and to sell that in our program.

And it seems to be about ready to happen. There seems to be a protocol ready that may get signed in the next few days.

There are a lot of successes, major and minor, that maybe aren't evident. And I didn't know -- well, there were no M&O people asked to present. Integration wasn't a topic for the meeting that I knew of. It was a technical meeting. And it may be -- you know, maybe we should learn a lesson to make sure that at least one talk in a meeting like this is focused on integration because I can see where the perception comes from that we lack integration.

But I really believe and I think maybe most of the project people would agree that the lack of integration, it's more of a perception than reality. And I think we may

be better integrated than we look on paper or that sometimes we come off in meetings like this. But we work very hard and on a continual basis to understand each other and maybe that's just not indicated as effectively as it could be.

MR. HINZE: Thank you very much.

Darrell?

MR. LEAP: May I just follow up with a question. How easy is it for one party to get data from another? In other words, how long does it take and what do you have to go through to get it? You've got the DOE. You've got the USGS, Woodward-Clyde, State of Nevada, a lot of other people working. But if somebody, say the USGS wants some data, how easy is it to get?

MR. FLINT: I'd like to answer that. From within the project, from my own experience, it's very easy to get data. I take data right off my computer and I hand it someone from Sandia National Labs right there in the building.

They go out in the field and collect data with us. We send it to Bo. We send it to Los Alamos. We send them samples. They'll process them and send them back.

We have a very good cooperative relationship among the principal investigators, the scientists on the program in handing data to each other and information to each other. That's very easy to do and it's done I think a lot at our

level. Down in the trenches we do that quite well.

MR. HINZE: Linda?

MS. LEHMAN: I'd like to comment. I'm glad it's easy for the other participants but it hasn't been easy for us. And I reported to you several years ago that we had outstanding data requests for up to 10 years.

We have received a lot of that 10 year old request now due to the efforts of INTERRA. They have helped us there. But as far as recent data, borehole data on the site, we were given the INTRAVAL data package and that's all that we've had as far as site specific data.

Now if there's some way that we could be in the loop where the data goes to the Labs that we could also have it, we would really appreciate that.

One of our problems is we have to write a data request and we don't know what's out there usually to request it.

MR. HINZE: Claudia, are you going to provide the answer to that?

MS. NEWBERRY: Yes. The first time I ever came to an ACNW meeting was about data four years ago. And in the interim we put together a system which I believe you get lots of catalogues now --

MR. HINZE: Yes.

MS. NEWBERRY: -- where all of the data that's

collected on this site is reported. It's tracked in a tracking system and we produce catalogues on a quarterly basis which we are required to do.

Those catalogues to the state, and if the state sees fit to provide them to their contractors and the contractor looks at those catalogues and finds the data that they require, we're more than happy to provide it to them. But it takes a formal process because otherwise we don't know what's been requested. If informal requests are made to the USGS, DOE has no control. And that's one of the primary reasons we went to the data tracking system.

MR. HINZE: Is that available now on an on-line basis through some type of easy access Internet type of bulletin board?

MS. NEWBERRY: I wish I could say yes, it is, but no, it's not. It is available to the Laboratories on-line.

Larry, it's on-line to you. I don't believe it's available on something like Internet, though, yet.

MR. HAYES: I'd like to add to the data problem and I don't -- well, let's say I'd like to add clarification to it. I've added enough problems already, right, Dave?

Linda is not -- I'm not going to totally disagree with her. It is much more difficult for the state to get data than it is for us to share among participants. Part of the reason is Alan can pull his data, share it with Sandia

and Los Alamos, anyone on the project, without going through an official review process.

I don't know if the Labs operate this way but the way the Survey operates, any time we're doing work as a participant for a customer such as DOE, we can share data with any other participant immediately. That's up to Alan to do it when he wants to, now he see he should, whatever.

In order for the Survey to give information to the state who is not a participant to the Yucca Mountain project, I have to have those data reviewed and approved by the Survey.

Now, we are aware this is a problem. Carl Johnson has asked the Survey for a lot of data recently and I think Carl should have those data. And it's partly because of that that the Survey has developed this document that I gave you, Bill, where we're identifying periodic data submittals to our LRC, because before the information goes into the LRC it has to go through all the review checks.

So once it goes into the LRC, very shortly thereafter it goes to the DOE central records facility and then Linda can get it quickly from the central records facility.

So there has been a problem with sharing outside the project in a timely way, but I think we're starting to work on that. I know DOE is putting a lot of emphasis for

all participants to get information through what's called the Technical Data Base here in Las Vegas. And as we get information into the Technical Data Base, again it's information that's been reviewed and it will be readily available to people outside the project.

MR. HINZE: Thank you very much.

With that, I see no more eager hands.

Bill Ford. Go ahead.

MR. FORD: Yes. Bill Ford, USNRC. One thing I just wanted to mention. Some of us have been thinking about on the staff that I didn't hear here -- in fact, the only time we get kind of insight usually is when we see progress reports or we have technical exchanges. And that is that in characterizing the unsaturated zone there's going to be a lot of research that's still required to know how to collect some of the parameters.

And we normally don't see that in study plan reviews of the Hydro Section. It would be nice to hear and see how things like bulk fracture properties or bulk properties of the rock. We're going to go about collecting data or confirming how we can collect data to characterize bulk fracture properties, what techniques you use, how would you put them together to account for the bulk fracture property for various saturations. And then how the modelers can test their codes against that data or put experiments

together to use that data for the modelers to test their codes to see if bulk fracture properties can be used, if it is a useful concept or not. And that's generally not seen.

So it seems like that would be a very important piece of information because you can't adequately characterize a site. If you're going to characterize a site for bulk fracture flow properties, you want to prove and be sure of your technology to collect those properties.

MR. HINZE: Thank you, Bill.

April? You may have the chance for the last word here.

MS. GIL: Just in conclusion I wanted to say something about integration. I don't feel like I can leave the meeting today feeling as if it was my response to your comment, Paul, that gave you the impression that our program, our project, is not integrated. And I appreciate Cady standing up and saying something because I feel very strongly about this.

We worked actively at all levels. And when I said the WBS managers, those are the DOE managers responsible for the budget. And that's the level I believe your question was at. So we worked actively day in and day out with the PI's, with the TPO's with people at the M&O, with people at the Labs.

So integration takes place on a day in, day out

basis at that level, which is very informal.

And I also feel strongly about the issue resolution process that I talked to the committee at some length about yesterday. There's a real success story in how we have integrated our program. We work with PI's. We're identifying specific issues in the regulations that are difficult to come to some kind of consensus on and we work with that on a day in, day out basis.

So I hope that clarifies something that I said earlier today.

MR. HINZE: Thank you, April. With that, I would on behalf of the committee like to thank the speakers today. They've been consistently excellent. And we have learned a great deal. We've accomplished, I believe, what we came here for. And we do appreciate it. We're looking forward to tomorrow.

I cannot help but thank our Reporter for his perseverance in saying all of these words. Let's give him a hand.

[Applause.]

MR. HINZE: And with that, the meeting and this workshop is adjourned. Thank you.

[Whereupon, at 7:50 p.m., the ACNW Working Group was adjourned.]

REPORTER'S CERTIFICATE

This is to certify that the attached proceedings before the United States Nuclear Regulatory Commission
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NAME OF PROCEEDING: ACNW Working Group on Yucca Mountain

DOCKET NUMBER:

PLACE OF PROCEEDING: Las Vegas, NV

were held as herein appears, and that this is the original transcript thereof for the file of the United States Nuclear Regulatory Commission taken by me and thereafter reduced to typewriting by me or under the direction of the court reporting company, and that the transcript is a true and accurate record of the foregoing proceedings.

Jon Hundley
Official Reporter
Ann Riley & Associates, Ltd.

DOE/YMP
Characterization of Unsaturated Zone Infiltration

Dr. Alan L. Flint
U.S. Geological Survey
Mercury, Nevada

DOE/YMP Characterization of Unsaturated Zone Infiltration

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Characterization of the Unsaturated Zone Infiltration (SP 8.3.1.2.2.1)

- Characterization of Hydrologic Properties of Surficial Materials (Activity 8.3.1.2.2.1.1)
- Characterization of Natural Infiltration (Activity 8.3.1.2.2.1.2)
- Evaluation of Artificial Infiltration (Activity 8.3.1.2.2.1.3)

Supporting Studies

- Matrix Hydrologic Properties Testing
- Characterization of the Meteorology for Regional Hydrology

Photo: Aerial view of Yucca Mountain with site-scale model boundaries

Objectives

- To evaluate past, present, and possible future net infiltration: water infiltrating below the zone where it can be readily removed by evapotranspiration processes
  - by evaluating the mechanisms and processes by which precipitation becomes net infiltration
  - by assessing the spatial distribution of net infiltration over a large heterogeneous site
  - by assessing the temporal distribution of net infiltration over a large heterogeneous site
  - by modeling net infiltration using conditional simulations of precipitation and a site calibrated watershed model

Approaches used to evaluate net infiltration

- **Identify the field mechanisms contributing to net infiltration.**
- Identify physical and hydrologic properties influencing net infiltration, and necessary to produce surface infiltration units on a site scale, and as input for flow models.
  - unconsolidated materials (soils)
  - consolidated materials (bedrock)
- Evaluate methods to quantify net infiltration
  - water balance: evapotranspiration, precipitation, storage
  - 1D, 2D, and 3D flow models are used to predict borehole saturations and fluxes on various time scales
- Model surface net infiltration on a site scale under varying climatic conditions.

Arid Land Watersheds

Things to consider:

- Variable depth of alluvium overlying bedrock
- Fractured bedrock
- Variable bedrock porosity
- Variety of topographic positions providing differences in radiation load, soil depth, slope, runoff, run-on
- Timing of precipitation

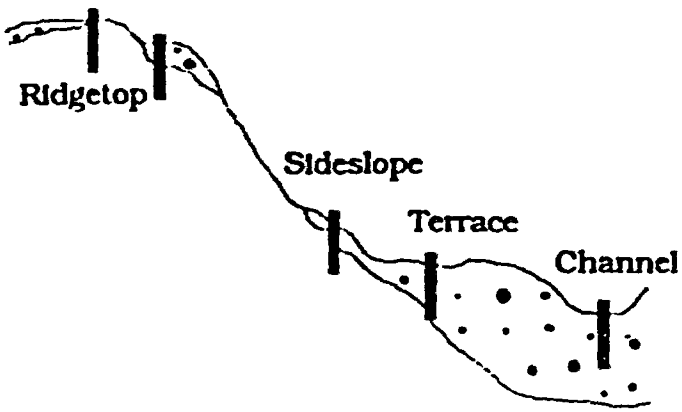
Photo: View of Yucca Mountain from Solitario Canyon to show large scale layering

Photo: Close up view of welded and nonwelded tuff in Solitario Canyon to show variable porosity and fractures

Photo: Aerial view of Yucca Mountain from the east

Photo: View of snow to show variable forms of precipitation

Topographic Positions



Dataset

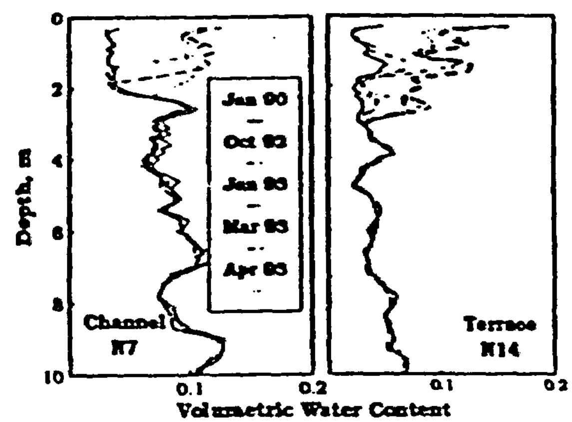
- Two watersheds, one erosionally controlled to the south, one fault controlled to the north
- Eighteen neutron-access boreholes, 6-19 meters deep, in each watershed
- Topographic positions of boreholes include ridgetops, sideslopes, alluvial terraces and alluvial channels
- Monthly readings of volumetric water content, at 0.1 m depth intervals, for three years

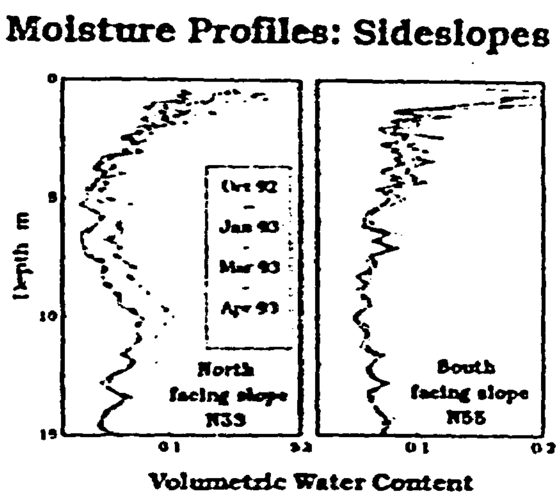
Photo: neutron moisture meter

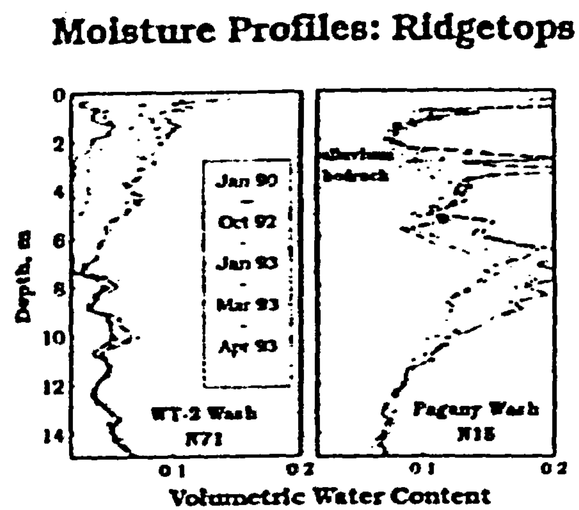
Photo: Aerial view of Pagany Wash with boreholes marked

Photo: Aerial view of WT-2 Wash with boreholes marked

Moisture Profiles: Channel/Terrace







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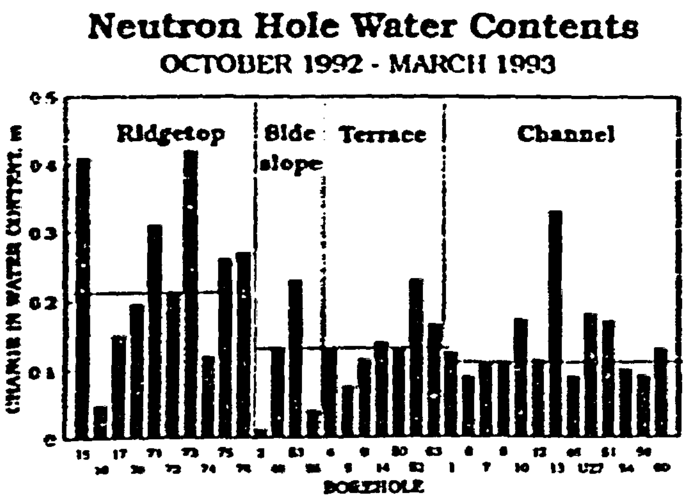
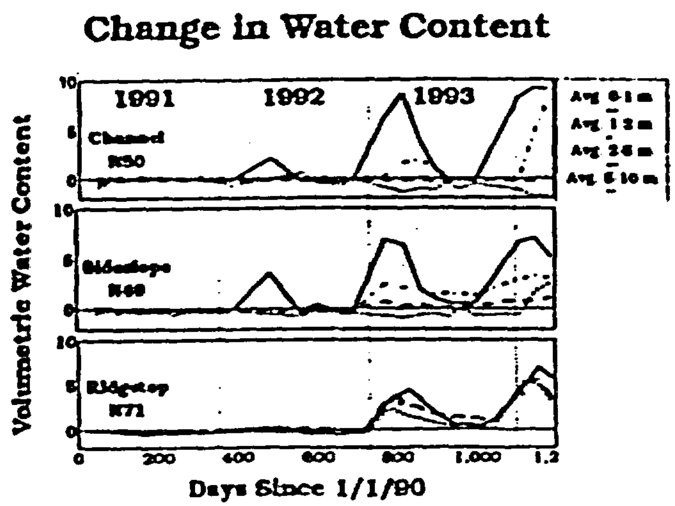
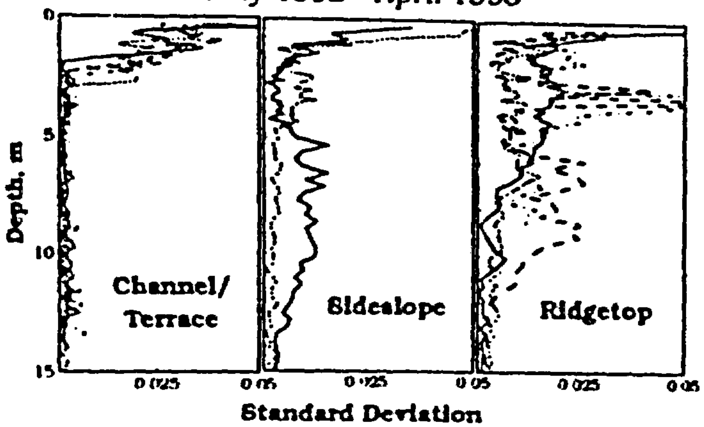




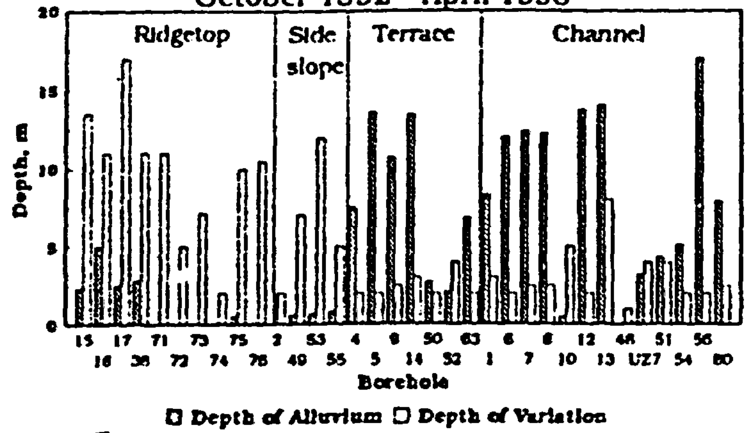
Variation in Water Content

July 1992 - April 1993



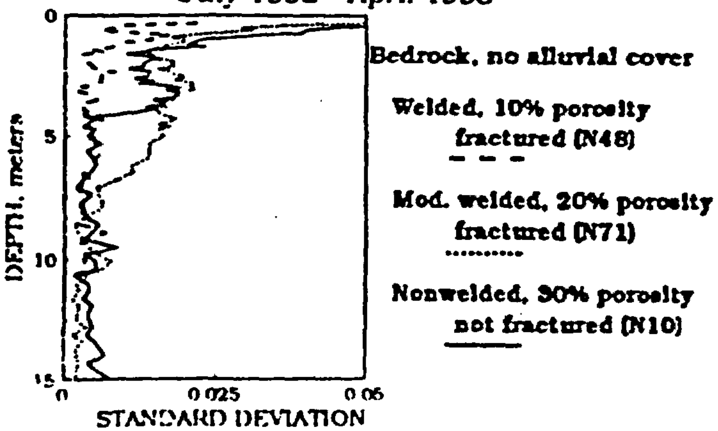
Water Content Variation

October 1992 - April 1993



Variation in Water Content

July 1992 - April 1993



Summary of Net Infiltration Processes

Net infiltration depends on how fast water can penetrate below the zone of evapotranspiration

- Ridgetops have the deepest penetration of a wetting front and the largest increase in saturation.
- The movement of the wetting front is faster in the ridgetops.
- Penetration is influenced by
  - the timing of precipitation
  - the potential for runoff
  - storage
    - the depth of alluvium
    - layering (low porosity zones, caliche or bedrock)
    - the porosity of bedrock
  - the occurrence of fractures and the water potential or saturation of the wetting front when it reaches the bedrock.

Approaches used to evaluate net infiltration

- Identify the field mechanisms contributing to net infiltration.
- **Identify physical and hydrologic properties influencing net infiltration, and necessary to produce surface infiltration units on a site scale, and as input for flow models.**
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2-D Horizontal Analysis of the Hydrologic Character of Unconsolidated Surficial Materials

Environmental parameters

- precipitation
- solar radiation
- net radiation
- air temperature
- soil heat flow
- evapotranspiration

Soil parameters

- water content, water potential
- hydraulic conductivity
- water retention functions
- texture, porosity
- depth to restrictive layer
- vegetation

Initial Modeling

Surface soil water content model

$$\Delta S = P - ET - R_{off} + R_{on} - D_{fc}$$

ΔS	Change in water content	**calculated**
P	Daily precipitation	**collected**
ET	Evapotranspiration	**modeled**
R_{off}, R_{on}	Surface run-off, run-on	**assumed zero**
D_{fc}	Drainage below field capacity (Richards equation submodel)	**estimated**

Initial Modeling (cont.)

$$ET = \alpha' \frac{S}{S+\gamma} (Rn - G)$$

ET = evapotranspiration
S = slope of vapor density curve [f(air temp)]
γ = psychrometric constant [f(air temp)]
Rn = net radiation
G = soil heat flux
$\alpha' = \alpha\,[1 - e^{(\beta\Theta)}]$

where α and β are model coefficients (site dependent), and $\Theta = \dfrac{\theta - \theta_r}{\theta_s - \theta_r}$

Preliminary modeling results (N7 Pagany Wash)

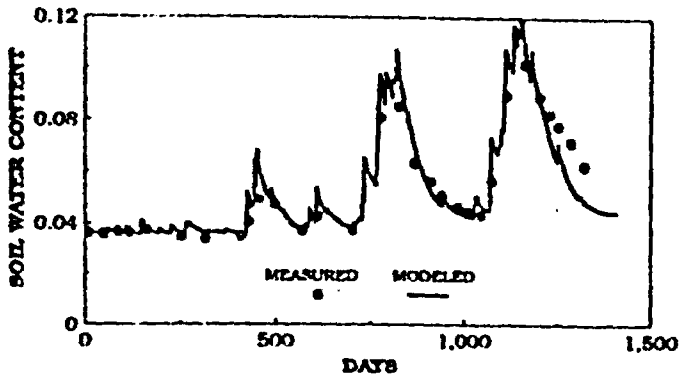

Photo: Aerial view of WT-2 Wash with transects and boreholes marked

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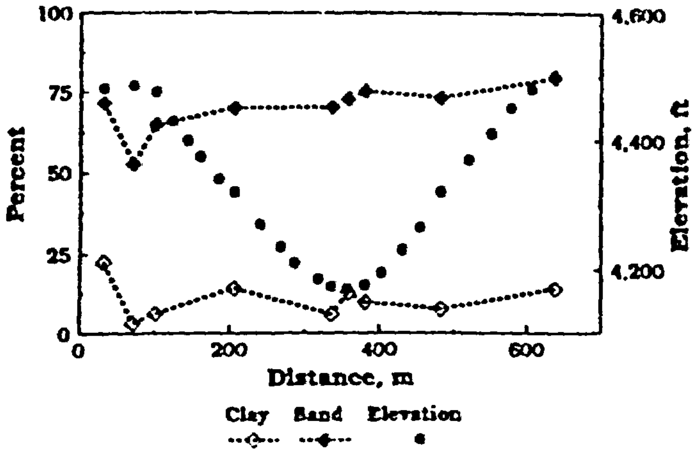
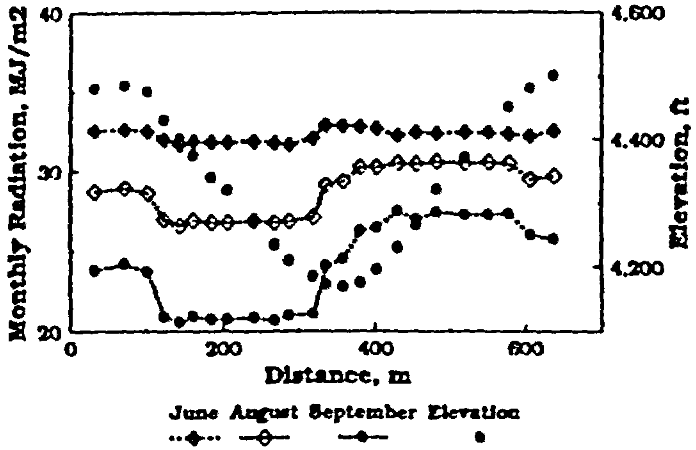
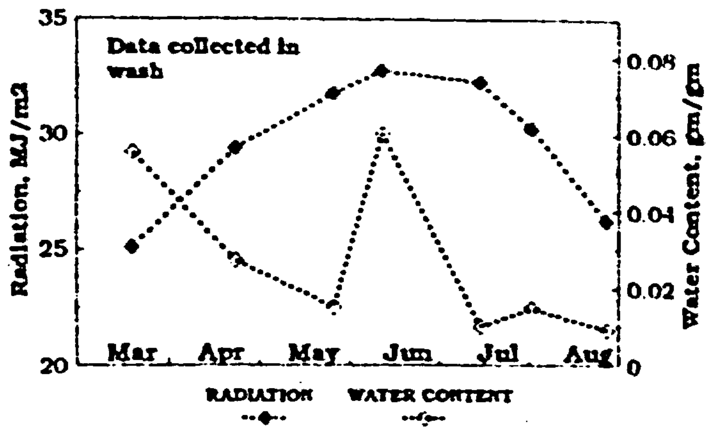
Texture



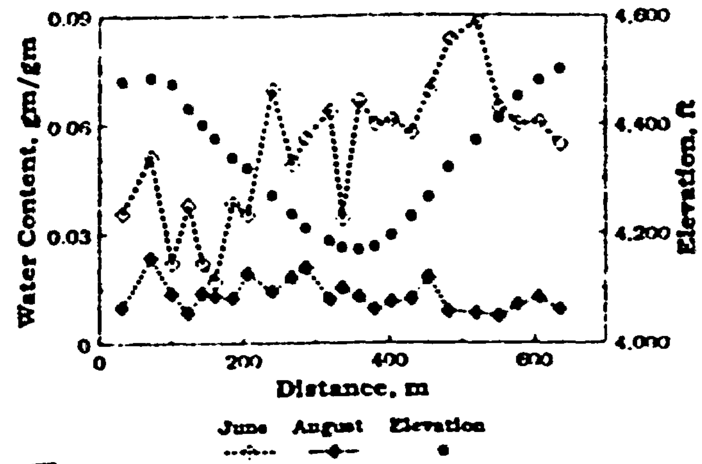
Solar Radiation



Monthly Variation



Water Content



PRELIMINARY DRAFT
INFORMATION ONLY

Photo: Map of estimated bulk density in WT-2 Wash

Summary of 2-D Horizontal Chracterization of Unconsolidated Surficial Materials

- Precipitation sets the initial distribution of surface soil water content
- Available energy controls the evapotranspiration process until the soil reaches a critical water content, then soil properties control evapotranspiration
- Soil properties control drainage away from the strong evapotranspiration processes

1-D and 2-D Vertical Analysis of the Hydrologic Character of Unconsolidated Surficial Materials

Objective

- To determine the hydrologic properties needed for the numerical modeling of a heterogeneous desert alluvium.
- To develop a methodology to transfer the information to other locations.

Method

1. Define important hydrologic properties needed for modeling.
2. Establish field and laboratory methods to obtain the necessary hydrologic information at a site where multiple methods can be employed.
3. Conduct field and laboratory measurements to collect data.
4. Develop transfer methodology using geophysics and soil properties.
5. Establish a modeling scheme to incorporate the field and laboratory data, use history matching to calibrate model, and employ prediction for model verification. (Inverse modeling may be incorporated for some property determination.)

1. Hydrologic properties needed for modeling

- Unsaturated hydraulic conductivity and/or moisture retention characteristics
- For finite difference modeling, the boundary conditions are required. If short time periods are modeled, initial conditions are also required.

2. Establish field and laboratory methods for a specific site.

	Laboratory	Field	
		Surface	Subsurface
Moisture	Water activity meter	Neutron probe/TDR	Inverse modeling of
retention	Pressure plate	and tensiometer	moisture retention
	Tempe cell	measurements	from infiltration and
	Tension table	over time	drainage
Saturated	Tempe cell	Infiltrometer	
conductivity	Texture		
Unsaturated	vanGenuchten &/or	Sorptivity and	Inverse modeling of
conductivity	Brooks & Corey	inverse model of	moisture retention
		Richard's equation	assuming vG or
			Brooks and Corey

3. **Conduct laboratory and field measurements to collect necessary data.**

Photo: View of 40-mile wash cut face at location of N-85 ponding study

Photo: View of 40-mile wash cut face at location of N-85 ponding study, close-up

Characterization of Layers

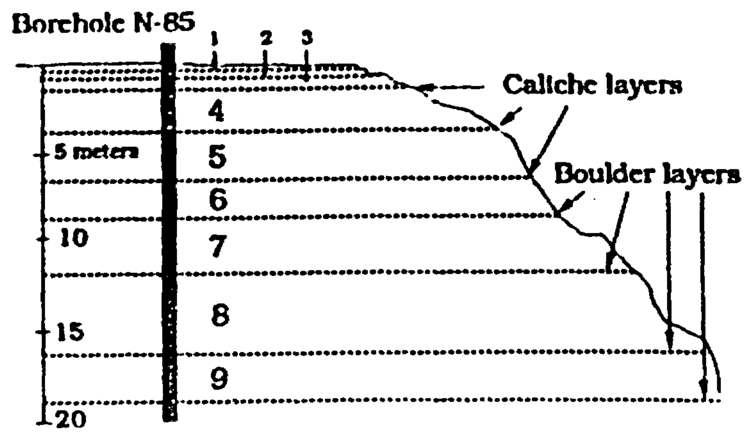
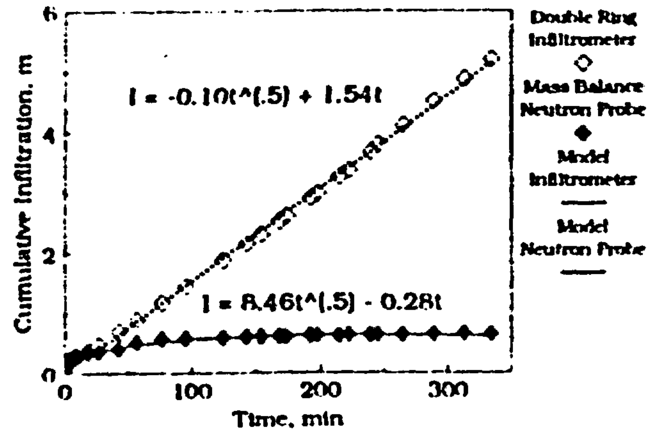


Photo: Double ring infiltrometer used in ponding study

Infiltration Measurements



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Data from ponding experiment

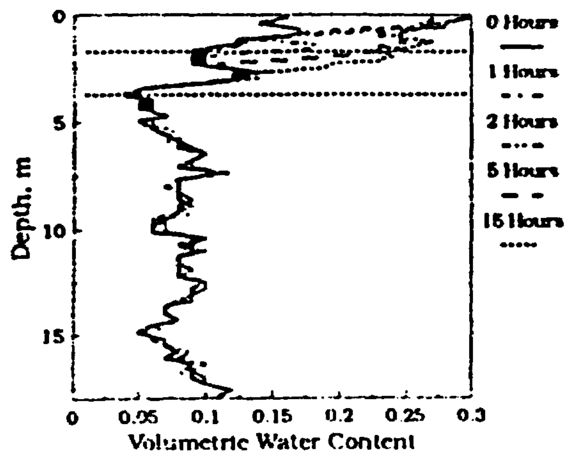
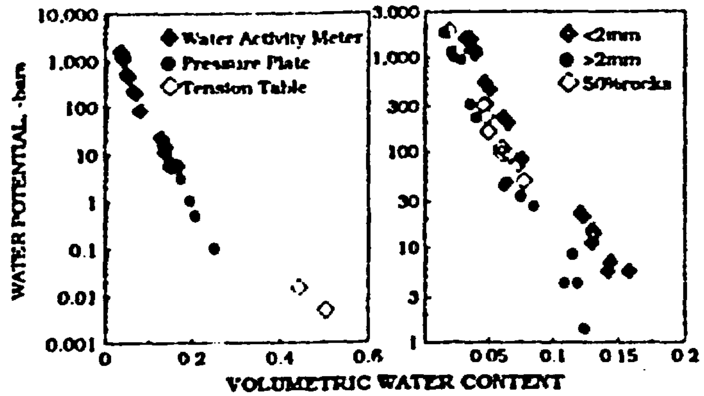


Photo: CX-2 water potential measurement system

Photo: Tempe cell for measuring moisture retention

Water Retention Curves



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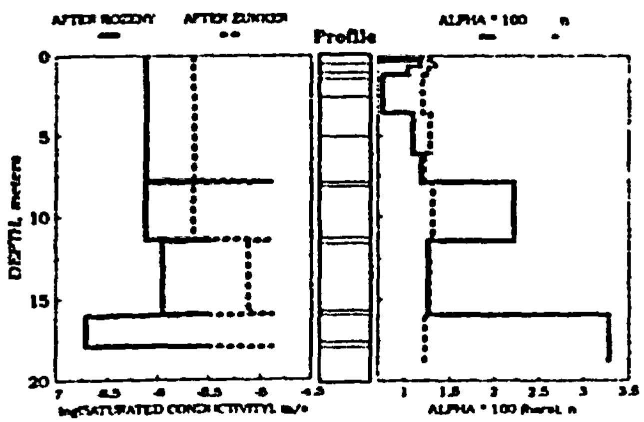
Lab characteristics of hydrologic properties



4. Develop transfer methodology using geophysics and soil properties.

Photo: soil constituents

Particle Size Analysis

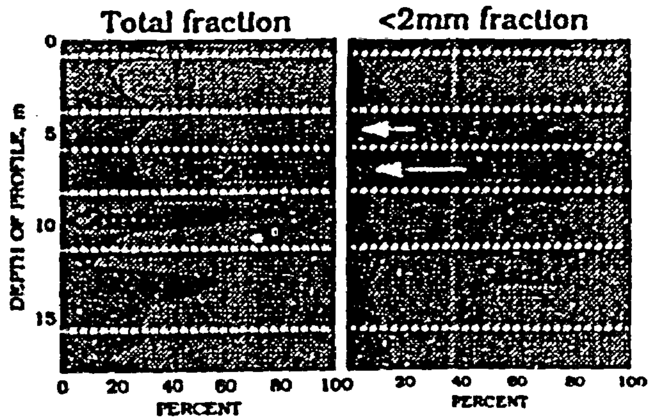
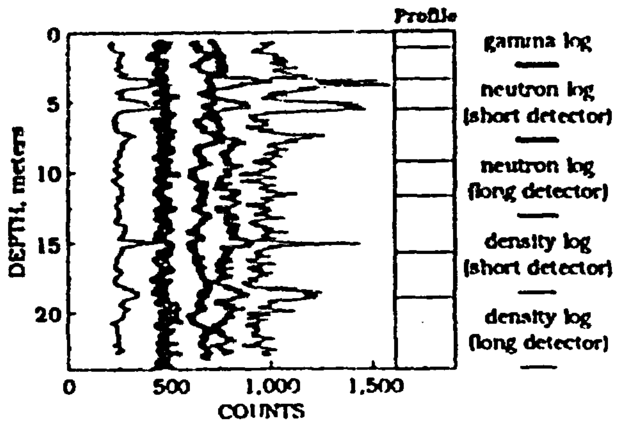
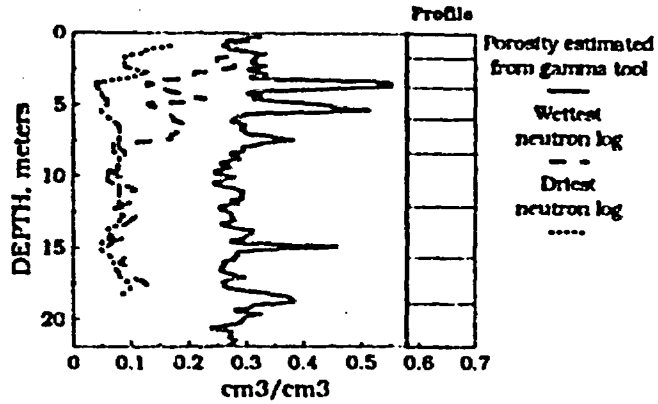


Photo: logging van

Geophysical Logs



Field Geophysics



5. Establish modeling scheme...

Modeling

- Use TOUGH for the 1-D, 2-D and 3-D models to incorporate liquid, vapor, and heat flow. Additional computer codes will be used for preliminary modeling.
- Set up 1-D model and use mass balance data from the neutron borehole as a flux boundary condition (which removes the loss to lateral flow).
- Set up 2-D model and use mass balance data from the large infiltrometer as a flux boundary condition.
- Set up 2-D model and use a water potential boundary condition.
- 3-D model?

Summary of 1-D and 2-D Vertical Characterization of Unconsolidated Surficial Materials

- Large scale soil layering may strongly influence the penetration of water and may cause lateral flow in washes.
- Without model verification the methodologies presented produce uncertain results.
- Borehole geophysics can provide the initial conditions and guidance for establishing layers.
- Rock fragments need to be accounted for in these soils when determining water retention characteristics.
- There is no data to support the use of textural information to estimate hydrologic properties for this site.
- In locations with no access to subsurface samples, inverse modeling of flow experiments and borehole geophysical data may be the only way to assess hydrologic properties of desert alluvium.

Approaches used to evaluate net infiltration

- Identify the field mechanisms contributing to net infiltration.
- **Identify physical and hydrologic properties influencing net infiltration, and necessary to produce surface infiltration units on a site scale, and as input for flow models.**
  - unconsolidated materials (soils)
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  - 1D, 2D, and 3D flow models are used to predict borehole saturations and fluxes on various time scales
- Model surface net infiltration on a site scale under varying climatic conditions.

Photo: Site-scale model boundary on photo

Process for estimating surface moisture flux

- Determine surficial tuff hydraulic properties (saturated permeability).
- Group surficial tuffs into flux units.
- Locate units on lithologic map, excluding alluvium.
- First approximation of flux is the saturated matrix permeability, used to identify distinct zones of infiltration potential.

Process for estimating surface moisture flux (cont.)

- Estimate current water content and water potential of surficial units at the depth where annual fluctuations are reduced, or at the tuff-alluvium contact. Assume a unit gradient and use relative permeability as the second approximation of flux.
- Add fracture density and fracture permeability, and fracture fill properties, and incorporate matrix properties as the third approximation of flux.
- Refine field measurements to better determine the properties and the potential gradient for flux.

Matrix Properties of Tuff

	Porosity			Conductivity (m/s)		
	Mean	Standard Deviation	No. of Samples	Mean	Standard Deviation	No. of Samples
Tiva caprock	0.133	0.035	6	2.1E-09	1.5E-09	3
Tiva mod. welded	0.239	0.052	77	5.0E-08	7.9E-08	13
Tiva welded	0.061	0.034	61	1.2E-09	2.8E-09	18
PTn	0.396	0.134	204	6.1E-06	2.9E-05	158
Topopah caprock	0.031	0.021	59	1.3E-09		1
Topopah welded 1	0.109	0.040	139	2.3E-08	9.4E-08	19
Topopah welded 2	0.072	0.021	24	5.1E-11	6.7E-11	3
Topopah vitrophyre	0.039	0.031	19	8.1E-10	1.4E-09	6
Calico Hills/Prow Pass	0.329	0.056	64	1.4E-10	1.2E-10	10

Photo of color topo: Distribution of surface flux

PRELIMINARY DRAFT
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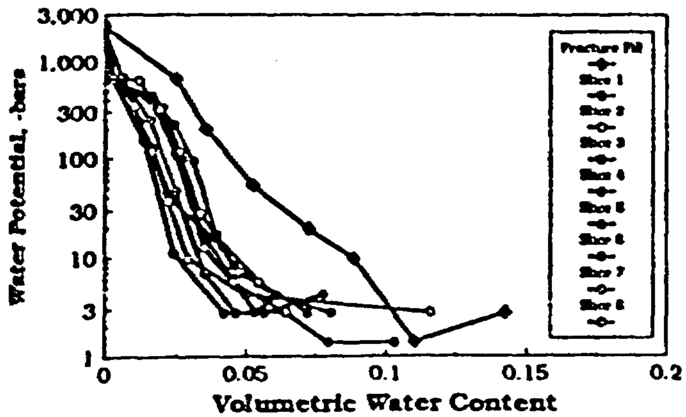
Photo: View of fractured wall of NRG-5, distant

Photo: View of fractured wall of NRG-5, midrange

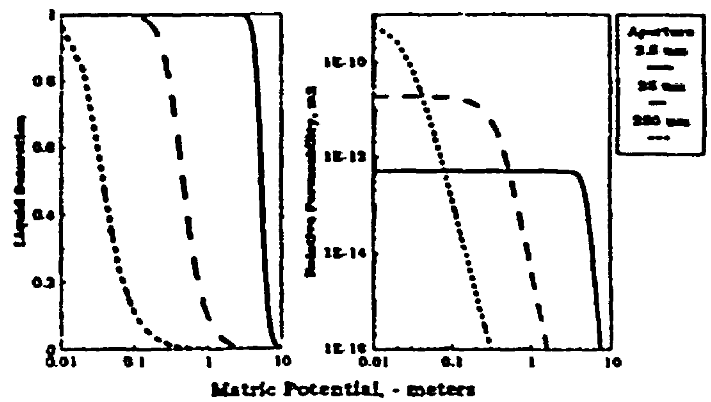
Photo: View of fractured wall of NRG-5, close-up

Photo: View of surficial fractures and fracture fill for lab analysis

Moisture Retention of Fracture Fill



Modeling Parameters for Fractures



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Water Balance

$$I = P - ET - R_{off} + R_{on} + \Delta S$$

I	Net infiltration
ΔS	Change in water content
P	Daily precipitation
ET	Evapotranspiration
R_{off}, R_{on}	Surface run-off, run-on

Photo: Neutron probe and meter in Pagany Wash

Photo: Rain gage in Pagany Wash

Photo: Bowen ratio station for the measurement of evapotranspiration in Pagany Wash

Photo: Flume located in Pagany Wash

Net infiltration is a function of unsaturated hydraulic conductivity

$$\frac{d\theta}{dt} = \frac{d}{dz}\left(K(\psi)\left(\frac{d\theta}{dz}\left(\frac{d\psi_m}{d\theta}\right) + \frac{d\psi_z}{dz}\right)\right) + U(\theta, z, t)$$

θ = water content

ψ = water potential

$K(\psi)$ = unsaturated hydraulic conductivity

$\frac{d\psi_m}{d\theta}$ = moisture characteristic curve

U = precipitation, evapotranspiration, runoff and run-on

Modeled Change in Water Content

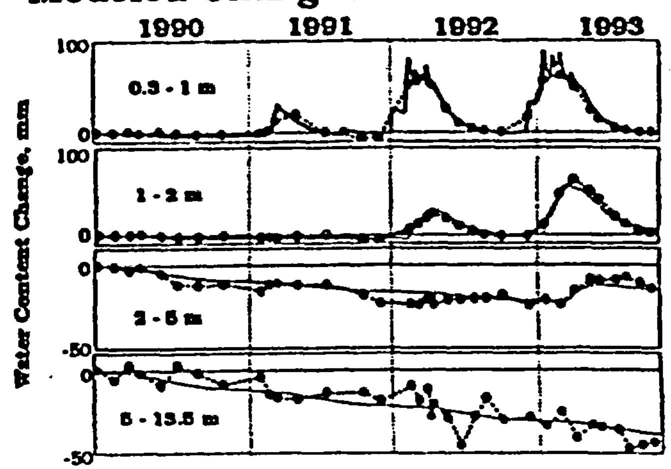

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Photo: drill rig

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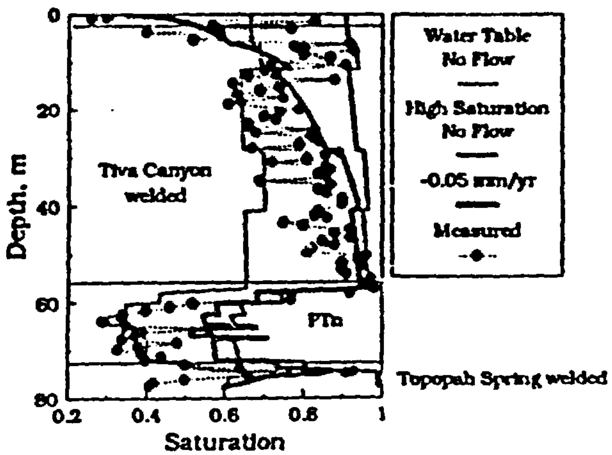
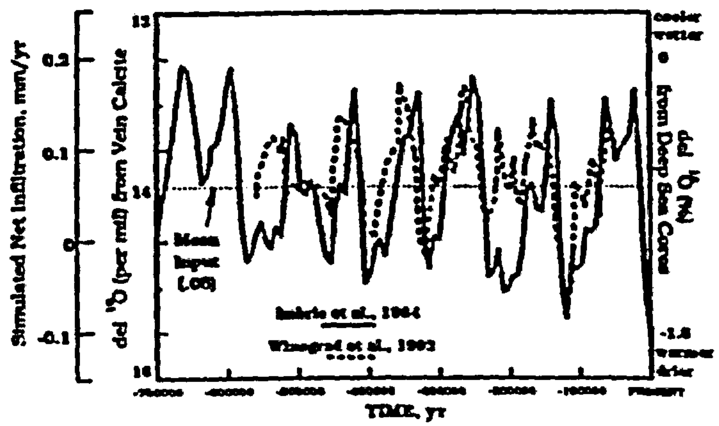
N-55 Saturations

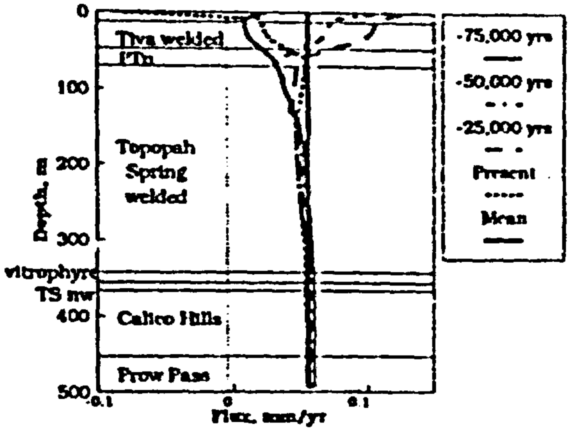


Past Climate Change

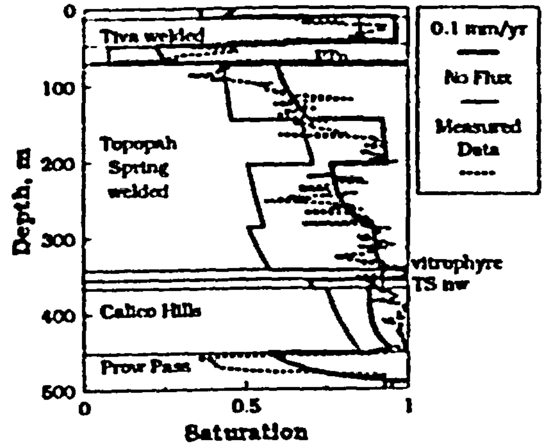


ACNW 12/14/93 81-84

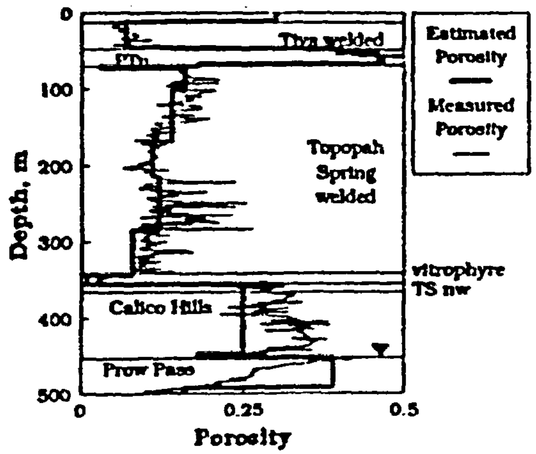
UZ16 Model



UZ16 Model



UZ16 Model



Approaches used to evaluate net infiltration

- Identify the field mechanisms contributing to net infiltration.
- Identify physical and hydrologic properties influencing net infiltration, and necessary to produce surface infiltration units on a site scale, and as input for flow models.
  - unconsolidated materials (soils)
  - consolidated materials (bedrock)
- Evaluate methods to quantify net infiltration
  - water balance: evapotranspiration, precipitation, storage
  - 1D, 2D, and 3D flow models are used to predict borehole saturations and fluxes on various time scales
- **Model surface net infiltration on a site scale under varying climatic conditions (future work).**

Summary of approaches used to evaluate the shallow unsaturated zone

- Development of a conceptual model
  - Hypotheses
  - Observations
  - Measurements
  - Numerical models
- Implementation of a measurement and modeling strategy
  - Characterize surficial materials and natural infiltration and model infiltration on a site scale
- Integration and evaluation
  - Compilation and analysis of available information (i.e. deep borehole program, geochemistry)
  - Performance assessment modeling for sensitivity analysis

KEY ISSUES ADDRESSED

(CONTINUED)

2. Could these mechanisms significantly change through future environmental modifications

   - Impacts of increased precipitation
   - Testing of scenarios
   - Importance of ongoing studies to assess climatic change over 10,000 years

KEY ISSUES ADDRESSED

(CONTINUED)

3. Passive and active approaches used to evaluate the unsaturated zone

   - Hydrologic data necessary to support complex performance assessment

4. Conceptual models considered to describe flow in the unsaturated zone

   - Data collection and testing to support models

KEY ISSUES ADDRESSED

(CONTINUED)

5. Describe interface between unsaturated zone site characterization and performance assessment

   - Integration of infiltration modeling to performance assessment
   - Data needs for performance assessment

6. Describe current results from age dating (UZ-16)

   - Support of conceptual model
   - Driver for future testing

U.S. DEPARTMENT OF ENERGY
OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT

ADVISORY COMMITTEE ON NUCLEAR WASTE (ACNW) WORKING GROUP

SUBJECT: REGULATORY ISSUES BEING ADDRESSED BY DOE/YMPO UNSATURATED ZONE STUDIES

PRESENTER: APRIL V. GIL

PRESENTER'S TITLE AND ORGANIZATION: ACTING CHIEF,
REGULATORY INTERACTIONS BRANCH
YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT

PRESENTER'S TELEPHONE NUMBER: (702) 794-7622

LAS VEGAS, NEVADA
DECEMBER 14, 1993

REPOSITORY REGULATIONS

- 40 CFR Part 191 - EPA (remanded)
- 10 CFR Part 960 - DOE (under review)
- 10 CFR Part 60 - NRC

NRC OVERALL SYSTEM PERFORMANCE REQUIREMENT

- 10 CFR 60.112
- Conformance with EPA environmental standards for radioactivity

NRC SUBSYSTEM PERFORMANCE REQUIREMENTS

- 10 CFR 60.113 (b)(2)

  The geologic repository shall be located so that the prewaste-emplacement GWTT along the fastest path of likely radionuclide travel from the disturbed zone to the accessible environment shall be at least 1,000 years or such other travel time as may be approved or specified by the commission

NRC SITING CRITERIA - FAVORABLE CONDITIONS

- 10 CFR 60.122 (a)

  Combination of favorable conditions and engineered barriers must provide reasonable assurance that performance objectives for waste isolation are met

FAVORABLE CONDITIONS RELATED TO UZ HYDROLOGY

- 10 CFR 60.122 (b)(7)

  Prewaste-emplacement groundwater travel time along fastest path of likely radionuclide travel to accessible environment substantially exceeds 1,000 years

- 10 CFR 60.122 (b)(8)

  Items specific to unsaturated zone

  - Low moisture flux
  - No fully saturated voids contiguous with water table
  - Low-permeability hydrogeologic unit above host rock
  - Host rock that provides for free drainage
  - Climatic regime in which precipitation is small percentage of potential evapotranspiration

NRC SITING CRITERIA - POTENTIALLY ADVERSE CONDITIONS

- 10 CFR 60.122 (c)

  Must be adequately investigated to determine extent to which they are present

  Impact must be assessed within context of performance objectives

POTENTIALLY ADVERSE CONDITIONS RELATED TO UZ HYDROLOGY

- 10 CFR 60.122 (c)(2)

  Potential for human activity to adversely affect groundwater flow

- 10 CFR 60.122 (c)(3)

  Potential for natural phenomena to adversely affect groundwater flow

- 10 CFR 60.122 (c)(4)

  Potential for strucutral deformation to adversely affect groundwater flow

POTENTIALLY ADVERSE CONDITIONS RELATED TO UZ HYDROLOGY

(CONTINUED)

- **10 CFR 60.122 (c)(5)**

  Potential for changes in hydrologic conditions that would affect the migration of radionuclides

- **10 CFR 60.122 (c)(6)**

  Potential for changes in hydrologic conditions from climatic changes

- **10 CFR 60.122 (c)(7)**

  Groundwater conditions in host rock that could increase the solubility or chemical reactivity of the EBS

POTENTIALLY ADVERSE CONDITIONS RELATED TO UZ HYDROLOGY

(CONTINUED)

- 10 CFR 60.122 (c)(8)

  Geochemical processes that would reduce sorption of radionuclides, degrade host rock, or adversely affect EBS

- 10 CFR 60.122 (c)(9)

  Groundwater conditions in host rock that are not reducing

- 10 CFR 60.122 (c)(20)

  Rock or groundwater conditions that would require complex engineering measures

POTENTIALLY ADVERSE CONDITIONS RELATED TO UZ HYDROLOGY

(CONTINUED)

- 10 CFR 60.122 (c)(22)

  Potential for water table to rise to repository

- 10 CFR 60.122 (c)(23)

  Potential for perched water to saturate repository or provide faster flow path to accessible environment

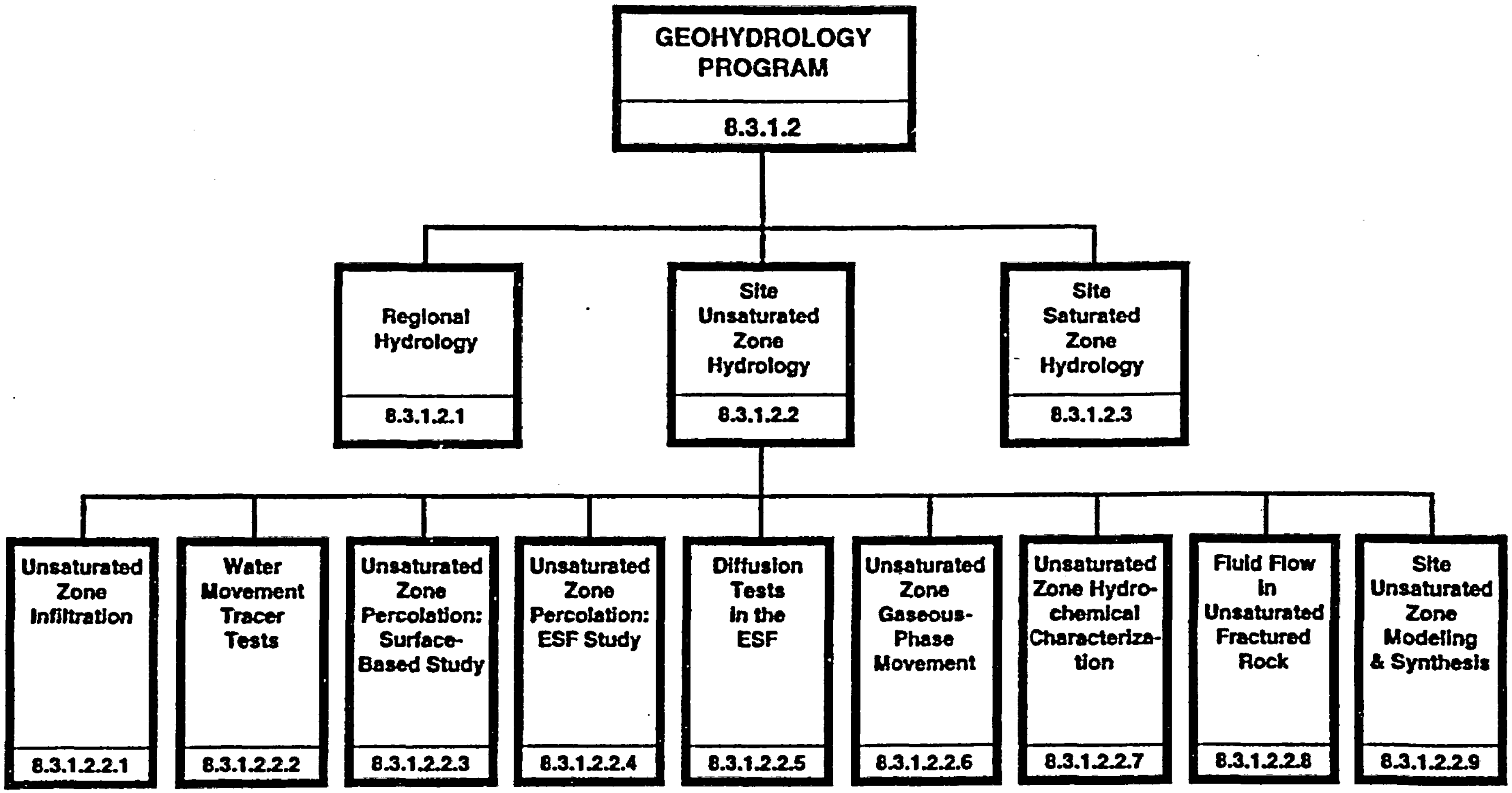
- 10 CFR 60.122 (c)(24)

  Potential for movement of gaseous radionuclides through unsaturated zone to accessible environment

EVALUATION OF ABILITY TO MEET NRC REQUIREMENTS

- Geohydrology program
  - Site investigations
  - Modeling
  - Study plans

- Annotated outline



HGIFCN5P.125.NWTRB/7-22-93

STUDY PLANS FOR FAVORABLE CONDITIONS

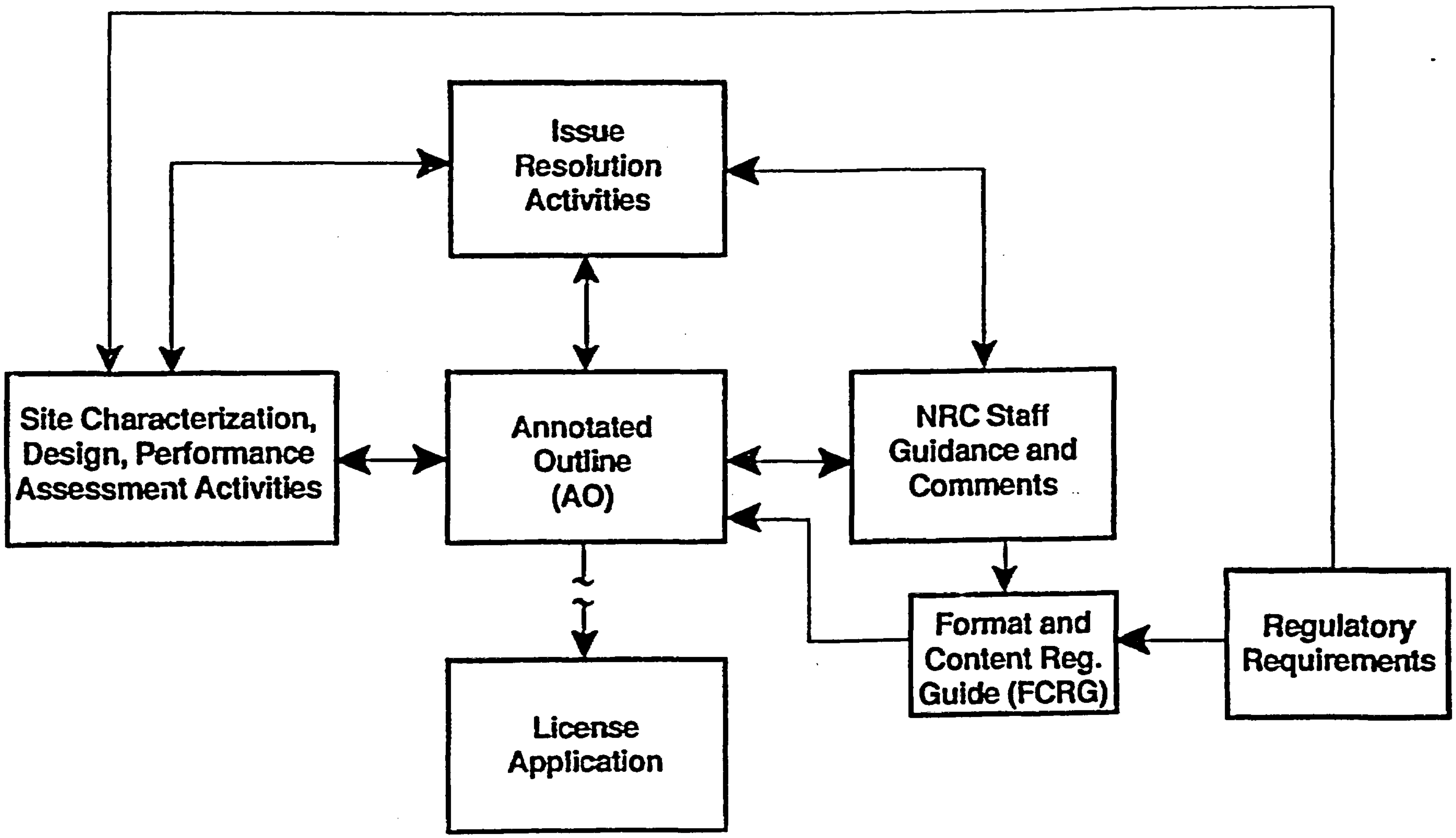
FAVORABLE CONDITIONS \ STUDY PLANS	TSPA	8.3.1.2.2.1	8.3.1.2.2.2	8.3.1.2.2.3	8.3.1.2.2.4	8.3.1.2.2.5	8.3.1.2.2.6	8.3.1.2.2.8	8.3.1.2.2.9	8.3.1.3.2.2	8.3.1.5.1.1
60.122 (b) (7)	X	X	X	X	X	X	X	X	X		
60.122 (b) (8)		X	X	X	X					X	X

STUDY PLANS FOR POTENTIALLY ADVERSE CONDITIONS

Potentially Adverse Conditions \ Study Plans	TSPA	8.3.1.2.1.2	8.3.1.2.2.1	8.3.1.2.2.2	8.3.1.2.2.3	8.3.1.2.2.4	8.3.1.2.2.7	8.3.1.2.2.8	8.3.1.2.2.9	8.3.1.3.1.1	8.3.1.3.2.1	8.3.1.3.2.2	8.3.1.3.4.1	8.3.1.3.4.2	8.3.1.3.4.3	8.3.1.3.5.1	8.3.1.3.5.2	8.3.1.3.6.1	8.3.1.3.6.2	8.3.1.3.7.1	8.3.1.4.2.2	8.3.1.5.1.6	8.3.1.5.2.2	8.3.1.8.1.1	8.3.1.8.1.2	8.3.1.8.3.1	8.3.1.8.3.2	8.3.1.8.3.3	8.3.1.9.3.2	8.3.1.17.4.6	8.3.1.17.4.7	8.3.1.17.4.12	8.3.4.2.4.5
60.122(c)(2)	X																																
60.122(c)(3)		X																					X	X	X					X	X	X	
60.122(c)(4)	X																									X	X	X					
60.122(c)(5)	X																						X						X				
60.122(c)(6)	X																					X	X										
60.122(c)(7)										X	X	X	X	X	X	X	X	X	X	X													
60.122(c)(8)							X																										X
60.122(c)(9)							X																										
60.122(c)(20)			X		X	X															X												
60.122(c)(22)									X																								
60.122(c)(23)			X	X	X	X		X	X																								
60.122(c)(24)	X																																

FAVCNSP.125 2/12-13-93

ANNOTATED OUTLINE PROCESS



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CONCLUSION

Evaluation of ability to meet NRC requirements

- Geohydrology Program
  - Site Invesitgations
  - Modeling
  - Study Plans

- Annotated Outline Process

U.S. DEPARTMENT OF ENERGY
OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT

ADVISORY COMMITTEE ON NUCLEAR WASTE (ACNW) WORKING GROUP

SUBJECT: UNSATURATED ZONE PROGRAM OVERVIEW

PRESENTER: JOSEPH J. DLUGOSZ

PRESENTER'S TITLE AND ORGANIZATION:
REGULATORY AND SITE EVALUATION DIVISION
YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT

PRESENTER'S TELEPHONE NUMBER: (702) 794-5102

LAS VEGAS, NEVADA
DECEMBER 14, 1993

PURPOSE OF MEETING

- Examine current understanding of matrix and fracture flow in the unsaturated zone
- Address concerns raised by the state of Nevada and the NRC regarding characterization and conceptual and numerical models

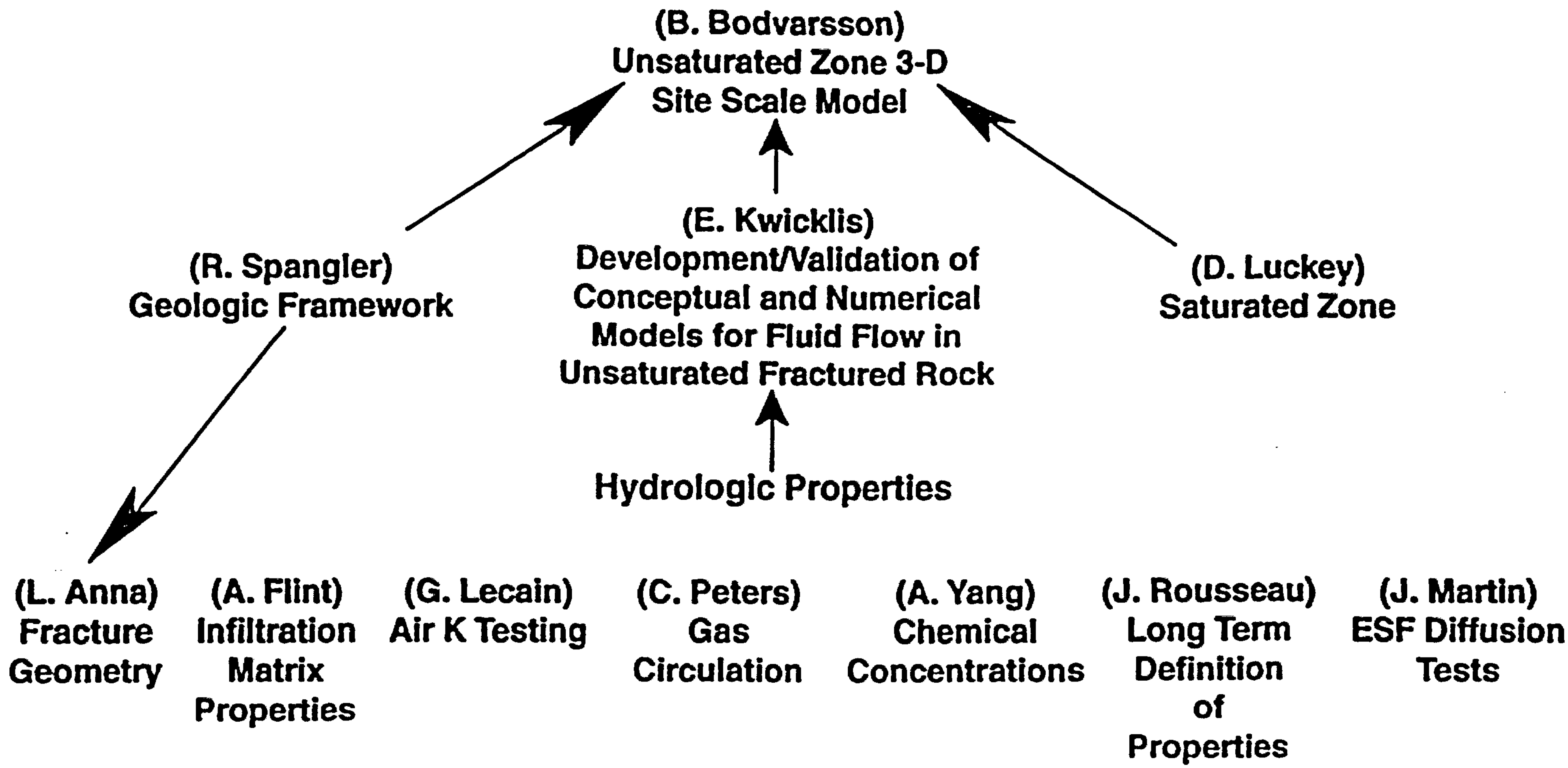
KEY ISSUES TO BE ADDRESSED

- Mechanisms for infiltration in the unsaturated zone
- Could these mechanisms change in the future due to environmental modifications
- Passive and active field tests
- What are the current conceptual models considered
- What are the interfaces between site characterization and performance assessment modeling
- What are current results for groundwater age dating

MAJOR POINTS

- A large part of the hydrology program is directed to the unsaturated zone
- UZ program is an integrated and well coordinated effort
- Success is dependent on the sampling and testing systems utilized in the field

UNSATURATED ZONE PROGRAM
(CHORNACK/DLUGOSZ)



MATRIXFRA5.126/12-14-93

U.S. DEPARTMENT OF ENERGY
OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT

ADVISORY COMMITTEE ON NUCLEAR WASTE (ACNW) WORKING GROUP

SUBJECT: OVERVIEW OF KEY ISSUES

PRESENTER: JOSEPH J. DLUGOSZ

PRESENTER'S TITLE AND ORGANIZATION:
REGULATORY AND SITE EVALUATION DIVISION
YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT

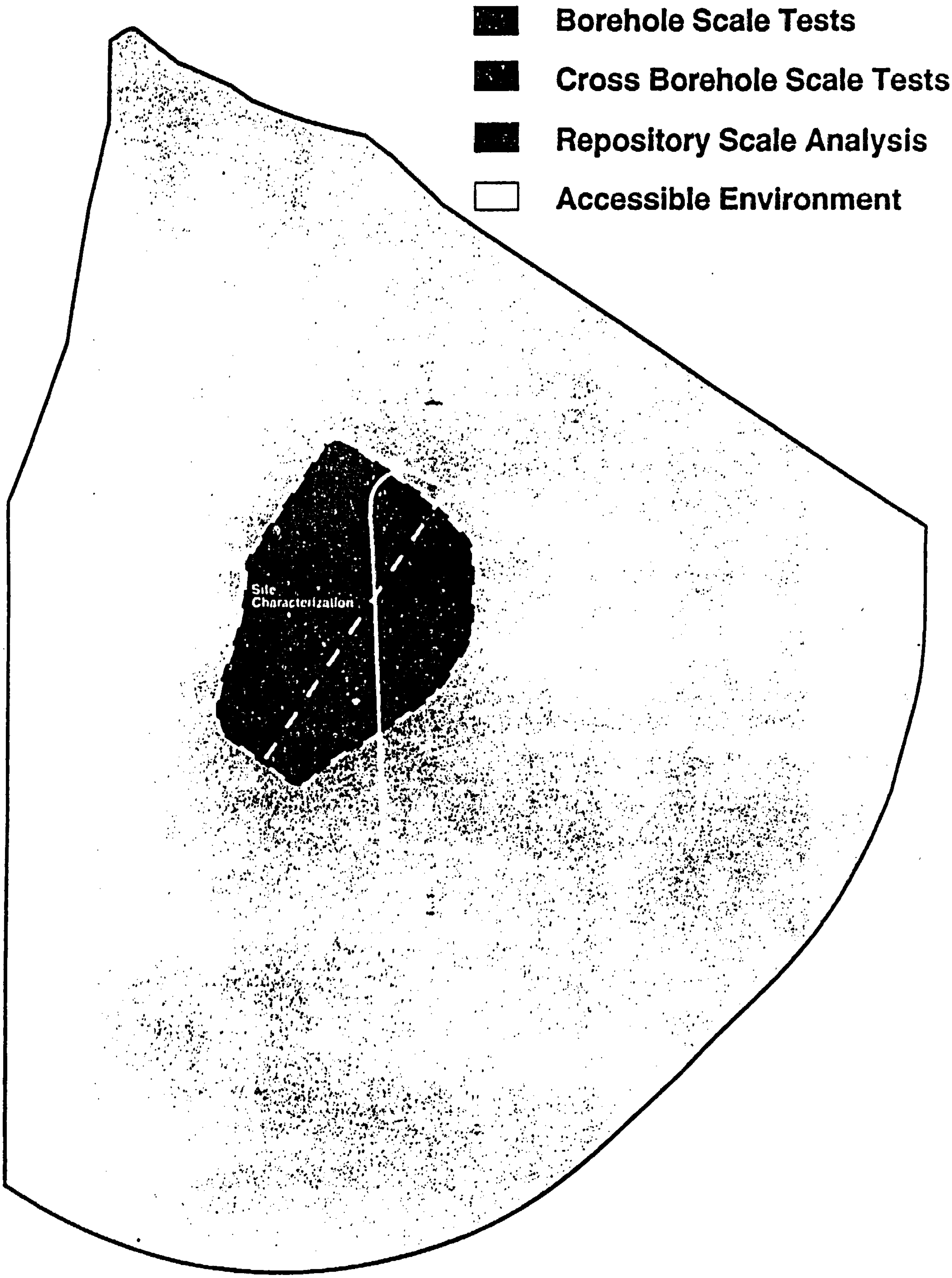
PRESENTER'S TELEPHONE NUMBER: (702) 794-5102

LAS VEGAS, NEVADA
DECEMBER 14, 1993

KEY ISSUES ADDRESSED

1. Mechanisms for infiltration and relationship to site performance

    - Relationship between precipitation, infiltration, percolation and recharge
    - Status of studies to interpret relationships
    - Existing uncertainties in infiltration and unsaturated zone flow



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FRACTURE GEOMETRICS

NECESSARY INFORMATION	SOURCE
1. Fracture radius distribution	ESF, pavements
2. Facture orientation distribution	ESF., pavements, wells, RS (soft data)
3. Fracture intensity	Wells, scanlines
4. Unit thickness f(characteristics)	To be determined
5. Understanding of relations between aperture, T, relative K, saturation, boundary conditions	Exper., test, modeling
6. Relation of 1-4 to lithology (density, welding, etc.)	Wells, boreholes (core)
7. Spatial variance over site/region	Relate to lithology (stochastic) RS (soft data)
8. Spatial variance and fracture boundaries	Mapping "pavements" scanlines

MATRIXFRA6.126/12-14-93

SCA COMMENT 123
JULY 31, 1989

- Comment paraphrased: Effects of ventilation of exploratory shafts and underground testing rooms may have been underestimated in evaluation of:
  - Potential interference with acquiring licensing data
  - Potential irreversible changes to baseline site condition
  - Ability of the site to isolate waste

- Recommendation: "At an early date, but before construction of the ESF is begun, DOE should provide an analysis of effects of ESF ventilation on adjacent rock, including both liquid and gas flows"

SCA COMMENT 123 INITIAL RESPONSE, CURRENT EVALUATION, AND STATUS

- Initial response
  - "Effects of ventilation of drying front is likely underestimated" is incorrect, because shaft will be lined with concrete (December 14, 1990)
- Current evaluation
  - Initial response not applicable under current design of using ramps and limited shotcrete linings
  - Secondary effects on baseline conditions (e.g., geochemistry) and effect on waste isolation under consideration
- Status
  - Comment remains open
  - Technical input and requirements to close comment undergoing by DOE

STATE OF NEVADA (JOHNSON) LETTER TO NRC (YOUNGBLOOD) FEBRUARY 4, 1993

Concern

- Continued priority assigned to early excavation of ESF
- Lack of predisturbance pneumatic database
- Suggests current schedule may prevent adequate characterization to support performance assessments and regulatory determinations
- Recommends tunneling delay to allow carefully designed surface-based testing program, with specific mention of pneumatic conductivity of bedded zone

STATE OF NEVADA (JOHNSON) LETTER TO NRC (YOUNGBLOOD) FEBRUARY 4, 1993

(CONTINUED)

Response

- Schedules for surface-based testing and ESF construction are under review to ensure pre-disturbance pneumatic data is obtained

- Enhanced surface-based data acquisition underway

- Study plans are being modified to respond to NRC and State of Nevada concerns

QUESTION 1, NRC REVIEW OF PROGRESS REPORTS 6 AND 7 MAY 5, 1993

- NRC comment
  - "What evaluation has DOE made of the potential for air movement from the ESF to adversely impact the collection of geochemical data necessary for site characterization?"
- NRC recommendation
  - In a timely manner, consider effect of air movement from ESF on surface-based geochemical tests
  - If anticipated to be significant, collect data before it can be compromised
- Status
  - Under evaluation by DOE
  - USGS reviewing testing program based on proposed revision to ESF

TECHNICAL RECOMMENDATIONS FROM USGS

- Establish baseline conditions in unsaturated zone:
  - Implement before disturbance by ESF construction (complete testing; monitor several months)
  - Monitor during construction and operation

- Implement additional testing program before disturbance

TECHNICAL RECOMMENDATIONS FROM USGS

(CONTINUED)

- Accelerate test program
  - To baseline conditions within or close to repository but away from construction

- Develop and implement similar test program along alignment of proposed ESF excavation

TECHNICAL RECOMMENDATIONS FROM USGS

(CONTINUED)

- Improve analytical models to simulate multi-phase flow under realistic stratigraphic, structural, and boundary conditions
- To predict effects of ESF construction on flow in the unsaturated zone

Effects of Alternative Conceptual Models and Modeling Assumptions on Performance Assessments

By

Linda Lehman & Tim P. Brown
L. Lehman & Associates, Inc.

State of Nevada Funded Research

1. Model assumptions which impact performance assessment.

2. Affect of alternative conceptual models on flux.

3. Need for an analysis of bias and a fair evaluation of alternative conceptual models.

Model Concepts and Assumptions

1. Matrix vs. fracture flow.

2. Dimensionality.

3. Distribution and amounts of infiltration.

4. Equilibrium assumptions:

    - matrix fracture interactions
    - water table
    - infiltration - transient vs. steady-state.

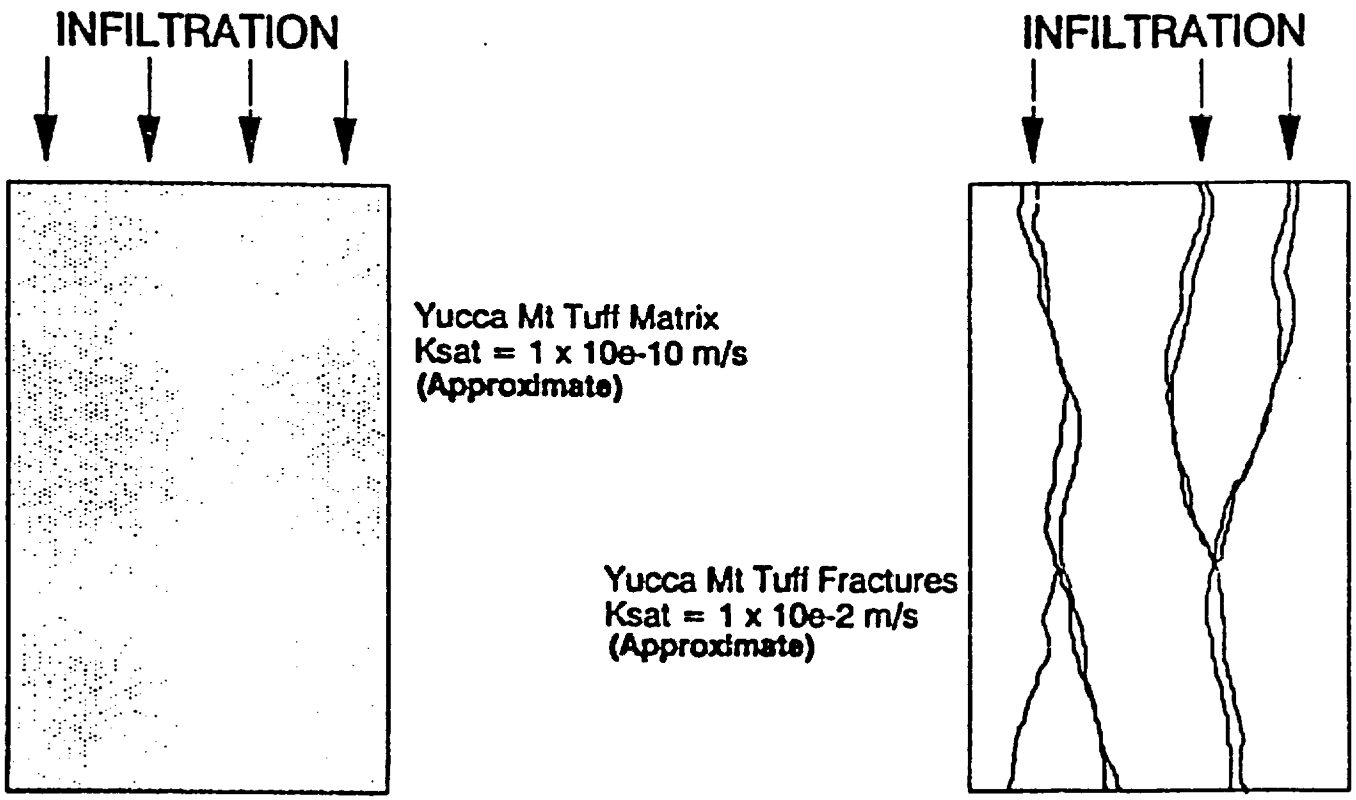
5. Boundary conditions:

    - no flow
    - wet vs. dry fractures.

6. Parameter models (modeled vs. measured):

    - infiltration
    - conductivity
    - water retention properties
    - porosity.

Matrix Versus Fracture Flow

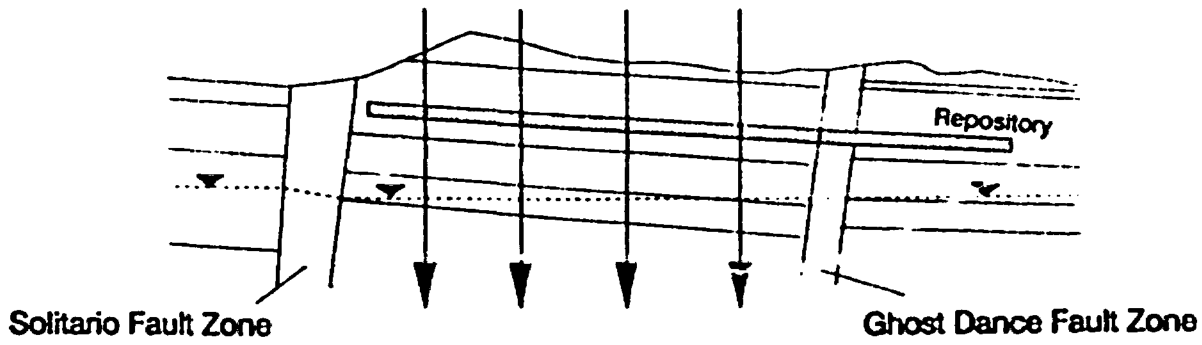


Relatively slow transport

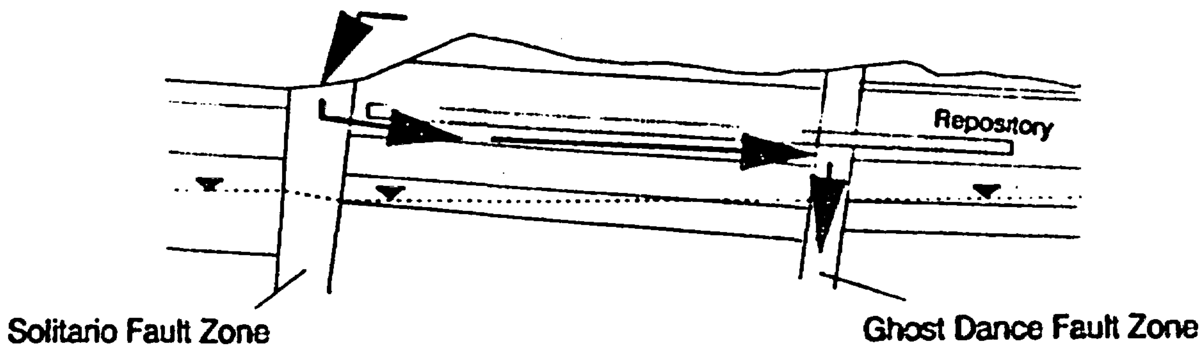
Relatively rapid transport

Dimensionality

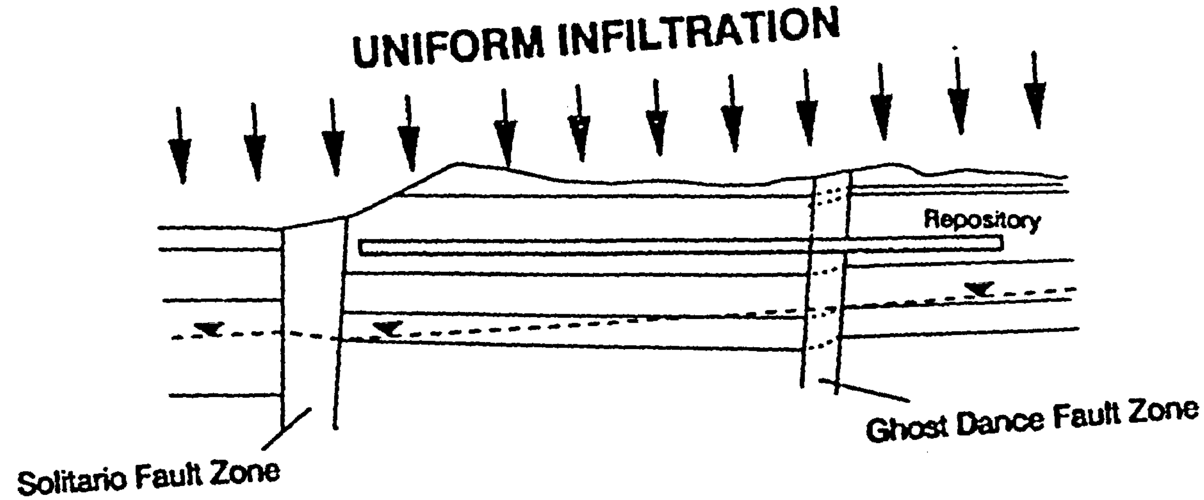
SIMPLE 1-D VERTICAL FLOW

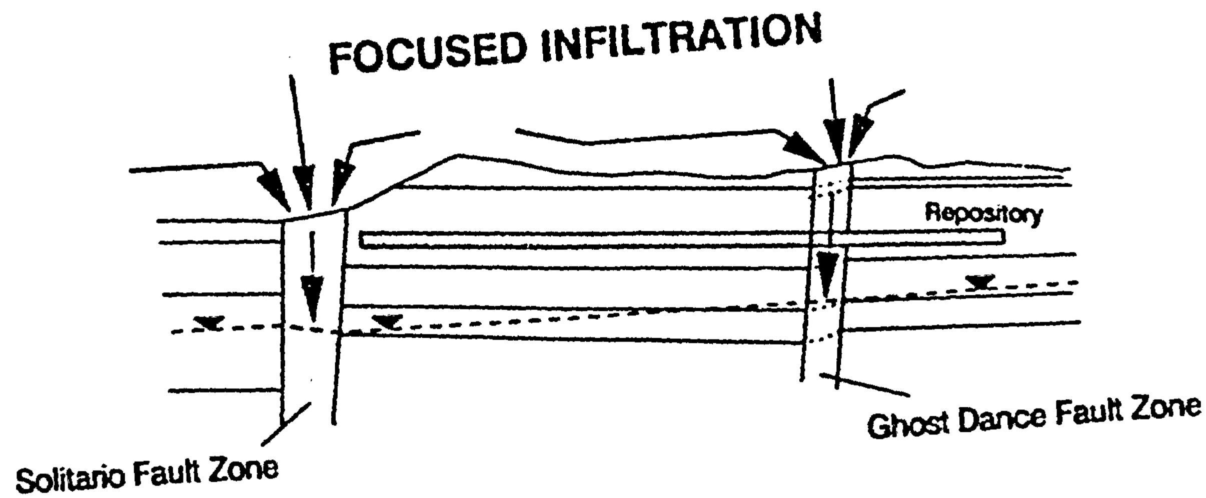


2-D VERTICAL AND HORIZONTAL FLOW

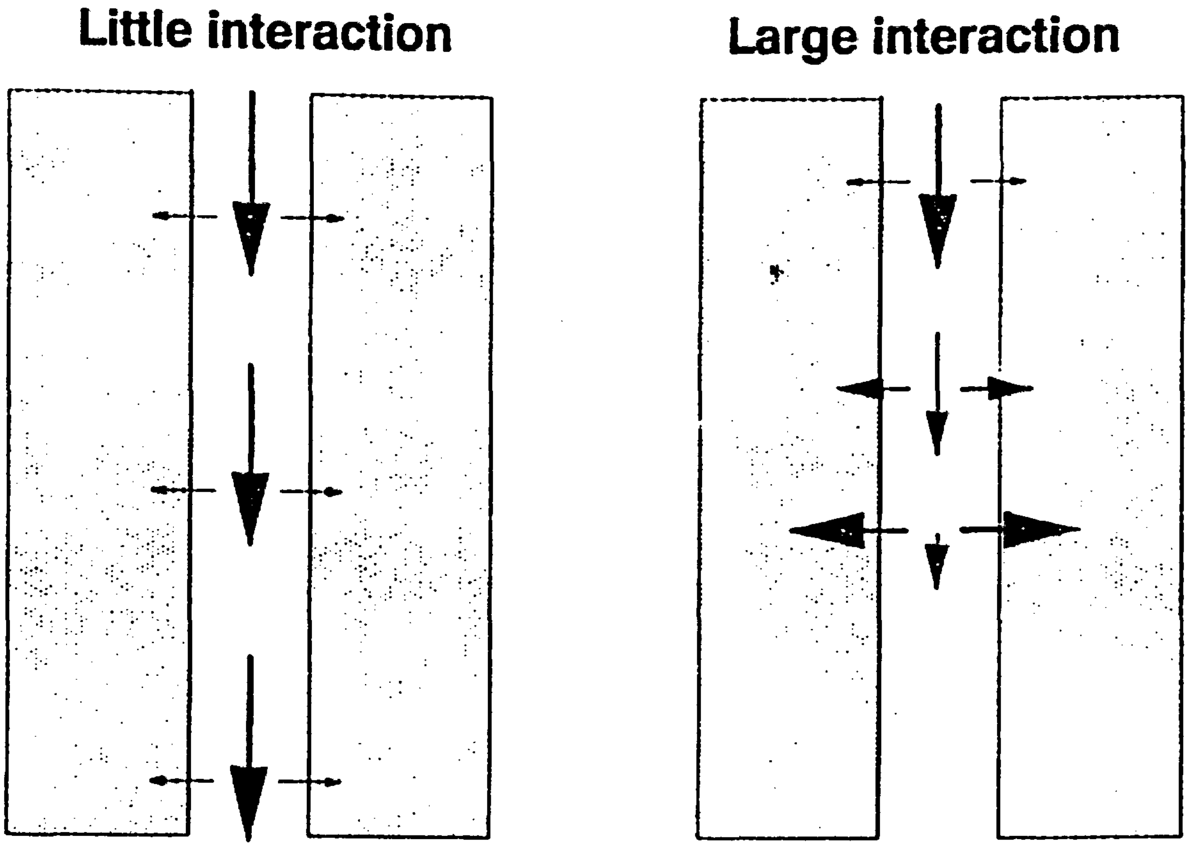


Distribution and Amount of Infiltration



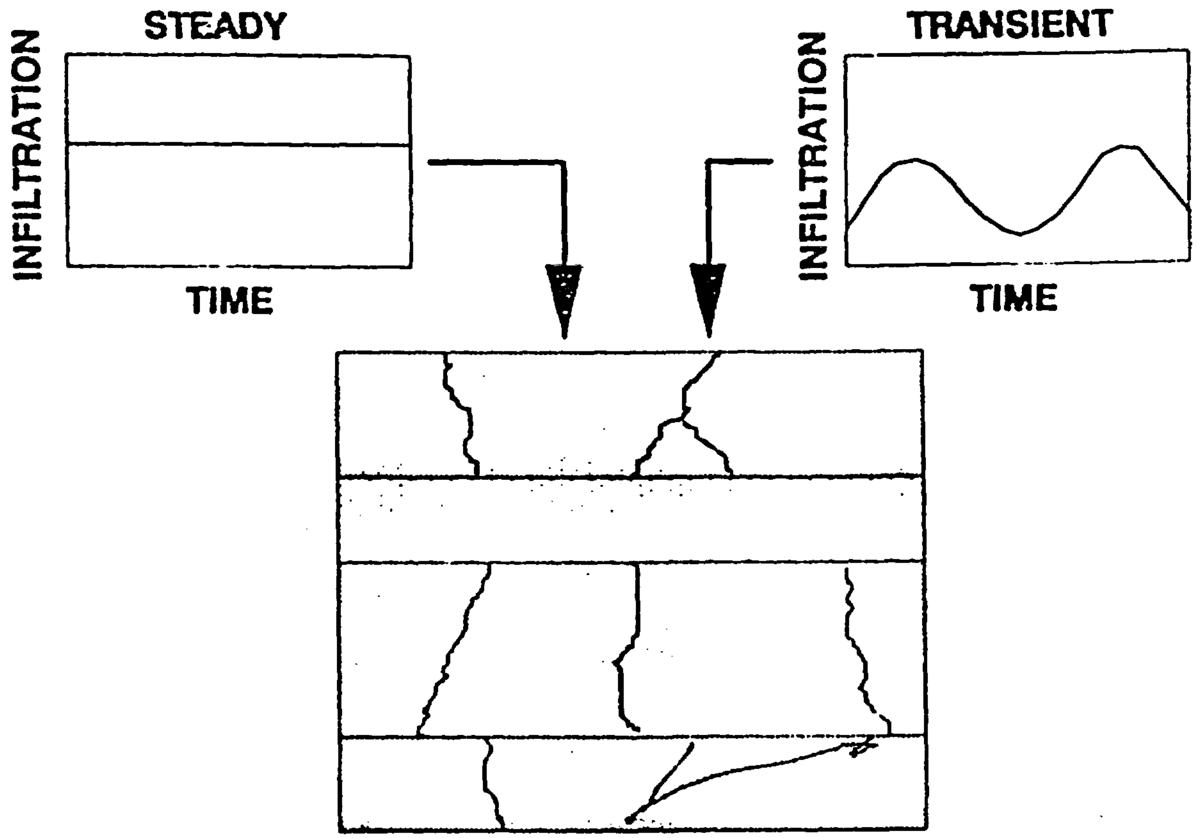


Matrix/Fracture Interaction



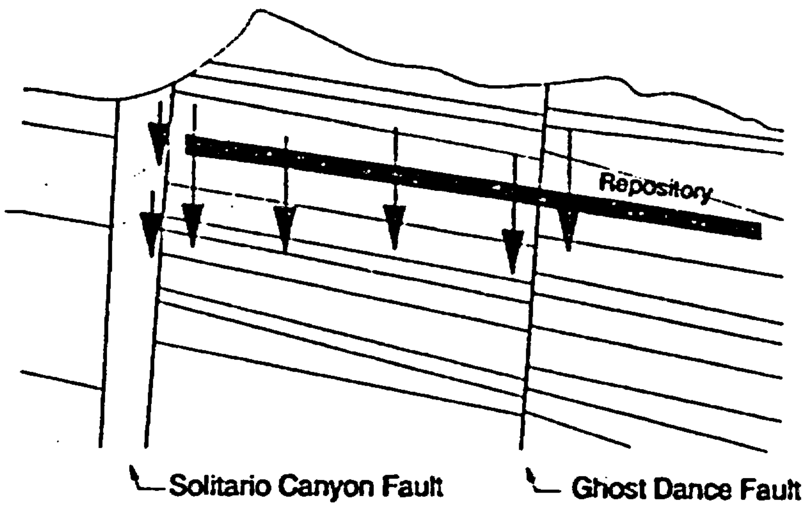
Controlled by pressures, conductivity of matrix and fractures time spent in fracture, fracture coatings, and infiltration assumptions, i.e. steady or transient

Infiltration - Transient Versus Steady

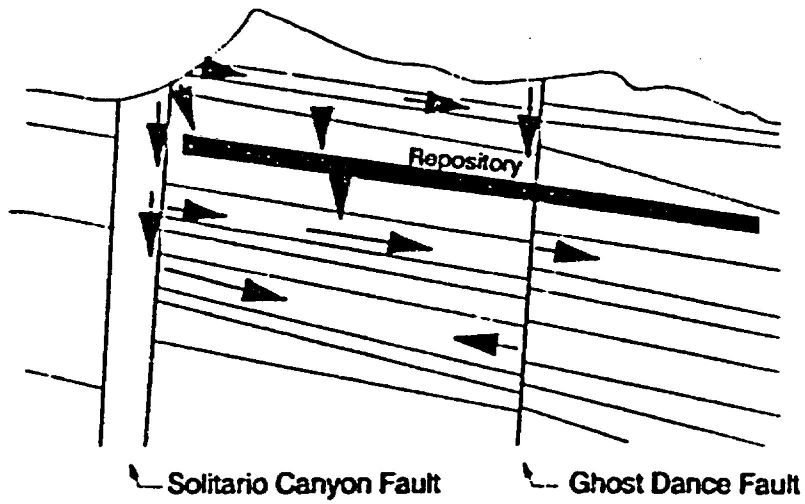


Boundary Conditions at Faults

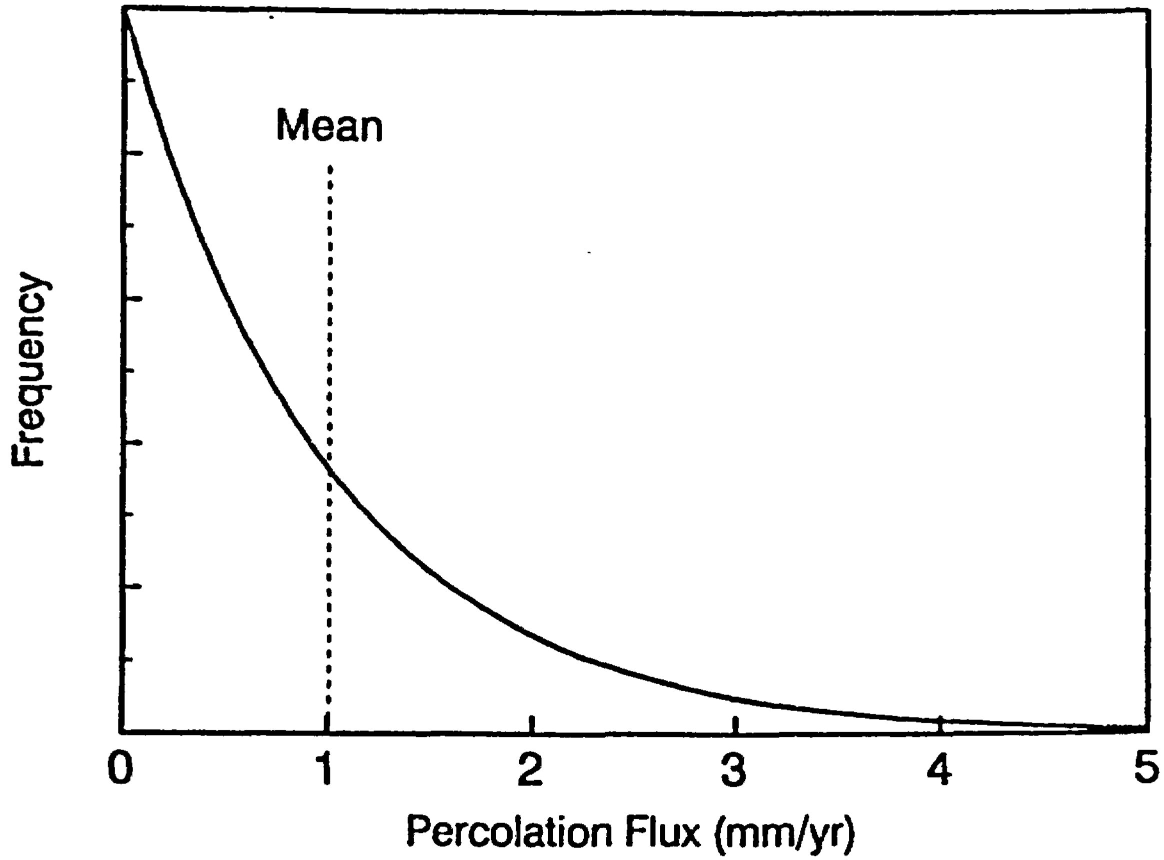
No-Flow



Specified Flux or Pressure



Model of Infiltration Magnitude used in TSPA 1991*



* Sandia National Laboratory Report # SAND91-2745, 1992

Conceptual model error can be very large.

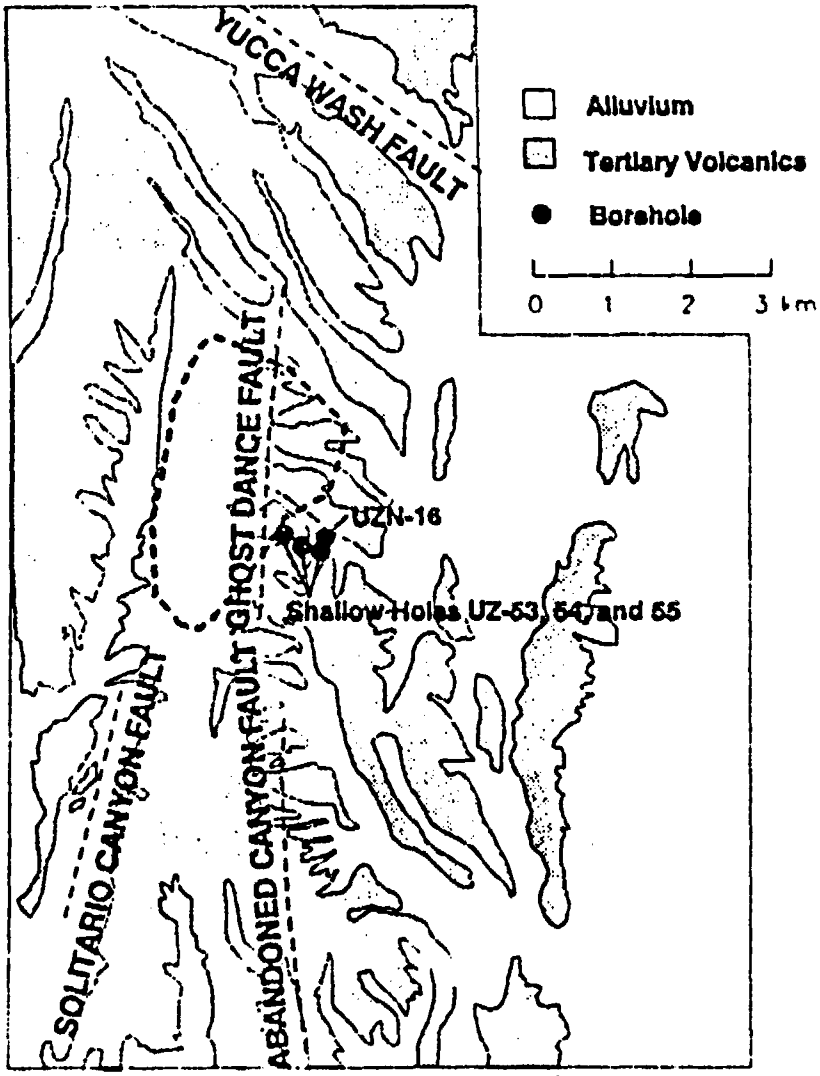
INTRAVAL Unsaturated Zone Working Group

Yucca Mountain Excercise Definition:

1. Calibrate models against water content profiles measured in shallow boreholes (100-120 meters deep) UZN-53, UZN-54, and UZN-55.

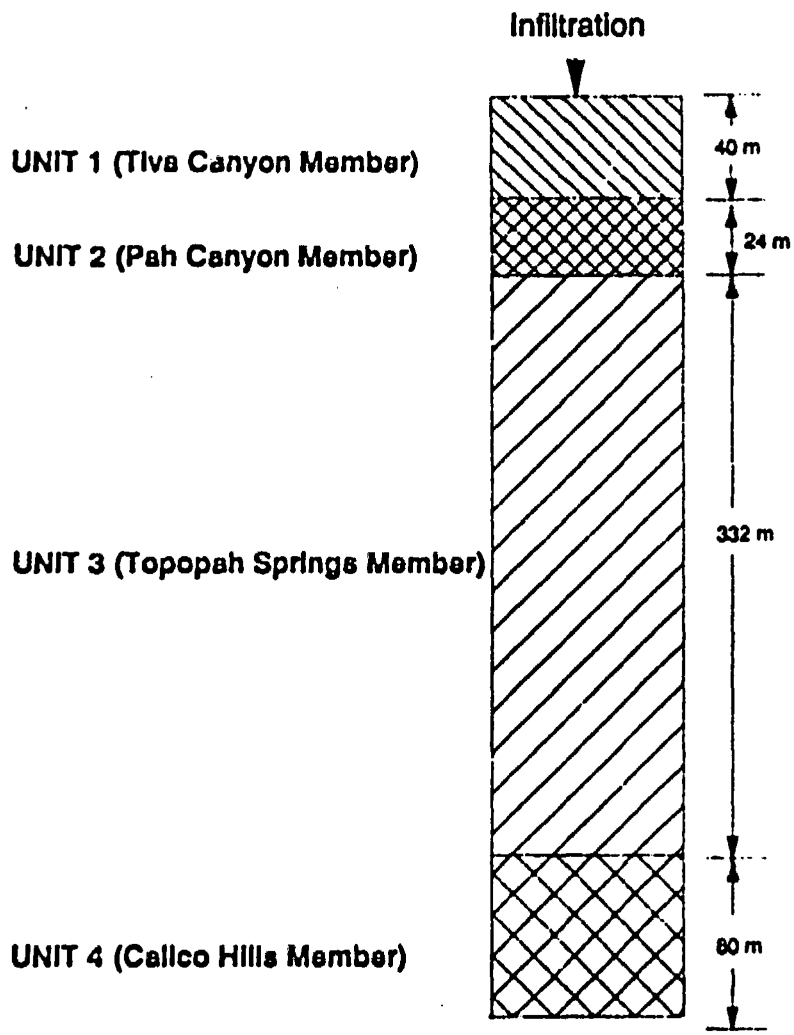
2. Perform a blind prediction of the water content profile in borehole UZ-16 using the calibrated models.

Location of Boreholes Used for Modeling Study

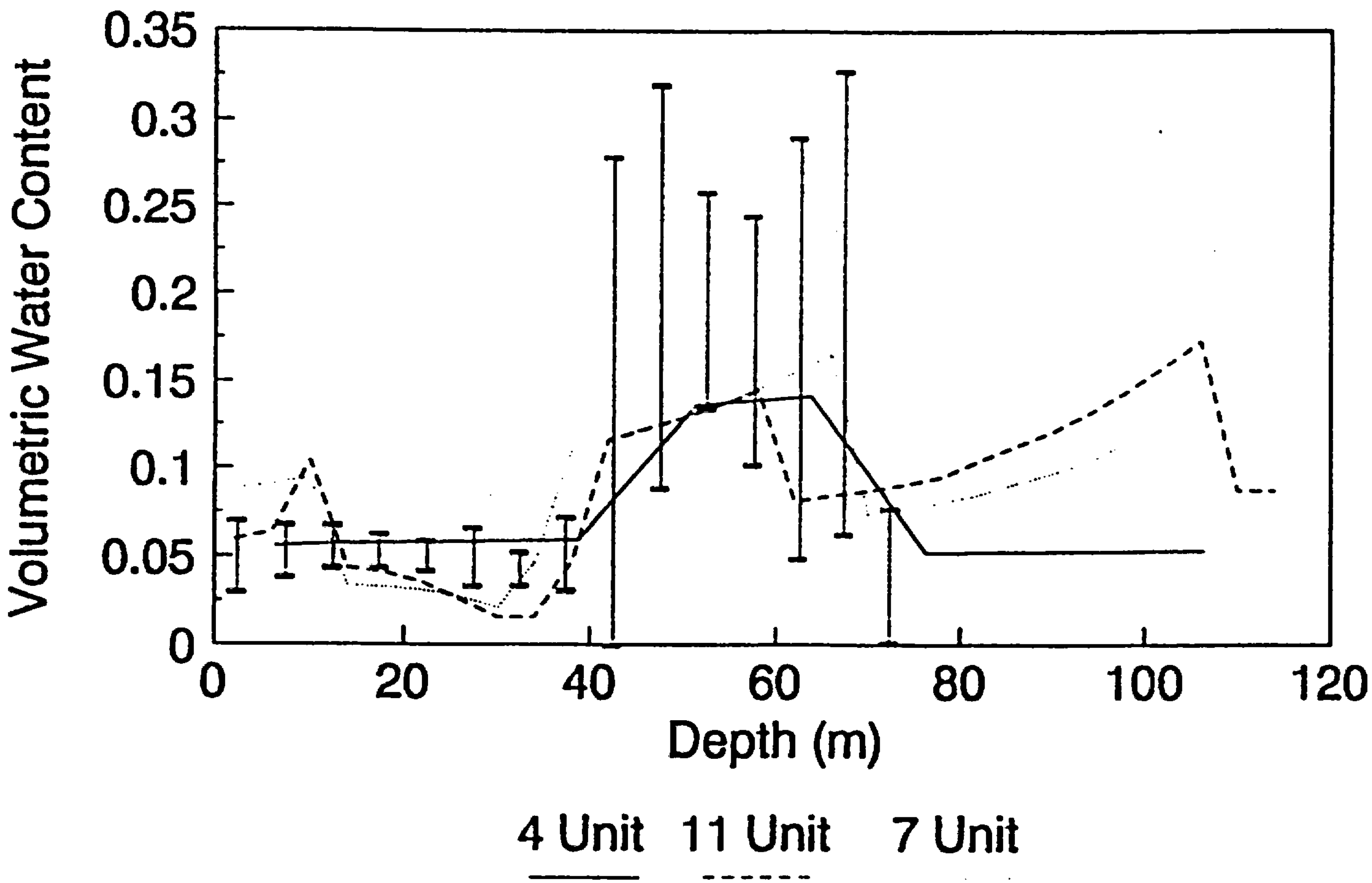


L. Lehman & Associates, Inc.
1993

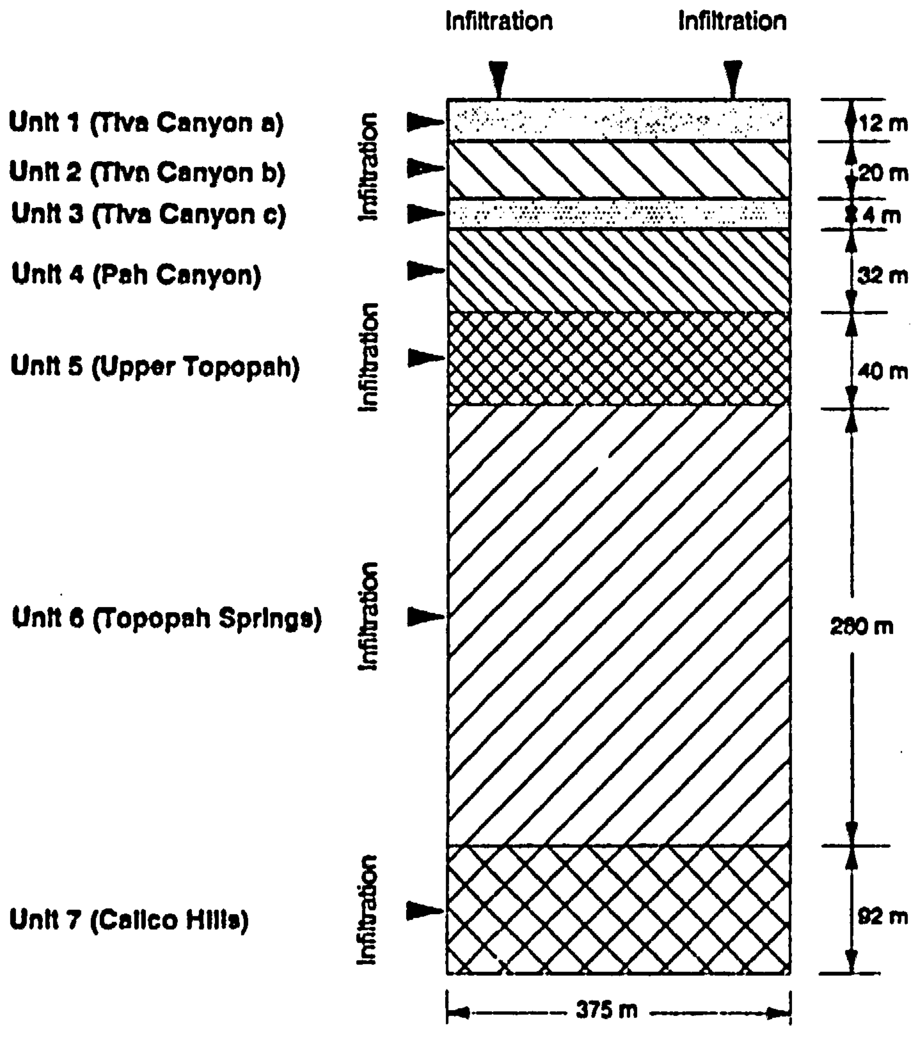
Schematic drawing of 4 Unit 1-Dimensional Model



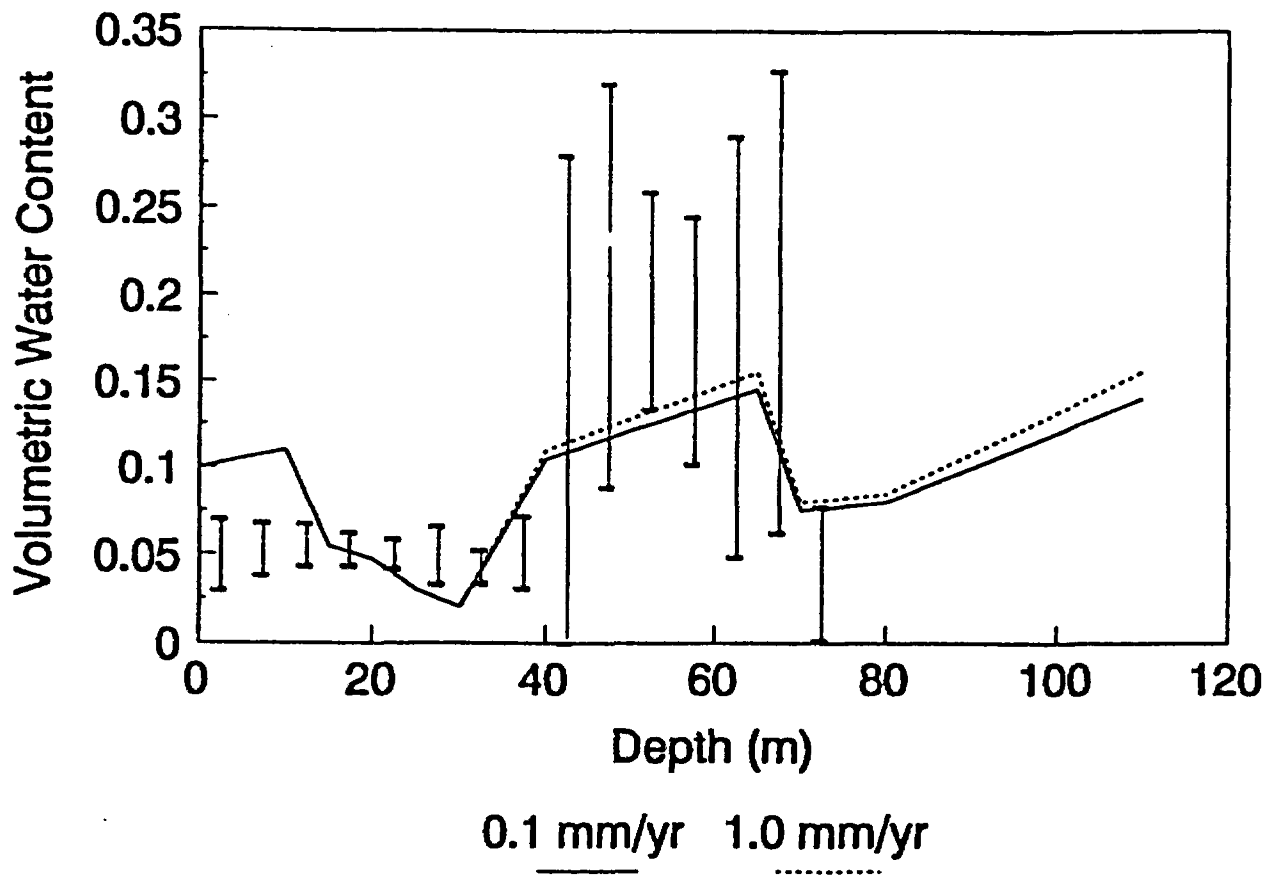
Comparison of 1-Dimensional Simulations with Hole Data



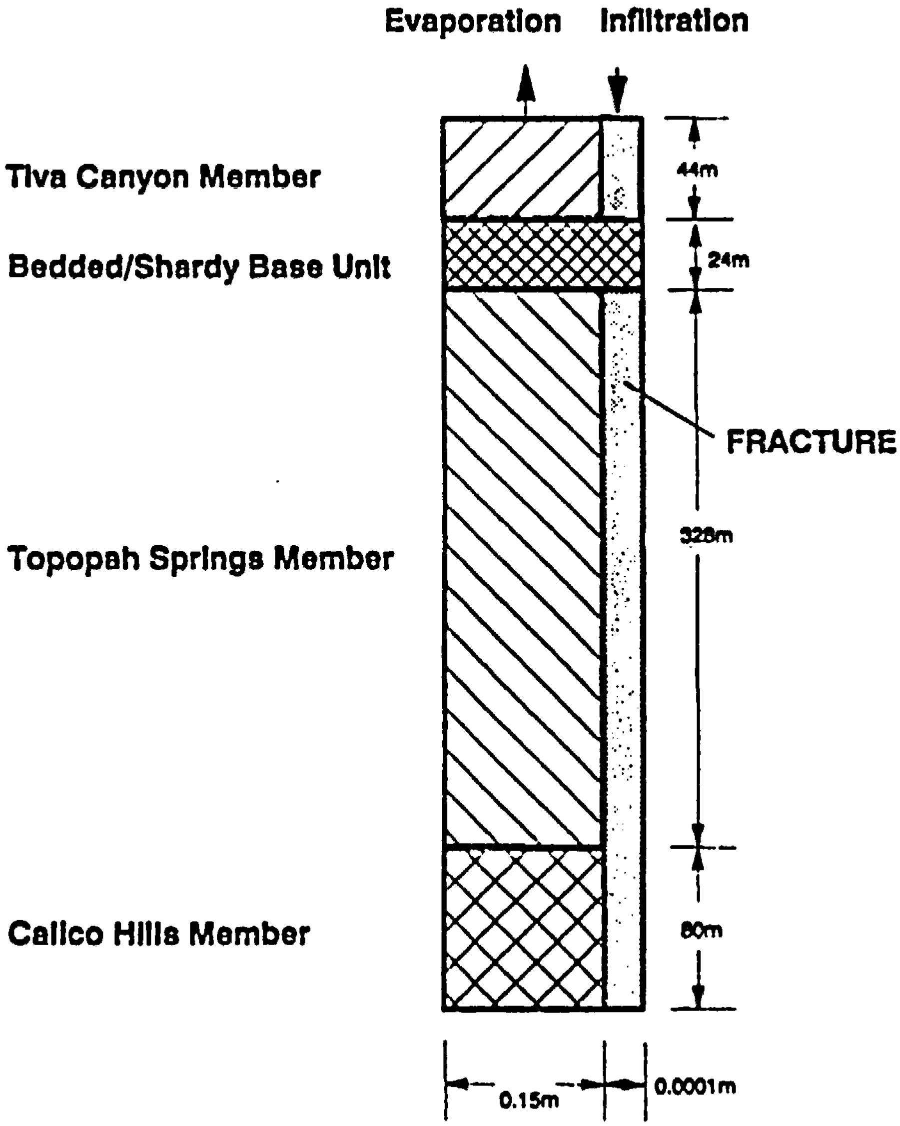
Schematic drawing of 7 Unit 2-Dimensional Model



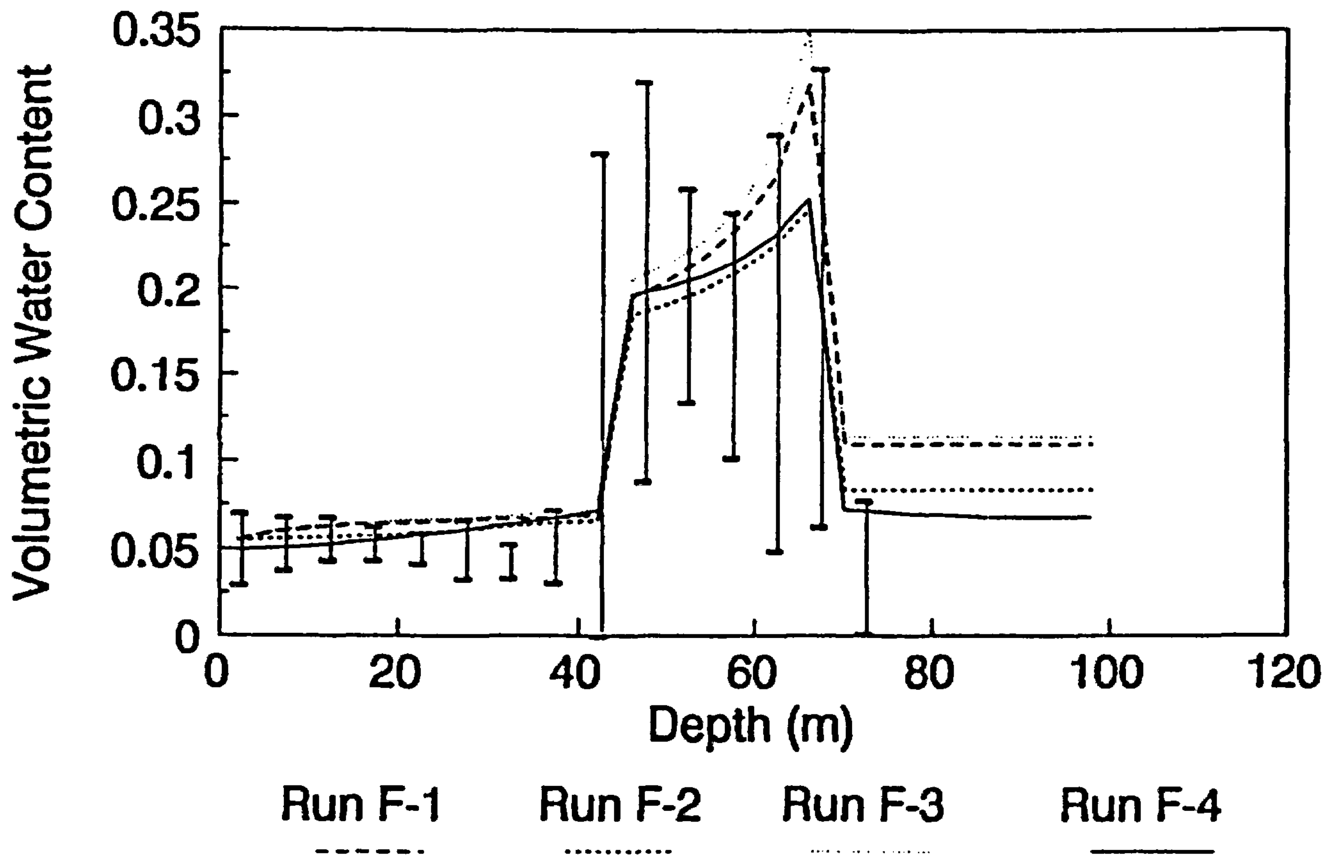
Comparison of 2-Dimensional Simulations with Hole Data



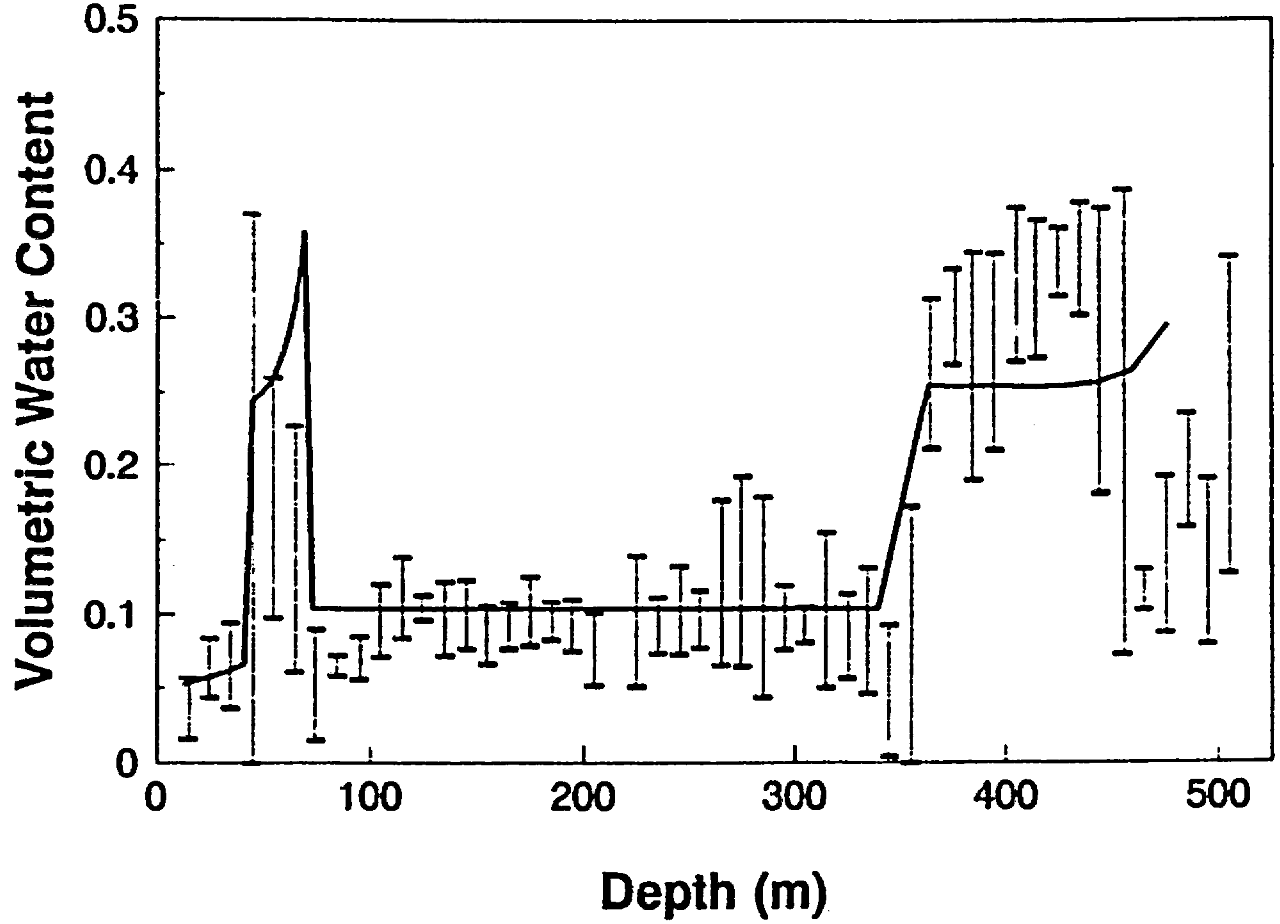
Schematic of fracture model geometry

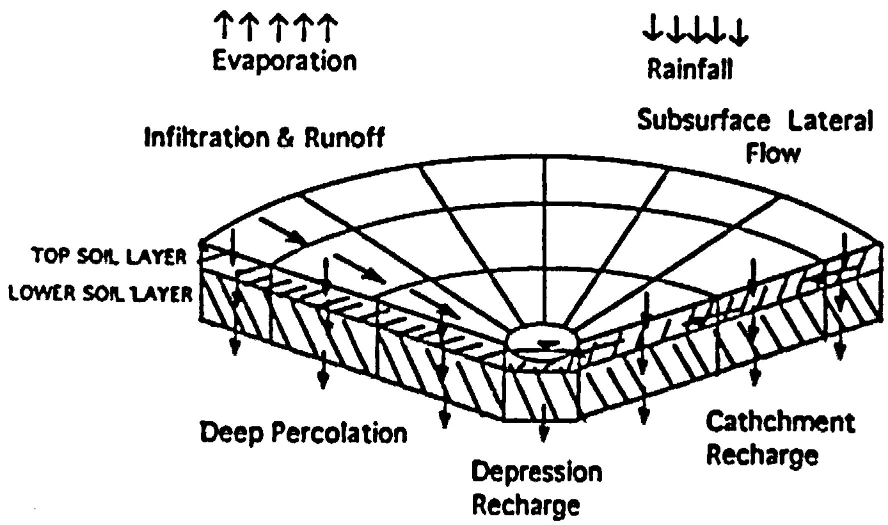


Comparison of Fracture Model Simulations with Hole Data

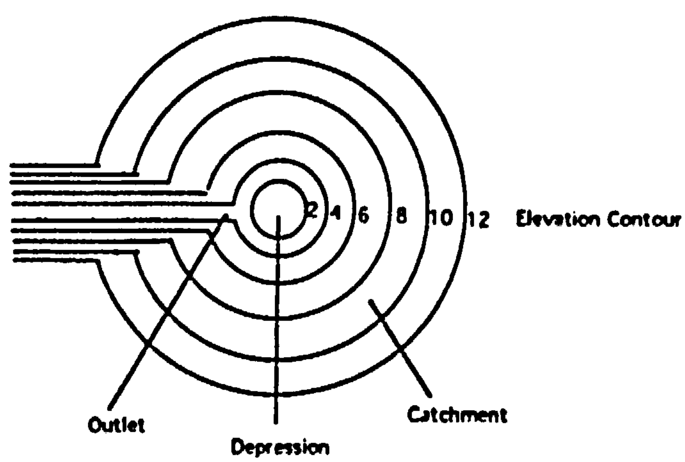


Comparison of fracture model predicted water content compared with UZN-16 data 95% confidence intervals





Evaporation
Rainfall
Infiltration & Runoff
Subsurface Lateral Flow
TOP SOIL LAYER
LOWER SOIL LAYER
Deep Percolation
Depression Recharge
Cathchment Recharge



2
4
6
8
10
12
Elevation Contour
Outlet
Depression
Catchment

A validation process should:

1. Examine potential sources of bias.

2. Utilize "confirmatory" and "consistency" type data.

3. Iterative and build confidence over time.

Confirmatory data - parameters that are capable of confirming or refuting a given flow field concept.

Consistency data - supporting data that could be examined for consistency with the chosen conceptual model.

Only the model which agrees with the confirmatory data <u>and</u> is most consistent with all other information should be preferred or validated.

Conclusions

1. Choice of alternative conceptual model has a large impact on certain parameters.

2. A methodology must be developed for fair treatment of alternative conceptual models.

3. An analysis of bias must be conducted on the way these alternative concepts are treated in the performance assessment.

Fracture and Matrix Flow in the Vadose Zone at Yucca Mountain

by
M. D. Mifflin
Mifflin and Associates, Inc.
Representing:
State of Nevada and Nye County, Nevada

Presented to:

Nuclear Regulatory Commission
Advisory Committee on Nuclear Waste

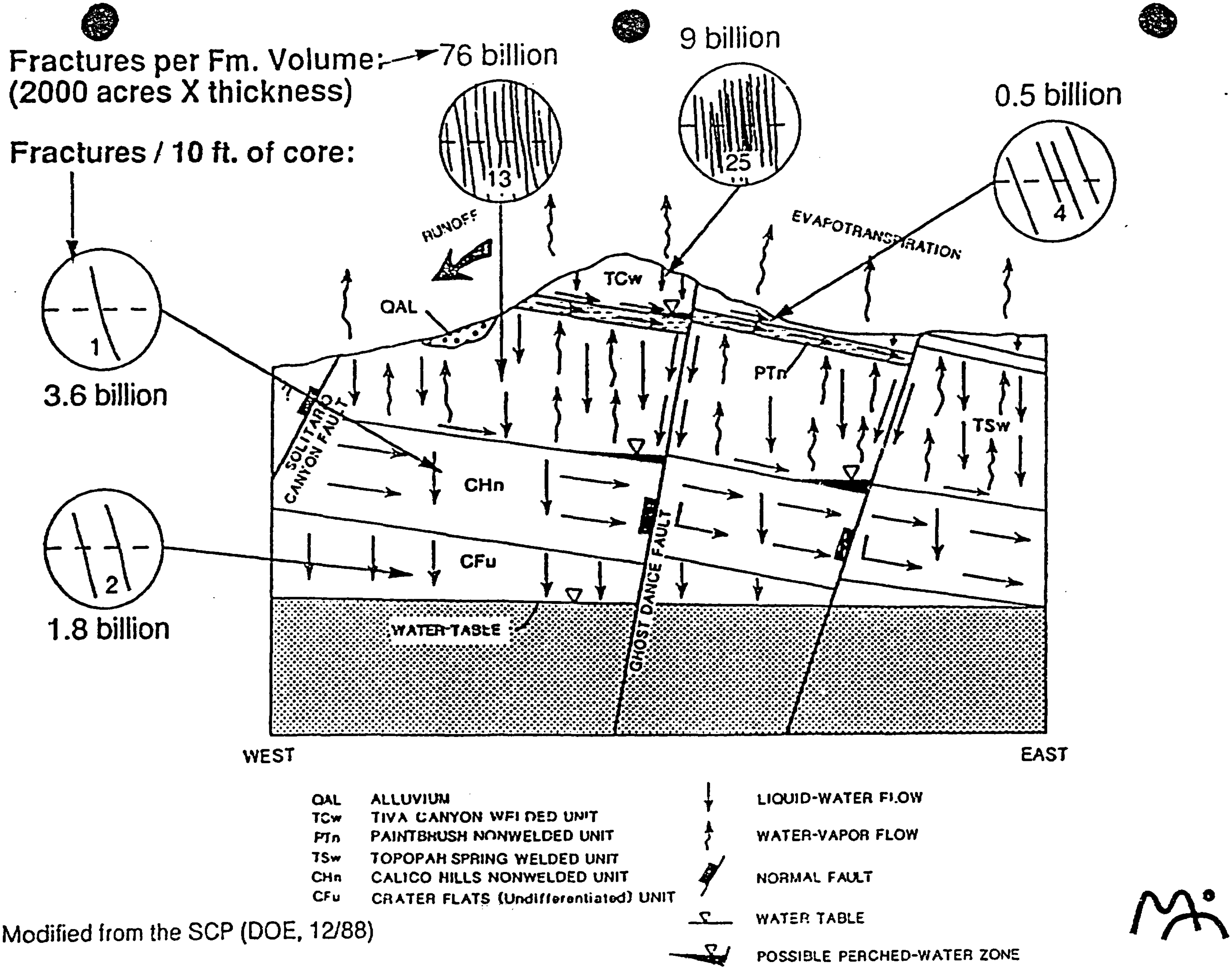
Working Group Meeting

December 14, 1993
St. Tropez Hotel
Las Vegas, Nevada

SUMMARY OF PRESENTATION

- **Introduce the importance of fracture flow and the conditions under which it would occur.**

- **Discuss loading scenarios and climate conditions under which fracture flow should be expected.**



Modified from the SCP (DOE, 12/88)

Properties of Hydrogeologic Units Within the Unsaturated Zone*

Yucca Mountain, Nevada

Hydrogeologic Unit	Thickness Range, m	Porosity	Saturated Hydraulic Conductivity mm/yr	Saturation (percent)
Tiva Canyon welded	0 - 150	0.12	0.73	67
Paintbrush nonwelded	20 - 100	0.46	3285	61
Topopah Spring welded	290 - 360	0.14	1.10	65
Calico Hills nonwelded (vitric)	100 - 400	0.37	1460	90
Calico Hills nonwelded (zeolitic)		0.31	2.92	91
Crater Flat unit (undifferentiated)	0 - 200	0.23	18.25	88

*Table 1 of P. Montazer & W.E. Wilson, 1984, USGS, WRIR84-4345.

APPARENT FLOW REGIMENS WITH ASSUMED STEADY RECHARGE RATES

Hydrogeologic Unit	Saturated Hydraulic Conductivity mm/yr.			Assumed Steady Recharge Rate mm/yr. matrix flow (M) fracture flow (F)			
				0.5	1.0	5.0	10.0
Tiva Canyon, welded	0.31 [c]	0.73 [b]	1.0 [a]	M/F	M/F	F	F
Paintbrush, nonwelded	109 [b]	3,300 [a]	12,300 [c]	M	M	M	M
Topopah Spring, welded	0.05 [c]	0.06 [b]	0.70 [a]	M/F	F	F	F
Calico Hills, nonwelded (vitric)	55 [b]	85 [c]	107 [a]	M	M	M	M
Calico Hills, nonwelded (zeolitic)	0.01 [b]	0.50 [a]	0.63 [c]	M/F	F	F	F
Crater Flat unit (Undifferentiated)	18.25 [b]	22.0 [a]	88.0 [a]	M	M	M	M

DATA SOURCES: [a] Environmental Assessment, 1986, DOE/RW-0073.
[b] USGS, WRIR84-4345, 1984.
[c] SAND 84-1471, 1984.

MY[illegible]

Will Yucca Mountain Be Subjected to a Pluvial Climate Within the Next 10,000 Years?

- 65 to 85 percent of the last 2.4 million years were perhaps cooler or colder climates as currently understood.
- Periodicity in climate change seems real, but dating problems with varied records combined with complex influences on local/regional climates contribute to uncertainty.
- The Milankovitch theory, which correlates varied insolation with climate/interglacial worldwide records, is currently under challenge by the Great Basin Devil's Hole travertine record.
- Great Basin pluvial climate records are not entirely synchronous as currently understood.
- One can conclude that over the radioactive life of the proposed repository, plenipluvial climates will occur.
- A better understanding of the complex Great Basin regional climatic responses to worldwide climatic changes, and the causes, is required to confidently predict over the next 10,000 years.

Plenipluvial Yucca Mountain Estimated Hydrology
(M. D. Mifflin opinion)

- Net infiltration (measured as evenly distributed recharge flux) at least 10X current recharge flux (unknown). Postulated range 10 to 30mm/year with local zones of higher and lower flux rates, and areas with little or no flux.

- Regional water table rise above the current water table to greater than 100m locally.

- Marked increase in extent of perched water zones in the vadose zone. Extensive perching on the Paintbrush bedded tuff, and on the bedded tuffs of the Calico Hills. Localized perching in the welded tuff units.

- Marked increase in both ephemeral and perennial fracture flow, but likely localized. Seasonal pulsed fracture flow, with very minor exchange between the matrix water and fracture water in much of the mountain due to the very small hydraulic conductivities.

Thermal Loading Concepts Fall into Three Groups

- The Site Characterization Plan Conceptual Design (SCP-CD)

  — Borehole emplacement of 10 years-out-of-core (YOC) spent fuel or high-level waste in thin wall, corrosion-resistant, unshielded containers at about 57 kW/acre, maximum drift wall about 130 C and maximum borehole wall about 230 C.

- Sub-boiling drift emplacement

  — Self-shielded casks containing 30 YOC fuel

  — Maximum 50 C, 1-4 PWR per cask, maximum 20 kW/acre

  — Maximum 90 C, 8-12 PWR per cask, maximum 40 kW/acre

- Extended Dry drift emplacement

  — Self-shielded casks containing 30 YOC fuel

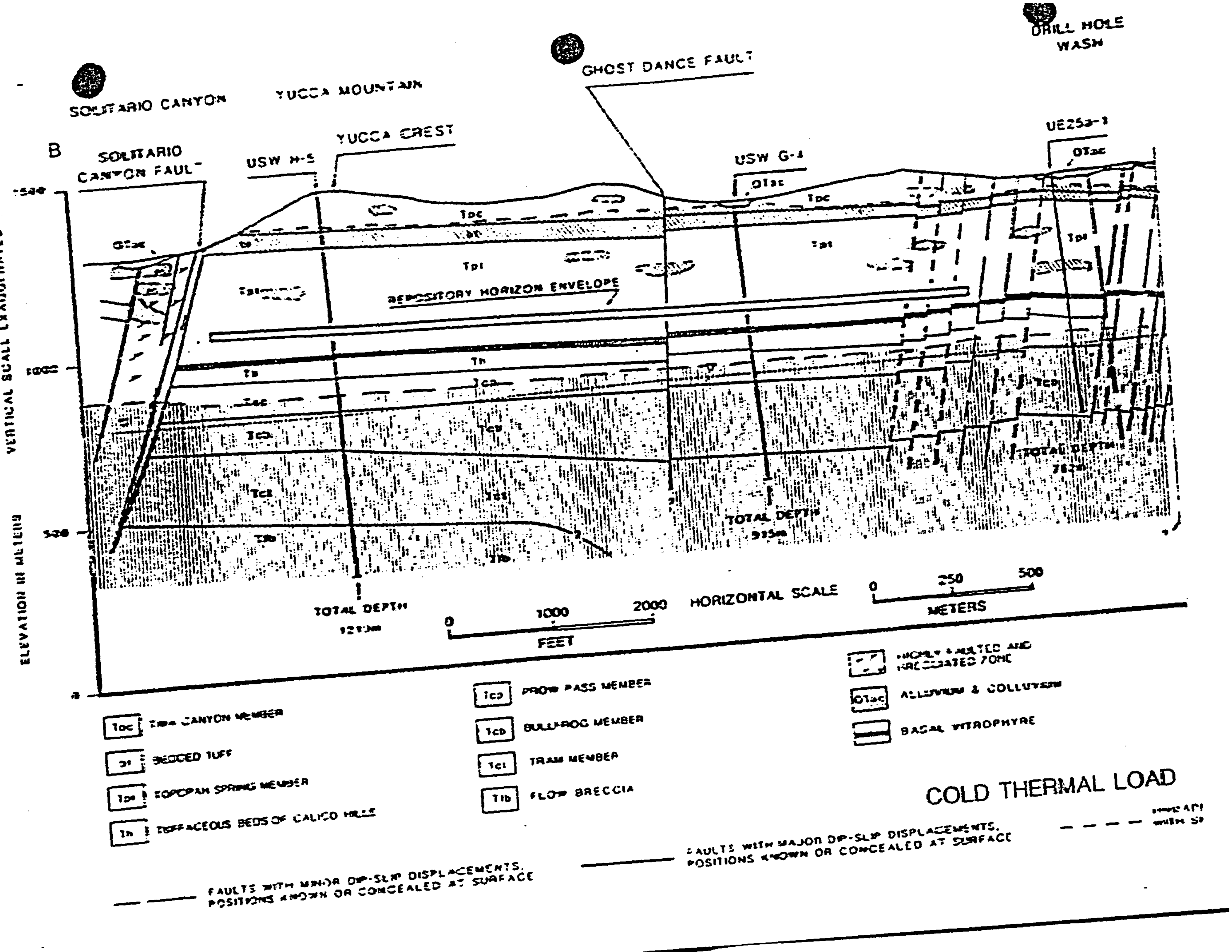
  — Maximum 205 C allows 21-24 PWR per cask at 114 kW/acre

  — Maximum 125 C allows 21-24 PWR per cask at 57 kW/acre

(From L. Ramspott, 1993)

PLENIPLUVIAL CLIMATE
Cold Thermal Loading Scenario
(20 to 40 kW/acre)

- **Repository extent greatly expanded in total area beyond the "block".**
- **Marked increase in water contact with waste packages likely due to the extent of the repository combined with marked increase in fracture flow and highly localized perching in the repository horizons.**
- **Gas phase transport of released vapor phase radionuclides (C-14) might be reduced by extensive perching above the repository, increased fracture flow in the most permeable fracture/fault zones, and carbonate mineral precipitation.**
- **Liquid phase transport of released radionuclides likely to travel much faster to regional saturation due to the marked increase in local zones with fracture flow dominating.**
- **Radionuclide containment would be heavily dependent upon waste package life in a corrosive environment and radionuclide retardation in the Calico Hills and saturation zone.**



COLD THERMAL LOAD

PLENIPLUVIAL CLIMATE

SCP Reference Thermal Loading Scenario
(57 kW/acre)

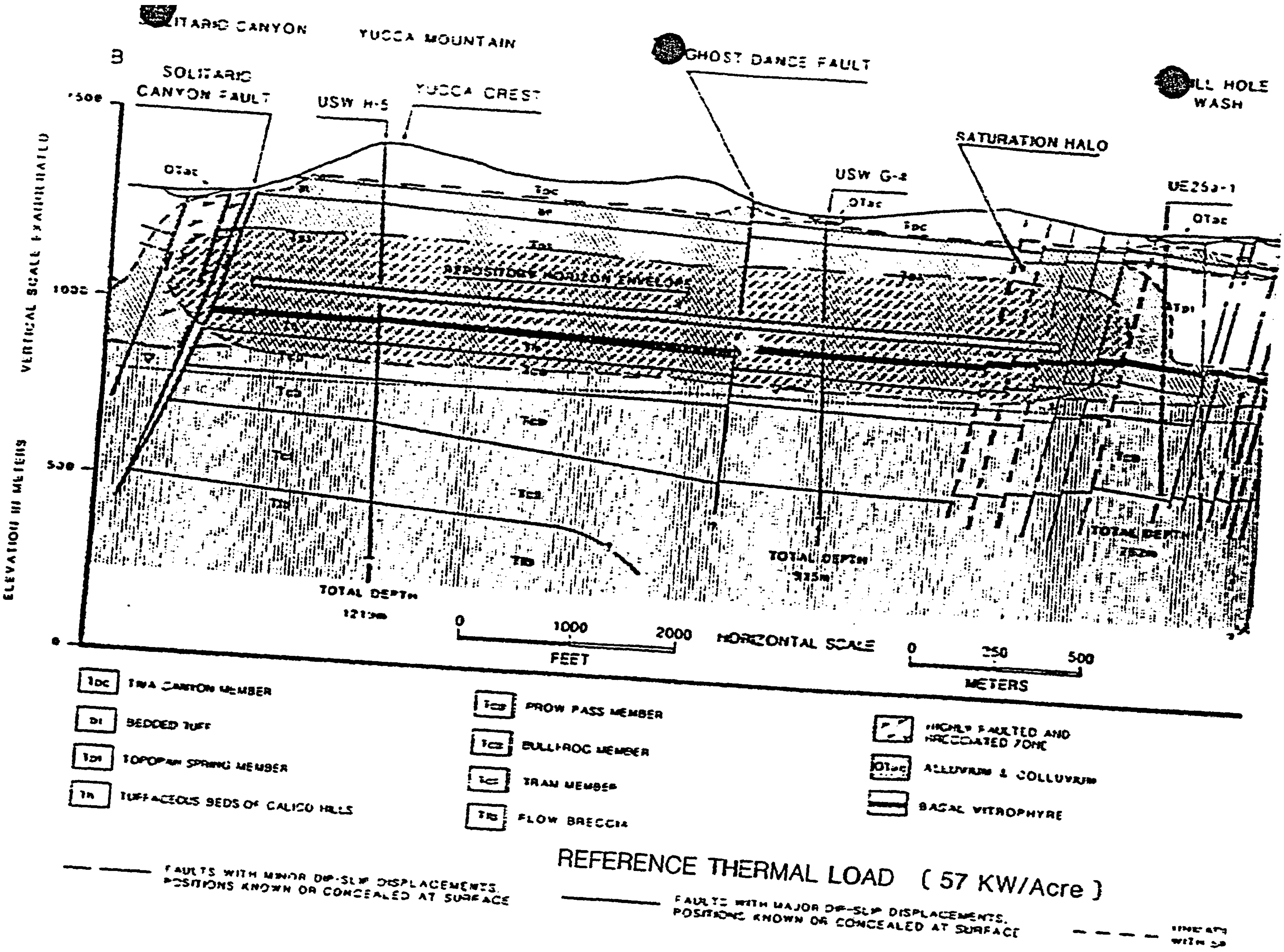
- **Probably minor impact on containment until cool down to about boiling (96°C) near the repository horizon, then enhanced corrosion and opportunity for partial or total flooding and rapid deterioration of the waste packages.**

- **Cool down to below boiling would occur during the 10,000 year containment period.**

- **Increase in supply of recharge during 96°C thermal envelope life would increase refluxing of water in the saturation halo located in the Topopah Spring and presumably concentrate salts in the saturation halo.**

- **May, upon early waste package failures, enhance vapor phase radionuclide release rate via ample water supply for hydrothermal venting locally along fault zones.**

- **Saturation halos above, laterally, beyond, and below the 96°C isotherm would be extensive, and upon cool down the repository horizon would likely be subjected to either localized or extensive flooding. Halo water probably charged with soluble salts concentrated near edge of the boiling zone.**



REFERENCE THERMAL LOAD (57 KW/Acre)

PLENIPLUVIAL CLIMATE
"Dry Out" Thermal Load Scenario
(114 kW/acre)

- **Small repository area, extensive and prolonged thermal envelope above 96^{o}C.**

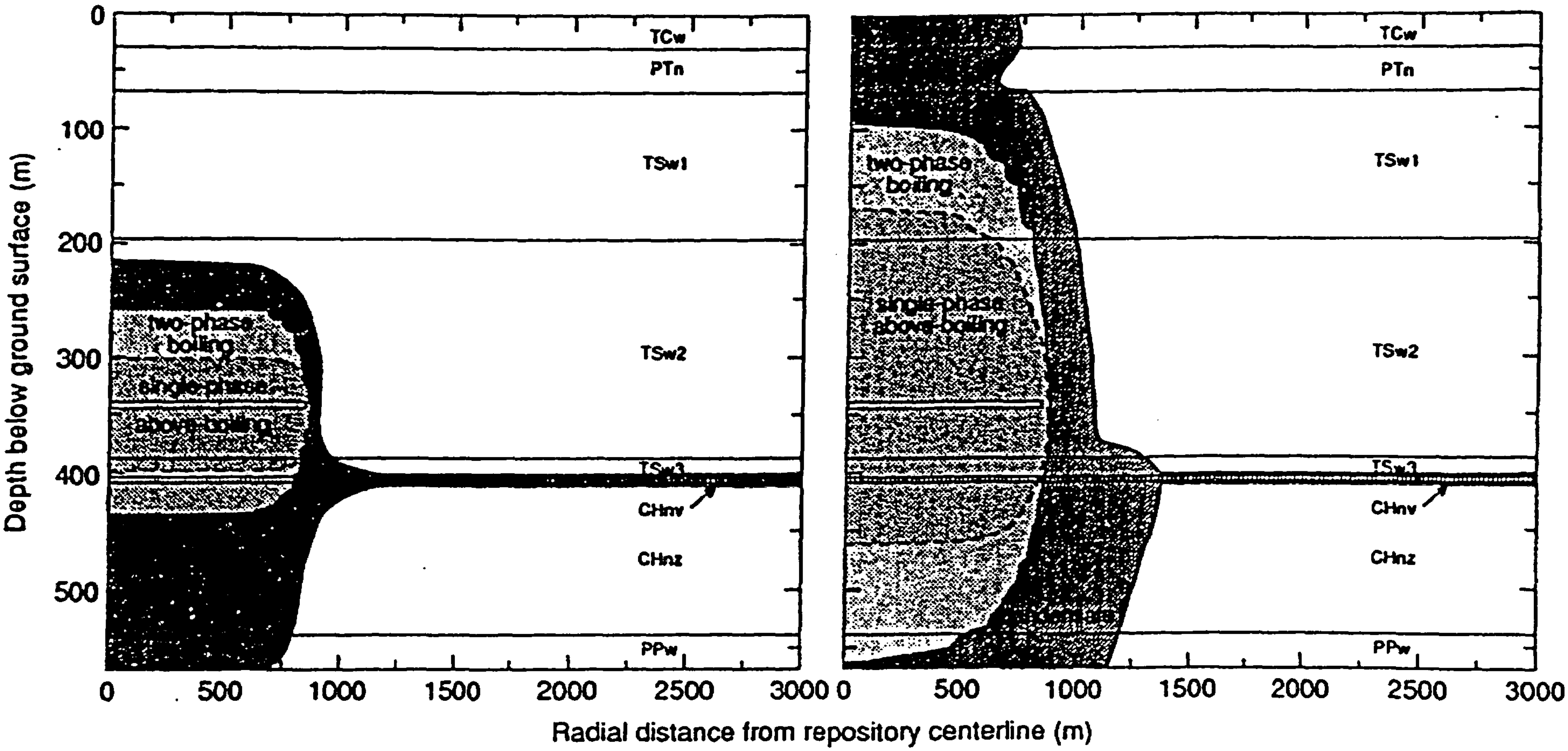
- **Prolonged hydrothermal discharge likely in local zones along major fault/fracture zones. Prolonged and extensive saturation above the Paintbrush Bedded Tuff in the Tiva Canyon Welded Tuff, with local discharge seeps on small springs, lower temperature water as well.**

- **Vapor phase radionuclide release to landsurface if or when waste packages fail over the 10,000 year containment period. Sufficient recharge to keep hydrothermal system active from local discharge vents over the duration of the pluvial climate.**

- **Partial or total repository horizon flooding upon cool down after 10,000 years with subsequent radionuclide releases downward via saturated zone flow paths.**

Repository heating can result in a single-phase above-boiling zone, a two-phase boiling zone, and a condensate zone

Dimensionless Liquid Saturation Contours for 30-year-old SNF, an APD of 114 kW/acre, and an AML of 154.7 MTU/acre



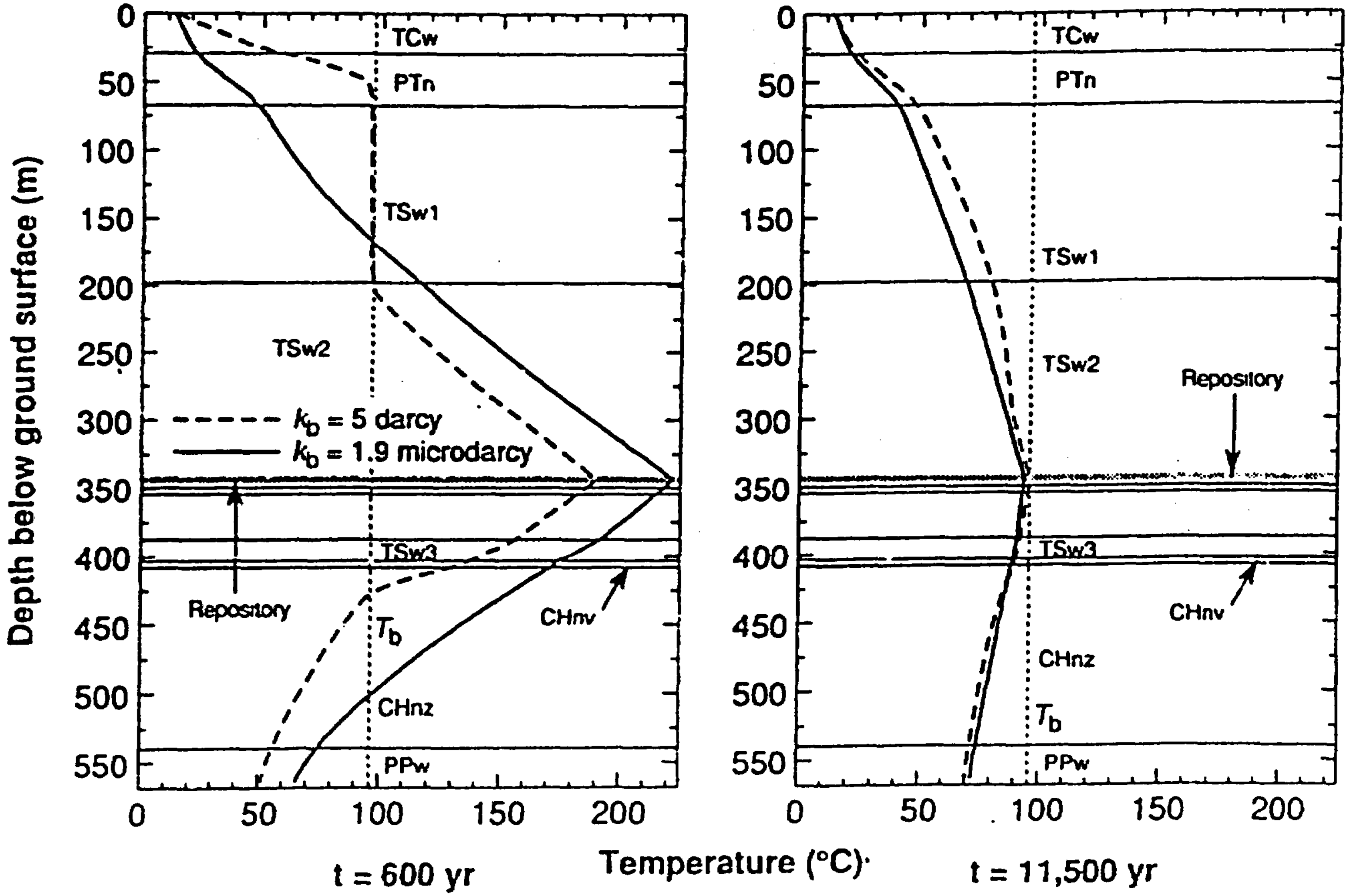
t = 100 yr

t = 1000 yr

(From T.A. Buscheck, 1993)

The duration of the repository boiling period largely depends on heat flow outside of the above-boiling region; convective processes that occur within the above-boiling region (heat pipes and buoyant vapor flow) affect the above-boiling temperature profile

Vertical Temperature profile along the Repository Centerline for 30-yr-old SNF, and APD of 114 kW/acre, and an AML of 154.7 MTU/acre



(From T.A. Buscheck, 1993)

U.S. DEPARTMENT OF ENERGY
OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT

ADVISORY COMMITTEE ON NUCLEAR WASTE (ACNW) WORKING GROUP

SUBJECT: INTEGRATION OF UNSATURATED ZONE DATA MODELING STUDIES AND PERFORMANCE ASSESSMENT

PRESENTER: CLAUDIA NEWBURY

PRESENTER'S TITLE AND ORGANIZATION: PHYSICAL SCIENTIST
YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT

PRESENTER'S TELEPHONE NUMBER: (702) 794-7942

LAS VEGAS, NEVADA
DECEMBER 14, 1993

SITE CHARACTERIZATION PROGRAM

- Collects and interprets hydrologic data
- Constructs 1, 2, and 3-dimensional Site Models
- Verifies and documents Site Models
- Tests Site Models to the extent practicable
- Provides Site Models to Performance Assessment

PERFORMANCE ASSESSMENT

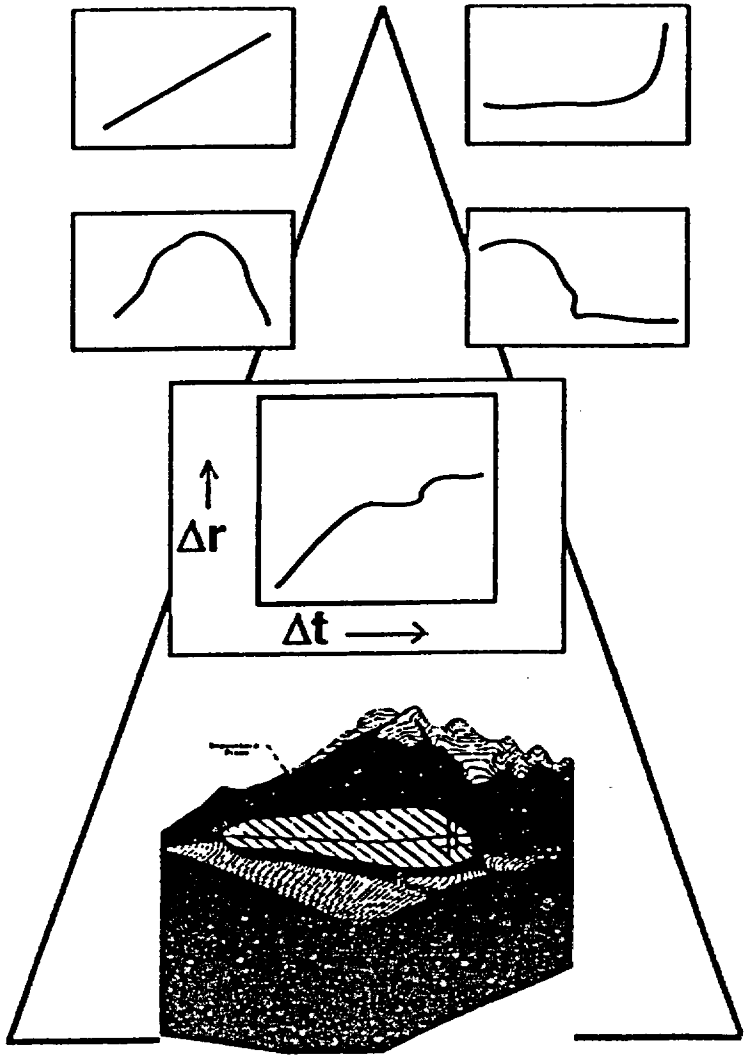
- Uses Site Models to refine process-level models
- Performs sensitivity studies using process-level models
- Provides feedback to Site Program and its Site Modeling effort
- Abstracts process-level models to obtain input and establish initial and boundary conditions for total-system models

THERE ARE THREE LEVELS OF MODELING

- Total system models are simplest in detail, but most complex in combining processes

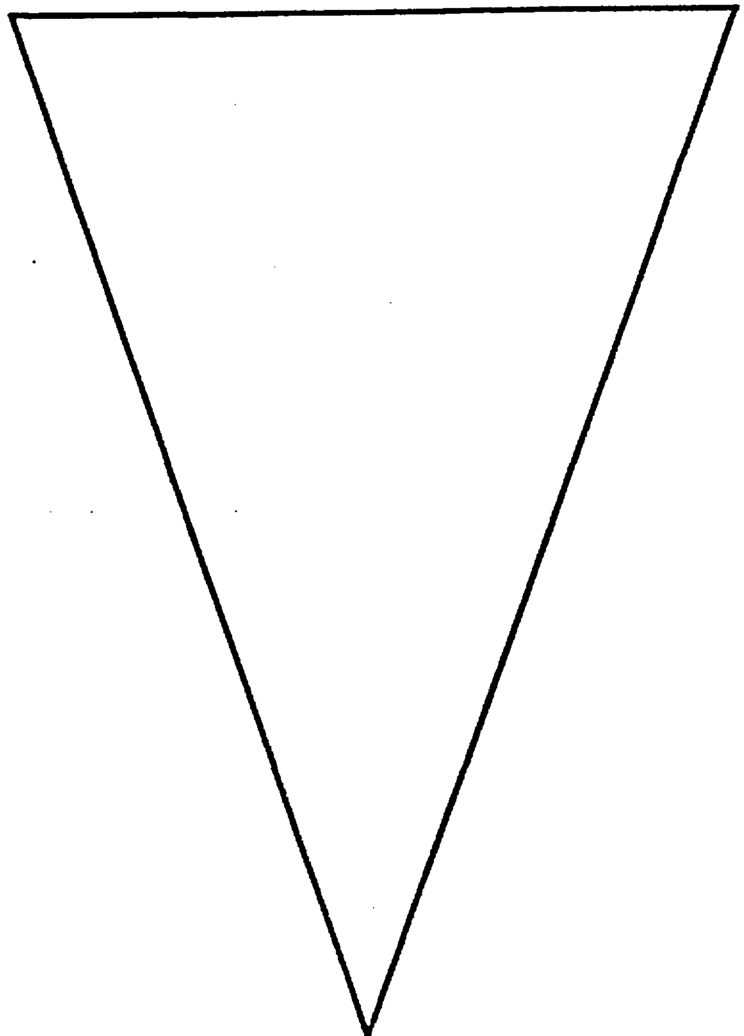
- Process models are complex and may address a single process or combine processes

- Site models are most complex in terms of data and stratigraphic detail



THERE ARE THREE STEPS IN PERFORMANCE ASSESSMENT

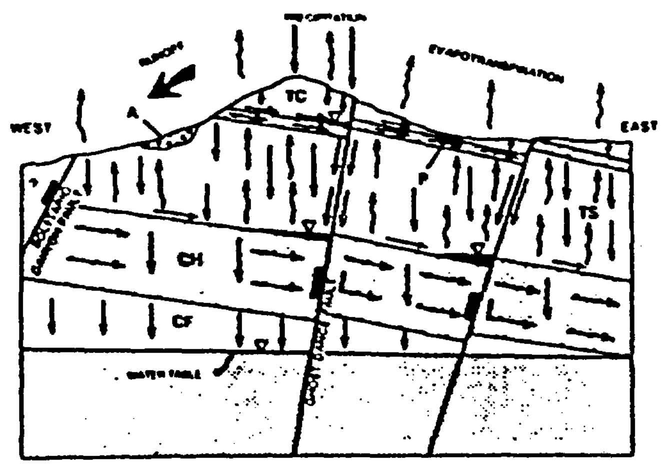
- First, use lowest level data and models to create, test and modify process level models
- Second, abstract from process model tests the information needed for total system models
- Third, perform total system analyses

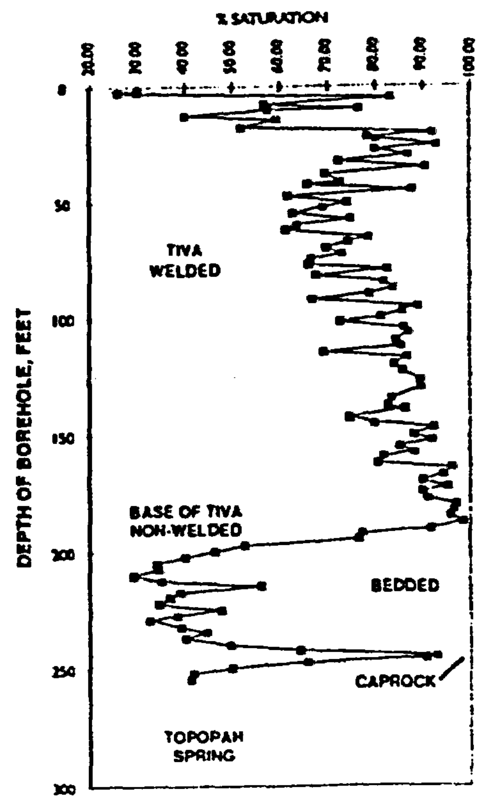


IZPACN5P5.PM4.125.ACNW/12-13/14-93

PERFORMANCE ASSESSMENT MODELS AND CODES ARE REFINED ON THE BASIS OF IMPROVED UNDERSTANDING OF SITE CONDITIONS AND PROCESSES

Unsaturated Zone,
Conceptual model of flow





KEY DEFINING ELEMENTS OF PERFORMANCE ASSESSMENT

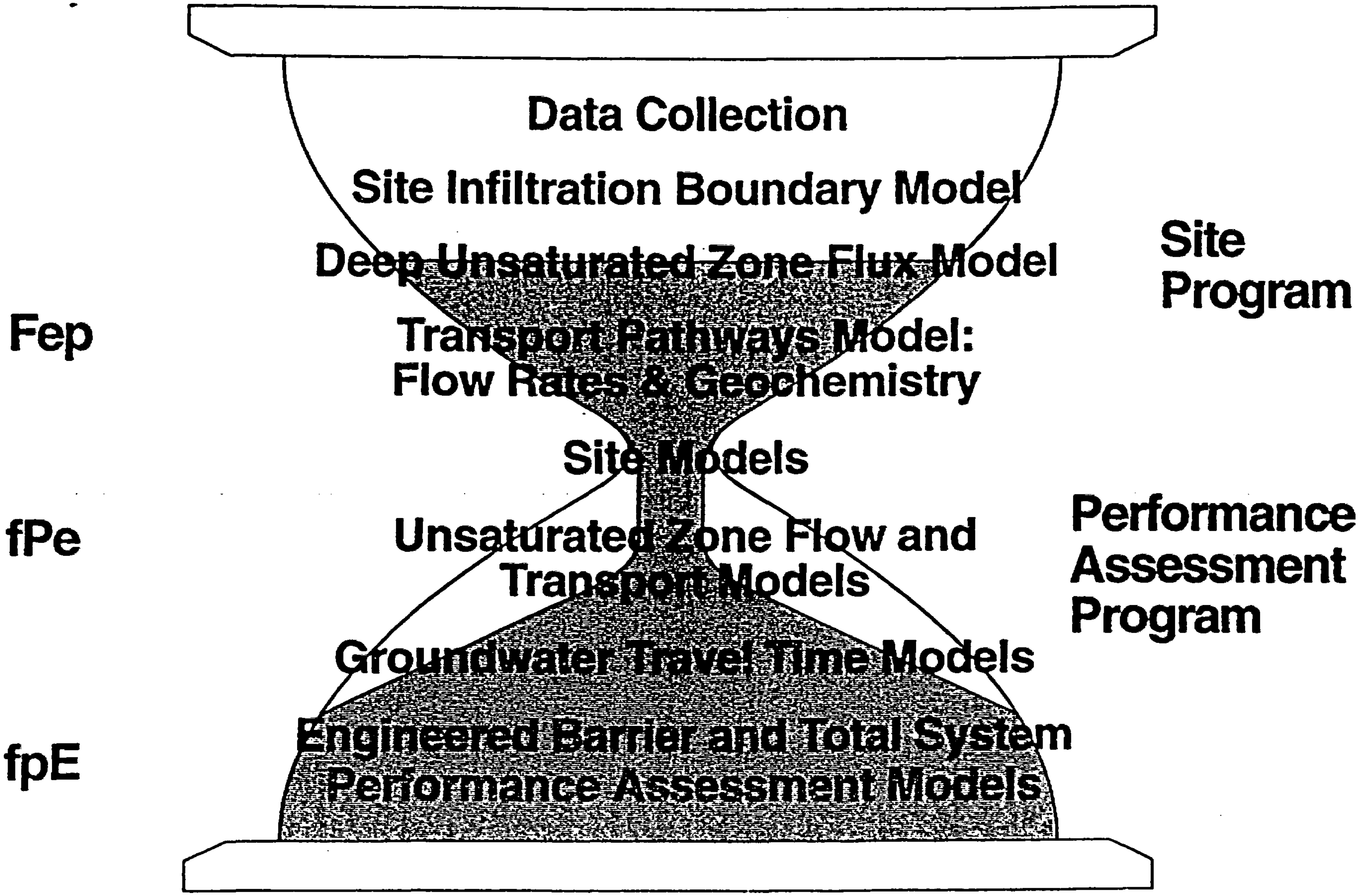
Performance assessment is:

A systematic process that identifies and models

features, events and processes (FEPs) that could affect the

safe performance and environmental acceptability of a radioactive waste repository

A MODELING HOURGLASS



UNSATURATED ZONE FLOW AND TRANSPORT MODELS

- A review of unsaturated flow and transport modeling capability recommended two codes for enhancement
  - TOUGH2, Lawrence Berkeley Laboratory: Flow of water, water vapor, air, and heat in one-, two-, or three-dimensional partially saturated porous media
  - FEHM, Los Alamos National Laboratory: Non-isothermal, multiphase, multicomponent flow and transport in two-dimensional, two-dimensional radial, or three-dimensional geometries

SITE DATA INPUTS VERSUS UNSATURATED ZONE MODEL COMPLEXITY

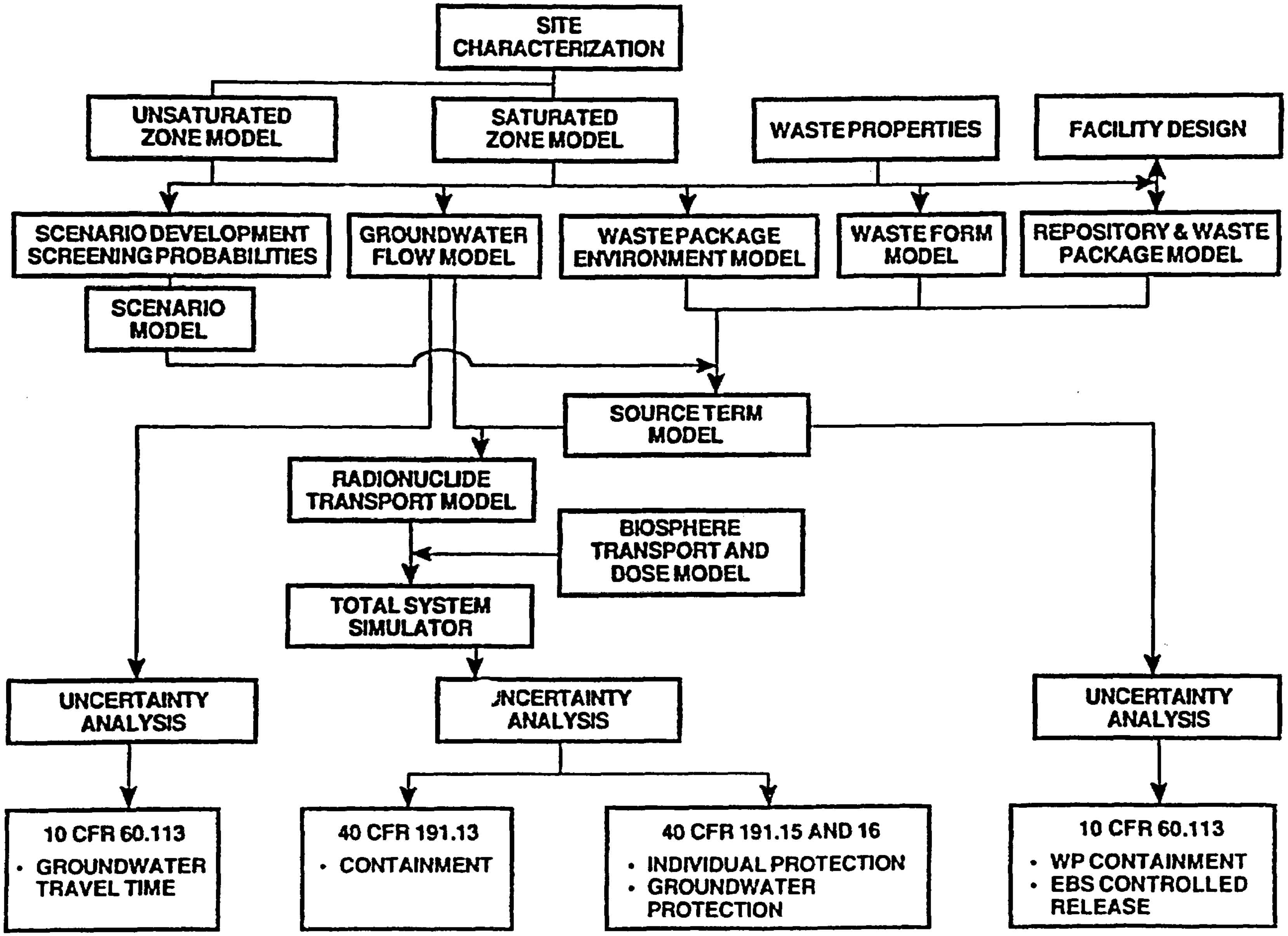
DATA REQUIREMENTS \ CONCEPTUALIZATIONS			RICHARD'S EQUATION ISOTHERMAL SYSTEM		GAS FLOW NON-ISOTHERMAL		MULTIPHASE NON-ISOTHERMAL	
			NO VAPOR TRANSFER		WITH VAPOR TRANSFER		WITH VAPOR TRANSFER	
					Liquid Saturation & Temp. Effects		Liquid Saturation & Temp. Effects	
			Porous Media	Porous Media	Porous Media	Porous Media	Porous Media	Discrete Fractures
			1	1	21	31	32	34F
POROUS AND FRACTURE MATERIAL CHARACTERISTICS	LIQUID WETTING FLUID PHASE	1						DATA REQUIRED
		2	DATA REQUIRED	DATA REQUIRED			DATA REQUIRED	DATA REQUIRED
		3						
		4						DATA REQUIRED
		5	DATA REQUIRED	DATA REQUIRED			DATA REQUIRED	DATA REQUIRED
		6						
		7						DATA REQUIRED
		8	DATA REQUIRED	DATA REQUIRED			DATA REQUIRED	DATA REQUIRED
		9						
		10						DATA REQUIRED
		11	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED
		12						
		13						
	GAS NONWETTING FLUID PHASE	14						DATA REQUIRED
		15			DATA REQUIRED	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED
		16						
		17						DATA REQUIRED
		18			DATA REQUIRED	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED
		19						
		20						DATA REQUIRED
		21			DATA REQUIRED	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED
		22						
		23						
		24			DATA REQUIRED	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED
		25			DATA REQUIRED	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED
		26			DATA REQUIRED	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED
		27			DATA REQUIRED	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED
		28					DATA REQUIRED	DATA REQUIRED
		29						
	THERMAL EFFECTS	30			DATA REQUIRED	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED
		31			DATA REQUIRED	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED
		32			DATA REQUIRED	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED
		33			DATA REQUIRED	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED
		34			DATA REQUIRED	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED
		35			DATA REQUIRED	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED
	FRACTURE PROPERTIES	36						DATA REQUIRED
		37						DATA REQUIRED
		38						DATA REQUIRED
		39						DATA REQUIRED
		40						DATA REQUIRED
		41						DATA REQUIRED
		42						DATA REQUIRED
		43						DATA REQUIRED
		44						DATA REQUIRED
FLUID PROPERTIES		45	LIMITED DATA REQUIRED	LIMITED DATA REQUIRED	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED
		46			DATA REQUIRED	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED
		47					DATA REQUIRED	DATA REQUIRED
		48	LIMITED DATA REQUIRED	LIMITED DATA REQUIRED	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED
		49			DATA REQUIRED	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED
		50			DATA REQUIRED	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED
		51			DATA REQUIRED	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED
		52			DATA REQUIRED	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED
		53			DATA REQUIRED	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED
BOUNDARY CONDITIONS		54	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED
		55			DATA REQUIRED	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED
		56	DATA REQUIRED	DATA REQUIRED			DATA REQUIRED	DATA REQUIRED
		57	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED
		58			DATA REQUIRED	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED
		59			DATA REQUIRED	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED
INITIAL CONDITIONS		60	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED
		61			DATA REQUIRED	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED
		62	DATA REQUIRED	DATA REQUIRED			DATA REQUIRED	DATA REQUIRED
		63	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED
		64			DATA REQUIRED	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED
		65			DATA REQUIRED	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED
GEOMETRY CONDITIONS		66	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED	DATA REQUIRED
		67	DATA REQUIRED	DATA REQUIRED			DATA REQUIRED	DATA REQUIRED
		68						DATA REQUIRED
FLOW CODES			TOUGH2	FEHM	TOUGH2	FEHM	TOUGH2	FEHM
Number of Input Data Sets →			14	14	33	33	41	58

(solid black)	DATA REQUIRED
(hatched)	LIMITED DATA REQUIRED
(blank)	DATA NOT REQUIRED

UNSATURATED ZONE FLOW AND TRANSPORT MODELS
(CONTINUED)

- Discrete fracture flow capability is primary recommended enhancement
  - FRACMAN, Golder Associates, Inc., is being modified so as to have a computational mesh compatible with FEHM
  - FRACMAN output may also be used in TOUGH2
- The Site Models are needed to create unsaturated flow and transport models for Yucca Mountain using these process-level codes

PERFORMANCE ASSESSMENT MODEL INTEGRATION



ANSPAM1P2.121/12-13-93

GROUNDWATER TRAVEL TIME (GWTT) MODELS

- A GWTT Issue Resolution Working Group is examining technical aspects of groundwater flow at Yucca Mountain
  - Objective is to develop approach for demonstrating compliance with natural barriers performance requirement
  - Approach must be technically prudent and acceptable to the Nuclear Regulatory Commission (NRC) staff

GROUNDWATER TRAVEL TIME (GWTT) MODELS

(CONTINUED)

- A technical exchange with the NRC staff is scheduled for March 1995
  - Understanding reached in this exchange will assist development of suitable approach
  - GWTT model will be defined as part of the approach
  - Topical Report on approach to showing GWTT compliance tentatively scheduled for submittal to NRC staff late FY 1995

ENGINEERED BARRIER SYSTEM PERFORMANCE ASSESSMENT MODELS

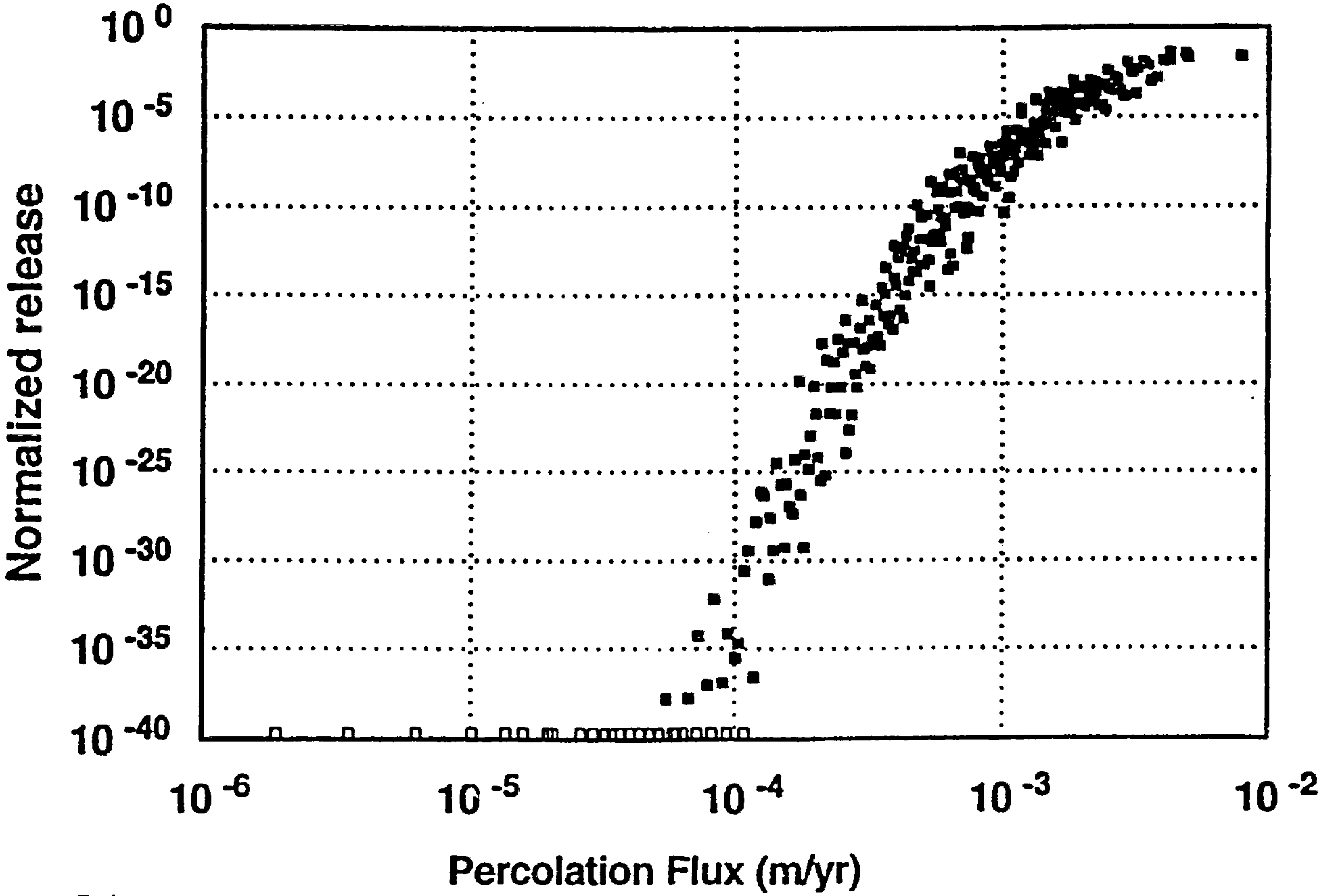
- The engineered system models YMIM and AREST are being enhanced
  - YMIM, Lawrence Livermore National Laboratory: Integrates multiple process effects on container performance and release
  - AREST, Pacific Northwest Laboratory (under M&O contract): Being enhanced to be next generation of engineered system model

TOTAL SYSTEM PERFORMANCE ASSESSMENT (TSPA) MODELS

- Total System Level Models TSA and RIP were recently demonstrated
  - TSA, Sandia National Laboratories, and RIP, Golder associates, Inc. (under M&O contract): Integrates abstracted results of lower level modeling important to defining system behavior
  - TSA was used in the TSPA-1991 exercise, RIP was used in a code comparison exercise in 1993

- Both codes were used to model total system performance in 1993, addressing system sensitivity to thermal perturbation

A TSPA-1991 RESULT: SENSITIVITY OF AQUEOUS RELEASES TO UNSATURATED ZONE FLUX



□ = No Releases

DCTSNLHD16.125.NWTRB/7-13/14-93

FUTURE TSPAS ARE TO SUPPORT MAJOR PROGRAM DECISIONS

- Near term program decisions include:
  - Site-suitability evaluation
  - Underground facility and engineered system design
  - Prioritizing and evaluating test program

- Longer term program decisions involve:
  - Advanced Conceptual and License Application Designs
  - Site Recommendation Report
  - Environmental Impact Statement
  - Safety Analysis Report/License Application

SUMMARY AND CONCLUSIONS

- Site and Performance Assessment are linked through Site Program data interpretation and modeling
- Site data and models are used to refine process-level Performance Assessment models
- Process-level models are tested and abstracted to provide initial and boundary conditions and input data for system-level models

SUMMARY AND CONCLUSIONS

(CONTINUED)

- Status of Performance Assessment Program:
  - Total System Performance Assessment models exist and are being enhanced
  - Subsystem-level models (engineered barrier system) exist and are being enhanced
  - Process-level models exist and are being enhanced

- Primary objective of Performance Assessment Program modeling effort:
  - Update and test codes based on site data and models
  - Test models and provide feedback to Site Program

UNSATURATED-ZONE TESTING TO BE CONDUCTED

IN THE EXPLORATORY STUDIES FACILITY

M.P. CHORNACK
U.S. GEOLOGICAL SURVEY

ADVISORY COMMITTEE ON NUCLEAR WASTE

WORKING GROUP MEETING

DECEMBER 14, 1993

OUTLINE

- UZ Studies in the ESF
- Purpose and Objectives of Studies
- ESF Tests
- Summary

UZ STUDIES IN THE ESF

- Construction Phase Tests
  - Radial-boreholes Tests (PI - G. LeCain)
  - Excavation-effects Tests (PI - F. Thamir)
  - Perched-water Tests (PI - C. Peters)
  - Hydrochemistry Tests (PI - C. Peters)
  - Major Faults Tests (PI - G. LeCain)
- Post-Construction Phase and Main Test Level Tests
  - Intact Fracture Tests (PI - G. Severson)
  - Percolation Tests (PI - F. Thamir)
  - Bulk-permeability Tests (PI - G. LeCain)

PURPOSE OF STUDY

- Provide hydrologic-parameter input for the resolution of design and performance issues
- Provide an understanding of the impacts of ramp and drift construction on the in situ hydrologic characteristics
- Contribute to an understanding of the in situ hydrologic characteristics of the unsaturated zone

OBJECTIVES OF STUDY

- Determine the in situ, unsaturated-zone hydrologic conditions from:

    - core and fluid samples
    - borehole geophysical logs
    - in situ borehole tests

- Determine the spatial distribution of present-day water flow within the unsaturated zone

- Characterize gas and vapor flow in the unsaturated zone

OBJECTIVES OF STUDY

- Provide hydrologic data for calculations of UZ ground-water travel time

- Provide hydrologic data for predictions of radionuclide releases to the accessible environment

- Provide hydrologic properties data to design analyses of underground facilities, repository seals, and waste packages

RADIAL-BOREHOLE TESTS

TESTING ACTIVITIES

- Four test programs for testing in 2 ramps
  - air permeability-anisotropy testing within hydrogeologic units
  - air-injection testing across the hydrogeologic contacts
  - long-term monitoring of selected boreholes
  - water-injection testing at the contact sites

RADIAL-BOREHOLES TESTS

SPECIFIC TEST OBJECTIVES

- Quantify gas permeability and anisotropy of the hydrogeologic units within the UZ
- Estimate tortuosity and effective porosity of drained flow paths within the UZ hydrogeologic units
- Quantify the boundary effects at the hydrogeologic unit contacts
- Compare pneumatic and hydraulic test results, especially at the hydrogeologic unit contacts

EXCAVATION EFFECTS TEST

TESTING ACTIVITIES

- Tests conducted from alcoves on both sides of planned excavation
- Boreholes drilled parallel to proposed ESF opening
- Air-permeability testing before and after excavation
- In situ stress and mechanical property measurements conducted before, during, and after excavation

EXCAVATION EFFECTS TEST

SPECIFIC TEST OBJECTIVES

- Estimate the magnitude and extent of modification of the hydrologic properties in the Topopah Spring welded unit caused by excavation of the ESF

PERCHED-WATER TEST

TESTING ACTIVITIES

- Test will be conducted if perched water is encountered in the ESF
- If perched water is detected, hydraulic tests and chemical sampling will be initiated as soon as the area in the ESF is accessible
- Flow-rate measurements will be conducted if large inflows of perched water are encountered
- Boreholes will be drilled into perched-water zones for sampling, testing, and monitoring

PERCHED-WATER TEST

SPECIFIC TEST OBJECTIVES

- Detect the occurrence of any perched water
- Estimate the hydraulic properties of perched-water zones
- Determine the implication of the existence of perched-water zones on water flux, flow paths, and travel times

HYDROCHEMISTRY TESTS

TESTING ACTIVITIES

- Hydrochemistry gas samples will be collected from boreholes drilled for other ESF tests
- Short (1-2 m), small diameter boreholes drilled close behind the TBM to provide gas samples representative of pre-mining conditions
- Long borehole (~45 m) will be drilled from alcoves at selected locations for the collection of core samples and gas samples

HYDROCHEMISTRY TESTS

SPECIFIC TEST OBJECTIVES

- Collect and preserve core samples for extraction of unaltered water and gas
- Collect in situ water, water vapor, and gas samples from boreholes in the ESF
- Obtain hydrochemical and isotopic data for interpretation of transport mechanisms, flow direction, and travel time of water and gas in the UZ
- Determine the geochemical evolution of UZ water using hydrochemical and isotopic techniques

HYDROLOGIC PROPERTIES OF MAJOR FAULTS

TESTING ACTIVITIES

- Single- and cross-hole pneumatic testing conducted from two alcoves at each fault testing location
- Cross-hole pneumatic testing to characterize the permeability anisotropy within the fault disturbed zone and the fault
- Cross-hole tracer testing will be used to estimate tortuosity in fractures
- Cross-hole hydraulic testing provides the opportunity to compare pneumatic and hydraulic test results
- Boreholes will be instrumented for long-term monitoring

HYDROLOGIC PROPERTIES OF MAJOR FAULT

SPECIFIC TEST OBJECTIVES

- Measure pneumatic and hydraulic permeability, porosity, and anisotropy of major faults and associated fault zones
- Monitor for vertical flow of gas, water vapor, and water in major faults
- Estimate the tortuosity and effective porosity of major faults

INTACT FRACTURE TESTS

TESTING ACTIVITIES

- Fractures oriented perpendicular and parallel to the core axis will be collected from numerous locations
- Rock bolt anchors or metal bands are used to maintain the in situ geometry of the fractures after removal for testing
- Gas and water will be injected into the fractures subjected to varying confining pressures

INTACT FRACTURE TESTS

SPECIFIC TEST OBJECTIVES

- Evaluate fluid-flow and chemical-transport properties and mechanisms in relatively undisturbed and variably stressed fractures
- Permeabilities under in situ (lithostatic) pressure conditions can be determined for single fractures
- Develop water retention curves for fractures with differing aperture widths
- Provide fracture property data input for unsaturated-zone flow models

PERCOLATION TESTS

TESTING ACTIVITIES

- Large (2 m^3), isolated blocks will be excavated within selected hydrostratigraphic units
- Blocks will be instrumented to monitor fluid flow and tracer transport under controlled fluid-flow conditions
- Tracer-tagged water will be introduced on the surface of the block through a sand bed or trickle system
- Effluent from the block will be collected and analyzed to determine transport behavior

PERCOLATION TESTS

SPECIFIC TEST OBJECTIVES

- Observe fluid flow and solute transport processes through variably saturated, fractured welded tuff under controlled, relatively undisturbed conditions

BULK-PERMEABILITY TESTS

TESTING ACTIVITIES

- Three 60-meter long boreholes drilled in a frustum configuration
- Single- and cross-hole air-injection and water-injection testing using packers and downhole sensors
- Test locations will be spatially located to characterize the homogeneity of the Topopah Spring welded unit at the Main Test Level

BULK-PERMEABILITY TESTS

SPECIFIC TEST OBJECTIVES

- Assess the fluid transport properties in a relatively large volume of minimally disturbed tuff
- Determine bulk-permeability values for use in unsaturated-zone flow models

UZ STUDIES IN THE STARTER TUNNEL

- Started mining the first alcove in the starter tunnel for conducting UZ ESF studies
- Conducted initial (prototype) sampling of gas samples from short, hammer-drilled boreholes
- Will conduct hydrochemistry, gaseous-phase circulation, and radial boreholes testing in boreholes drilled in the alcove

SUMMARY

- Results will be used in the resolution of YMP performance and design issues concerned with fluid flow within the UZ

- Principal applications will be in
  - Assessment of ground-water and gas travel times
  - Design analysis related to the underground repository facility

- Issues concerned with the waste-package containment and engineered-barrier system will use information resulting from this study

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

Three-dimensional Model of Unsaturated Zone Flow

Gudmundur Bodvarsson
Nuclear Waste Department Head
Earth Sciences Division
Lawrence Berkeley Laboratory
(510) 486-4789

Advisory Committee on Nuclear Waste Working Group meeting on,
"Unsaturated Zone Flow Processes at the Proposed Yucca Mountain HLW Repository Site,"
St. Tropez Hotel, Las Vegas, Nevada, December 14, 1993

Coworkers

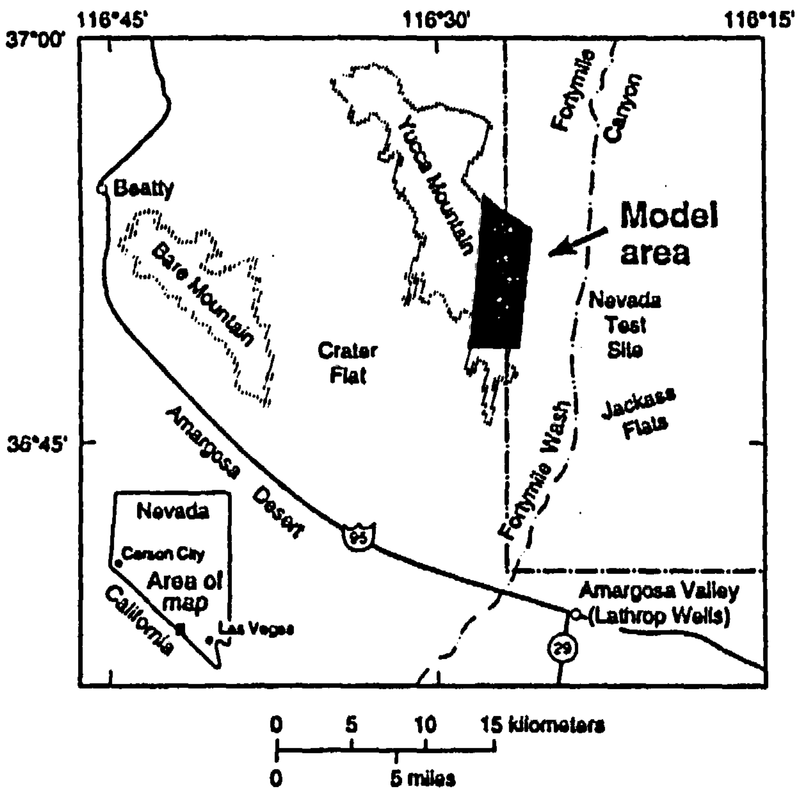
- G. Chen, LBL
- R. Bhogeswara, LBL
- M. Chornack, USGS
- A. Flint, USGS
- L. Flint, USGS
- E. Kwicklis, USGS, Co-Principal Investigator
- R. Spengler, USGS
- C. Rautman, Sandia

Presentation Overview

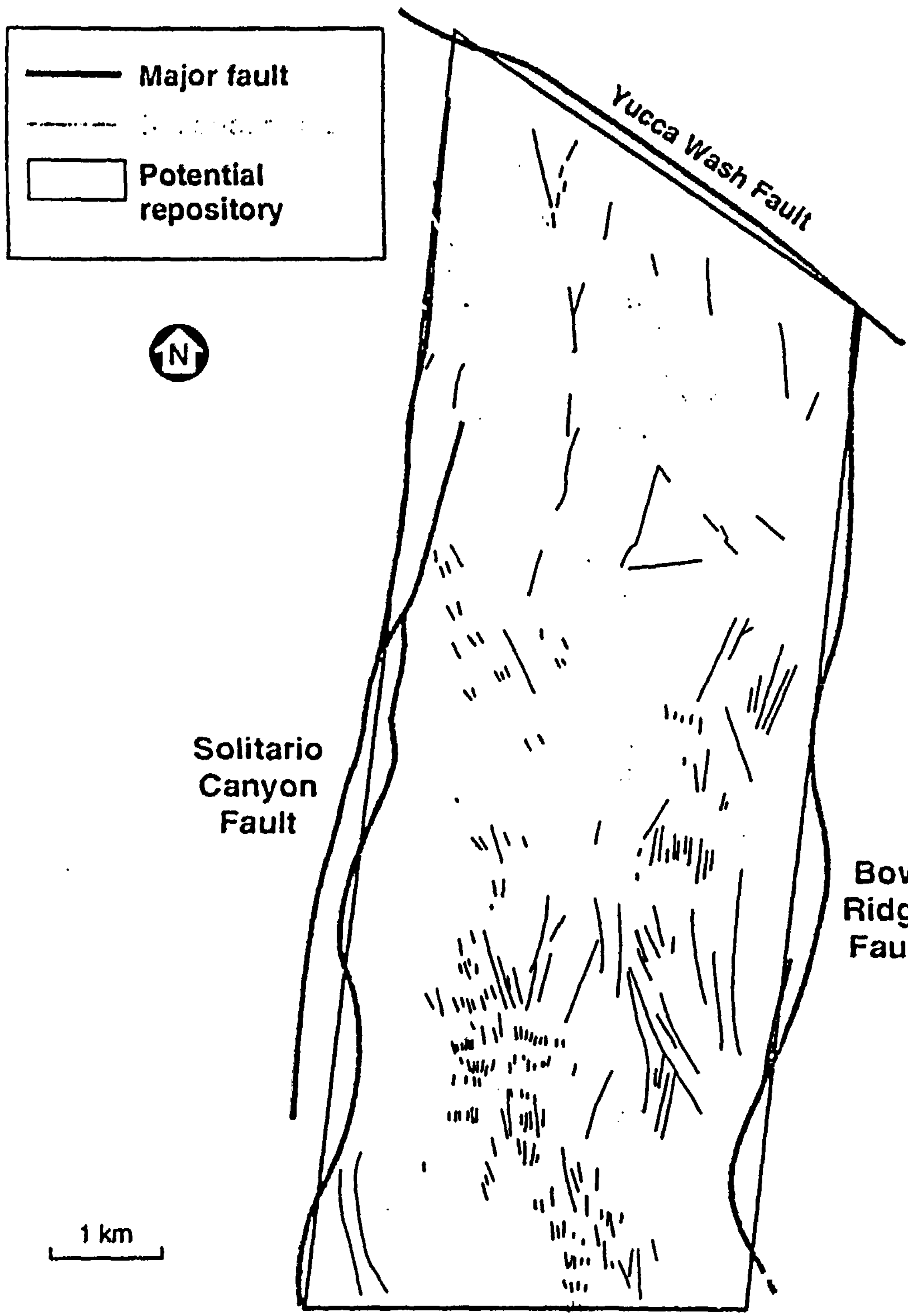
- Objectives of the study
- General approach
- Data needs and contributions from other studies
- Numerical modeling approach
- Results to date
- Current work
- Future work
- Credibility of the study

Why a model?

- The 3-D model will *integrate* the available data and information on Yucca Mountain.
- The 3-D model will provide estimates of *moisture, heat and gas* flow within the mountain.
- The 3-D model will be used to guide in the site-characterization effort ("enough"or "more" data).
- The 3-D model will be used to predict *thermo-dynamic conditions* (S, P_c, T, etc.) in new boreholes and in the ESF.



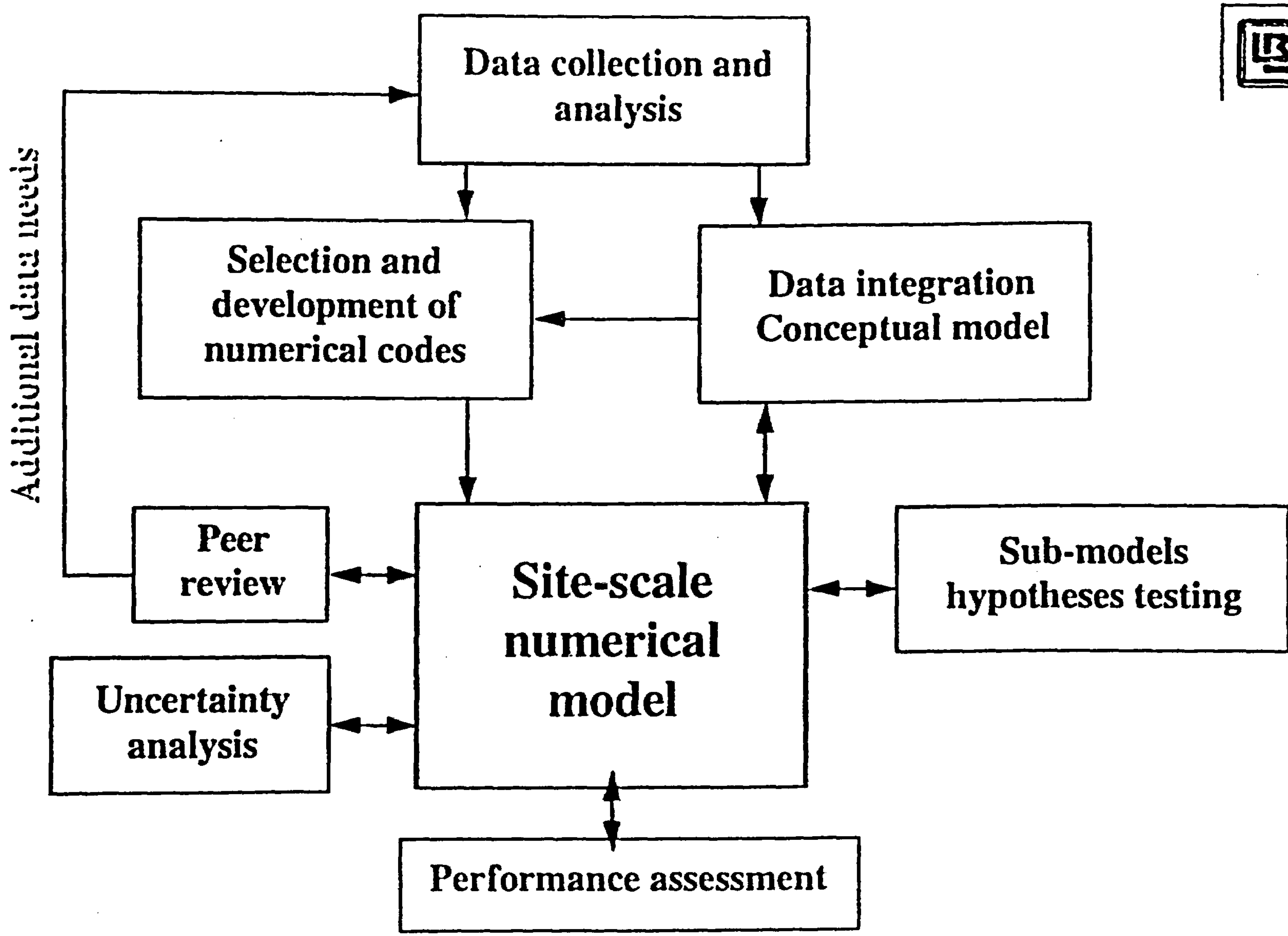
116°45'
116°30'
116°15'
37°00'
36°45'
Beatty
Bare Mountain
Yucca Mountain
Fortymile Canyon
Model area
Nevada Test Site
Crater Flat
Jackass Flats
Fortymile Wash
Amargosa Desert
95
Amargosa Valley (Lathrop Wells)
29
Nevada
Carson City
Area of map
California
Las Vegas
0 5 10 15 kilometers
0 5 miles



Major fault
Potential repository
N
Yucca Wash Fault
Solitario Canyon Fault
Bow Ridge Fault
1 km

How will we proceed?

- General approach
- Important hydrogeologic issues
- Model development steps


Data collection and analysis
Additional data needs
Selection and development of numerical codes
Data integration Conceptual model
Peer review
Site-scale numerical model
Sub-models hypotheses testing
Uncertainty analysis
Performance assessment

Some Site-Scale Modeling Issues

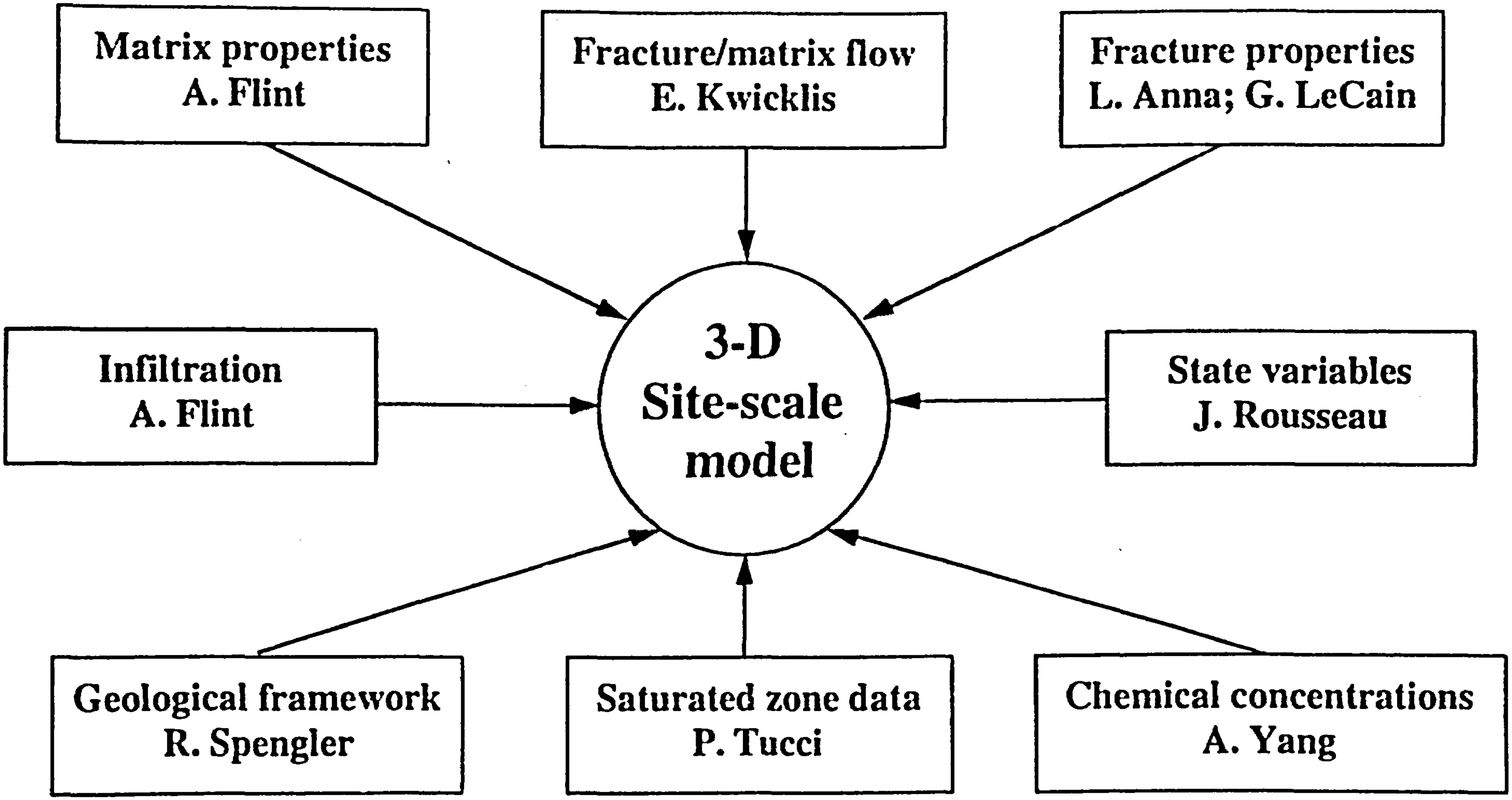
- Uncertainties in flux determination
- Densely fractured welded units; millions of fractures and matrix blocks
- Flow characteristics of major faults (e.g. Ghost Dance Fault)
- Matrix vs. fracture flow
- Gas flow (air + water vapor)
- Thermal effects on fluid flow
- Lateral flow and perched water
- Fracture and capillary barriers

Model Development Steps

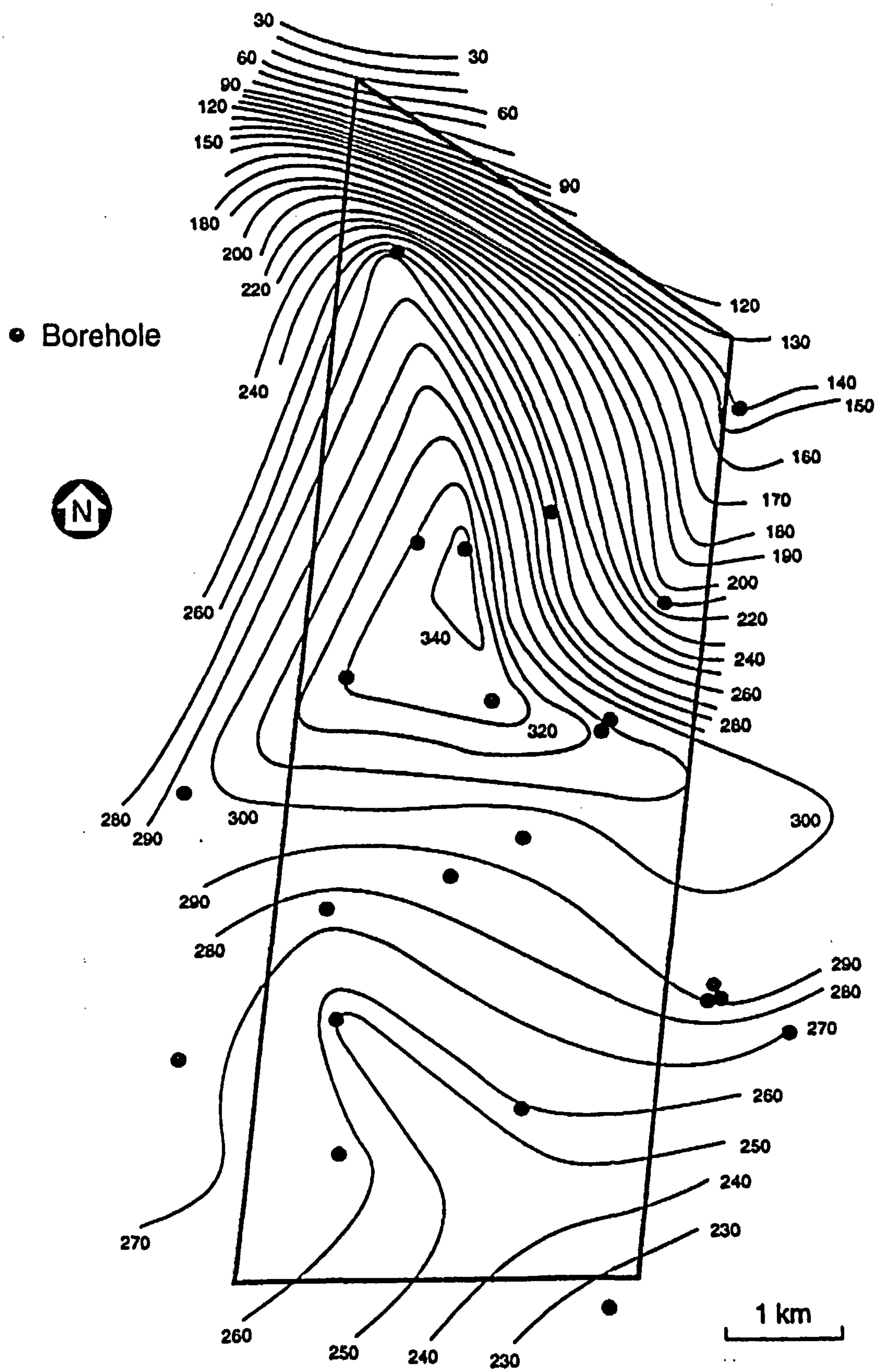
- Development of a moisture flow model
- Incorporation of geothermal gradient
- Incorporation of gas flow components
- Periodic calibration of model against observed data (moisture tension, saturation, gas pressure, temperature, chemical concentrations)
- Continuous use of model for prediction of state variables at new well locations and in the Exploratory Studies Facility
- Periodic use of model for sensitivity studies of further data needs ("enough or not")
- Continuous use of submodels for hypothesis testing

What data are essential?

- Data needs and contribution of other studies
- Hydrogeologic maps
- Important hydrological parameters


Matrix properties
A. Flint
Fracture/matrix flow
E. Kwicklis
Fracture properties
L. Anna; G. LeCain
Infiltration
A. Flint
3-D
Site-scale
model
State variables
J. Rousseau
Geological framework
R. Spengler
Saturated zone data
P. Tucci
Chemical concentrations
A. Yang

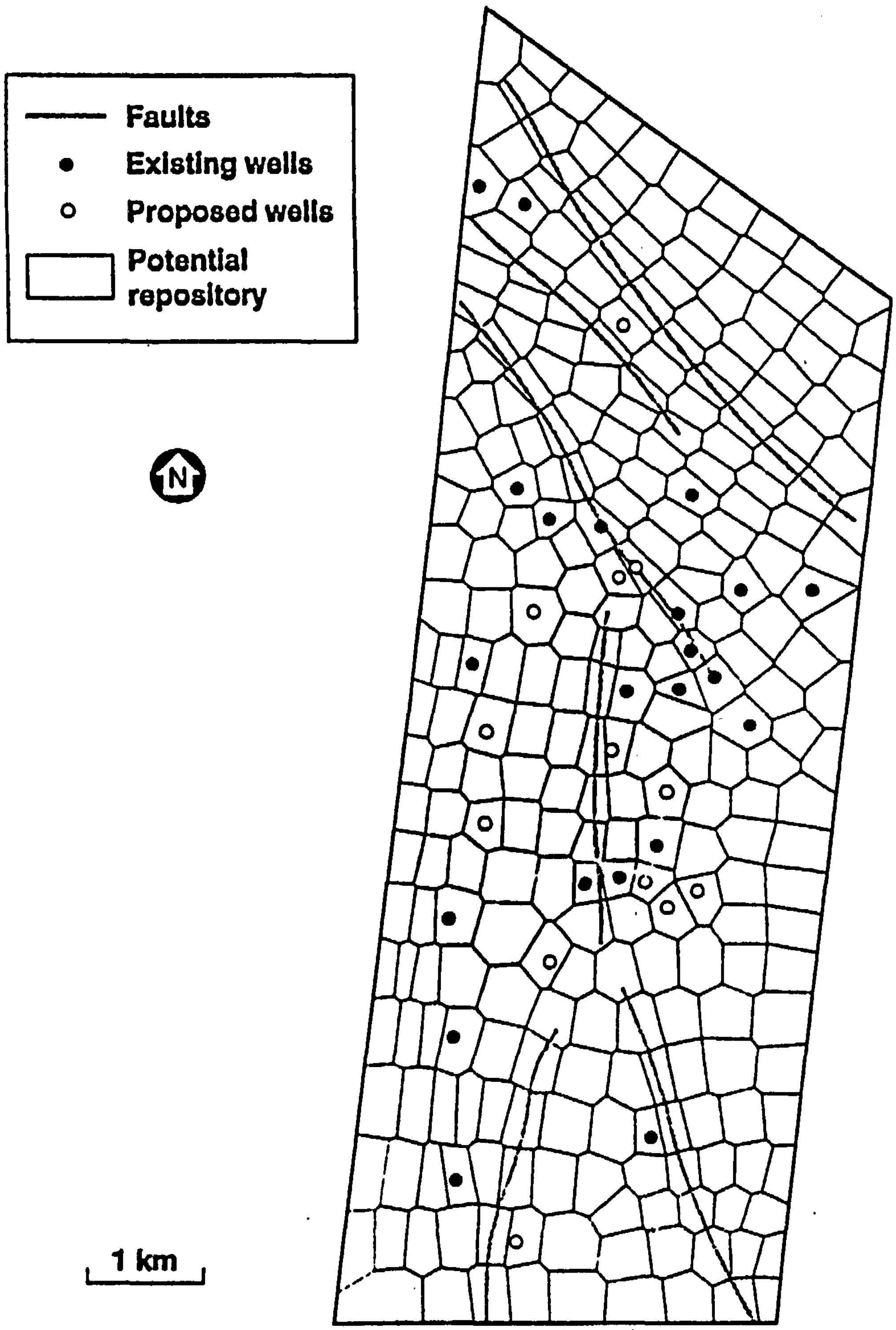
Topopah Spring Isopach Map (m)

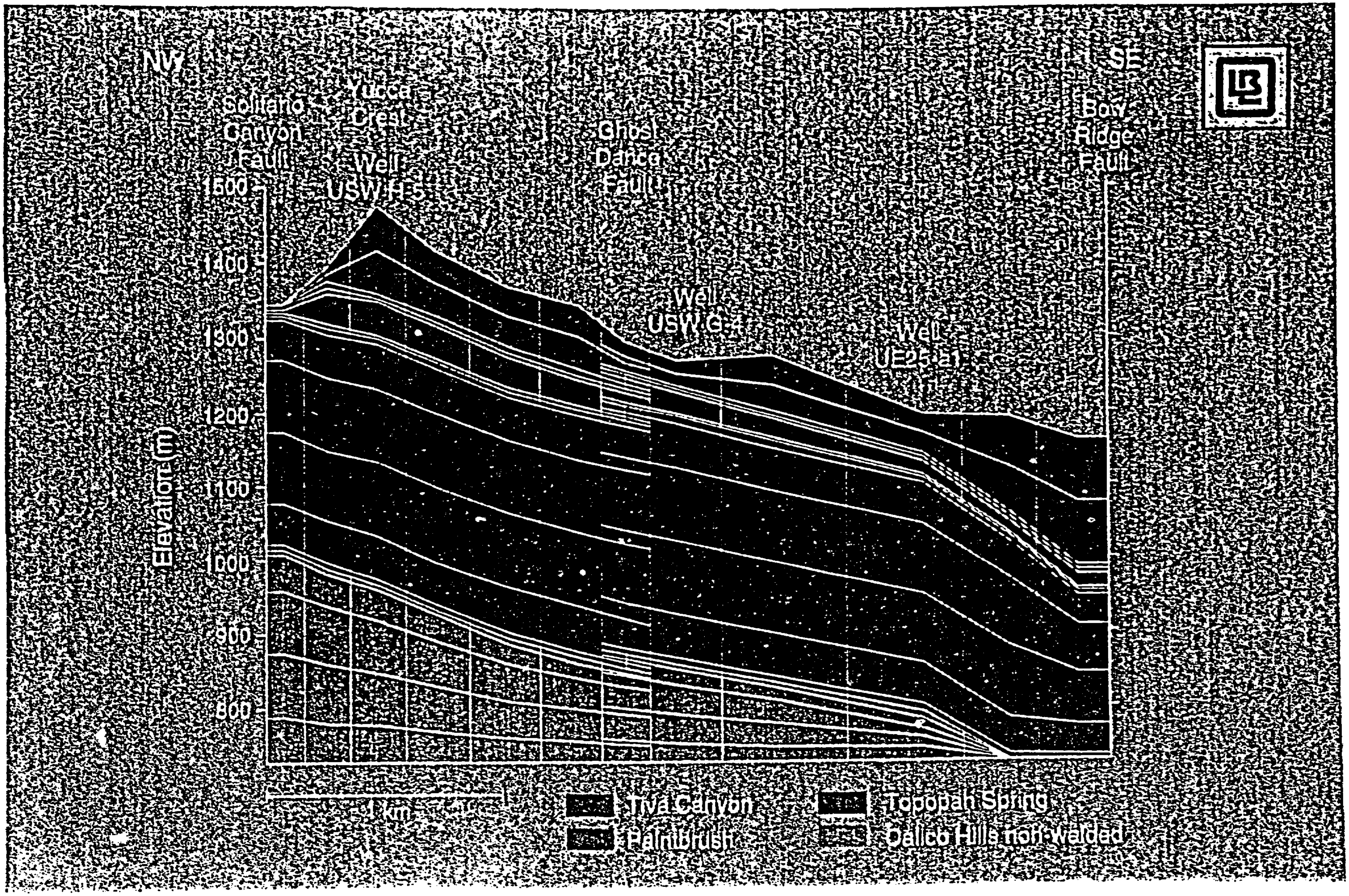


How will we "grid" the mountain?

- Factors controlling horizontal gridding
- Factors controlling vertical gridding
- Incorporation of faults and fractures
- Flexibility for grid modifications
- Development of new simulation techniques

Horizontal Grid



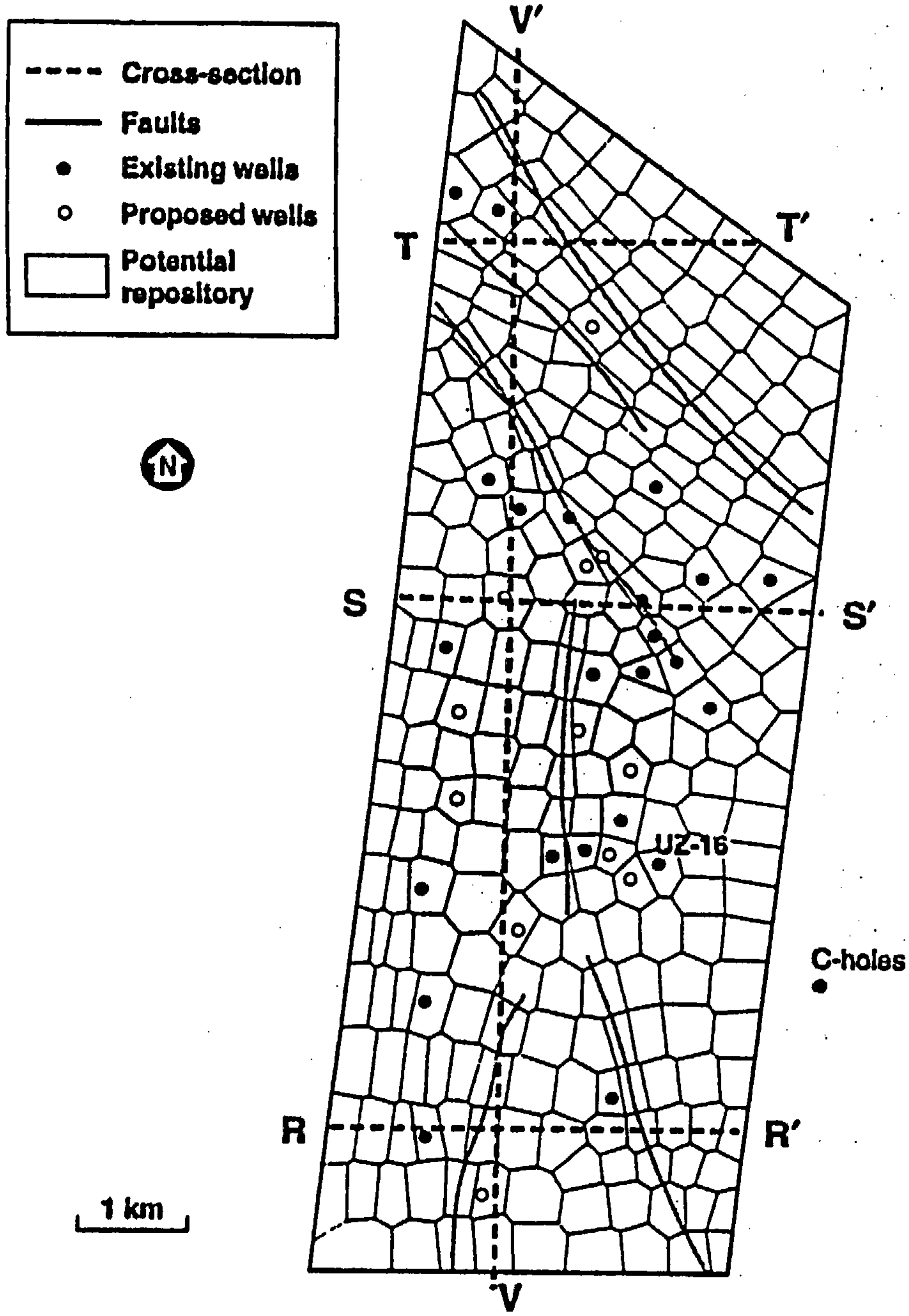

NW
SE
Solitario Canyon Fault
Yucca Crest Well USW H-5
Ghost Dance Fault
Well USW G-4
Well UE25 a1
Bow Ridge Fault
Elevation (m)
1500
1400
1300
1200
1100
1000
900
800
1 km
Tiva Canyon
Topopah Spring
Paintbrush
Calico Hills non-welded

Flexibility for Grid Modifications

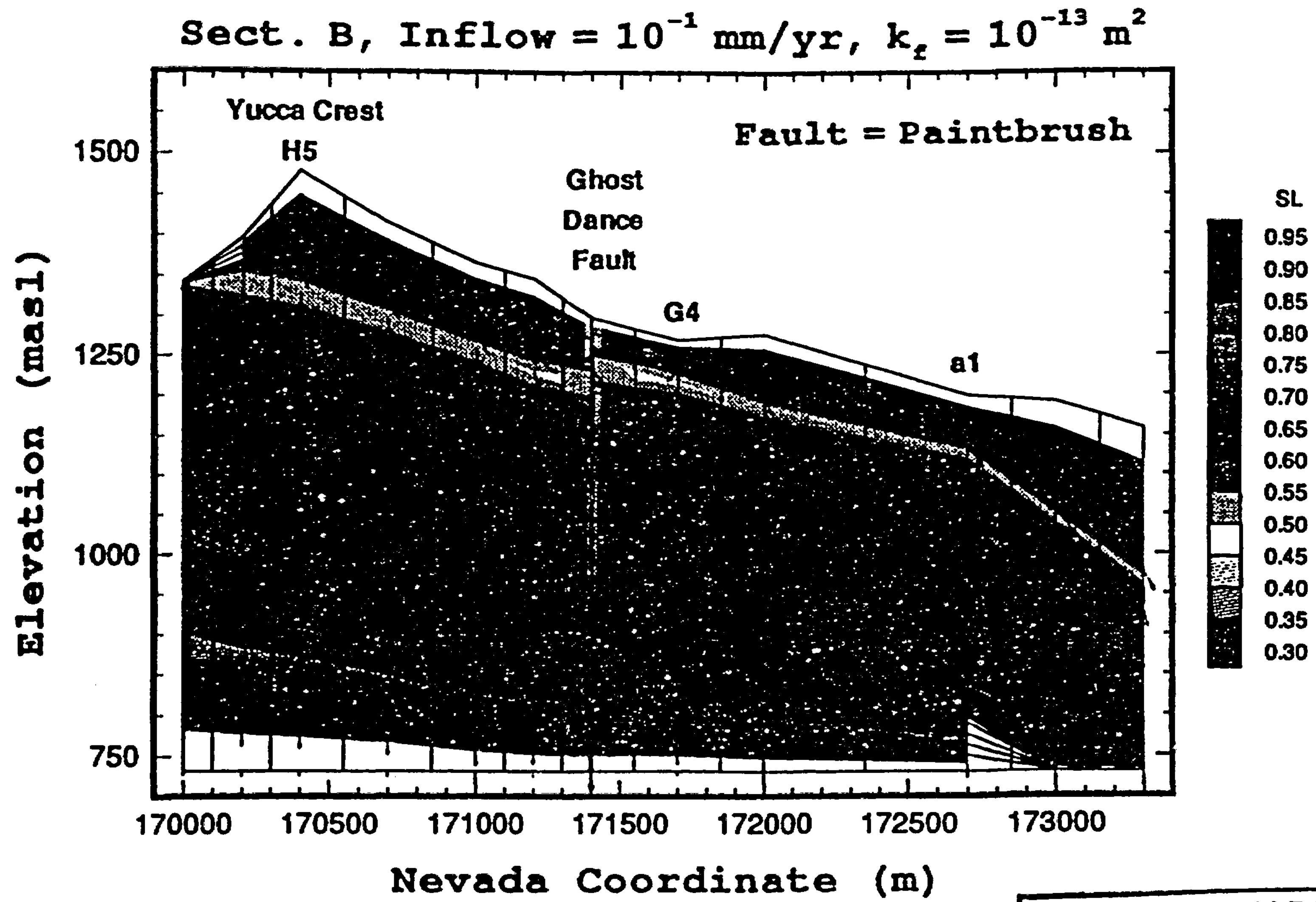
- The three-dimensional grid is *almost completely* computer generated
- Some manual patching of grid elements near faults is necessary

What have we learned so-far?

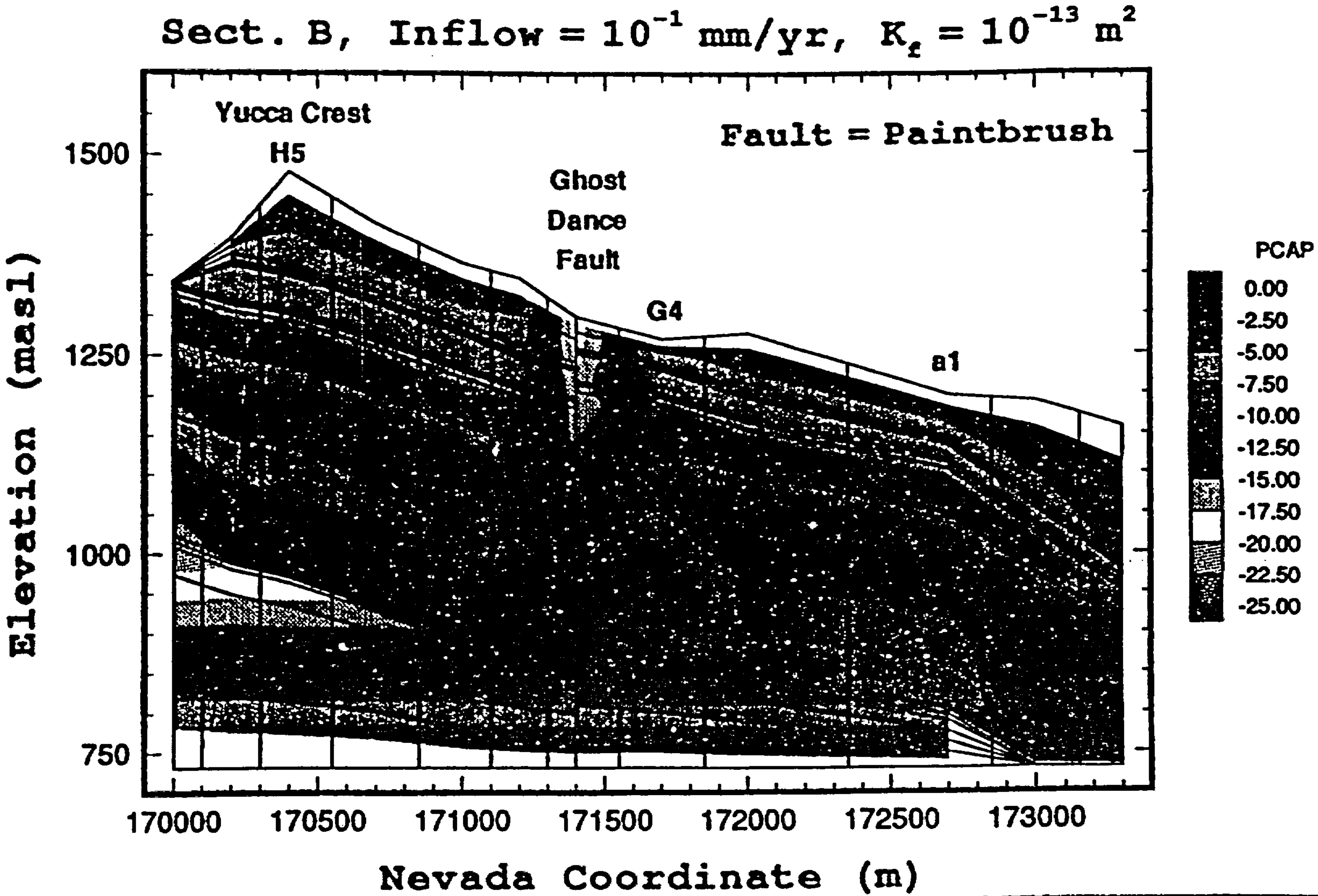
- Two-dimensional simulations
- Effects of major faults
- Grid Effects
- Three-dimensional simulations



Cross-section
Faults
Existing wells
Proposed wells
Potential repository
N
V′
T
T′
S
S′
R
R′
V
UZ-16
C-holes
1 km



PRELIMINARY DRAFT
INFORMATION ONLY



PRELIMINARY DRAFT
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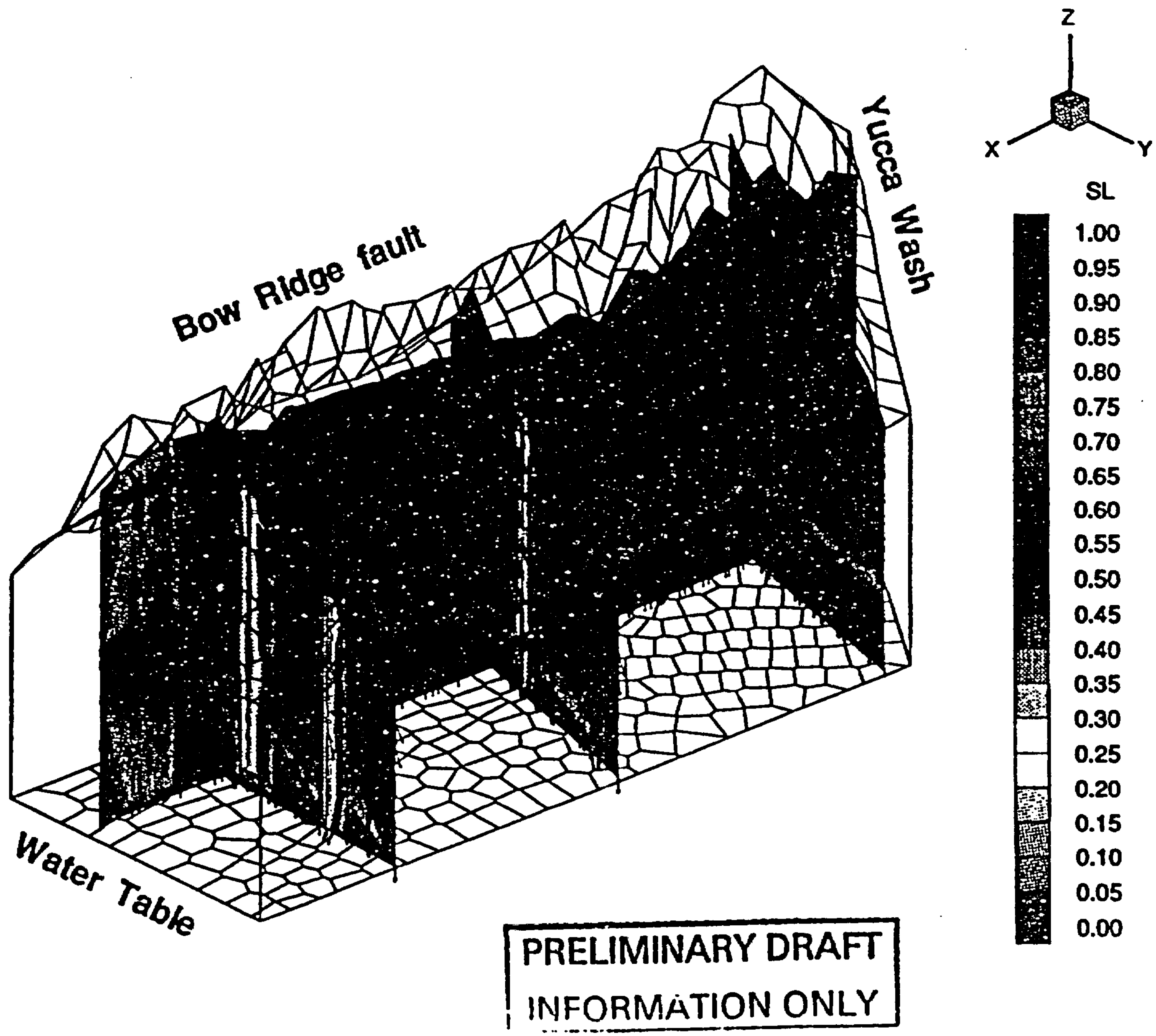
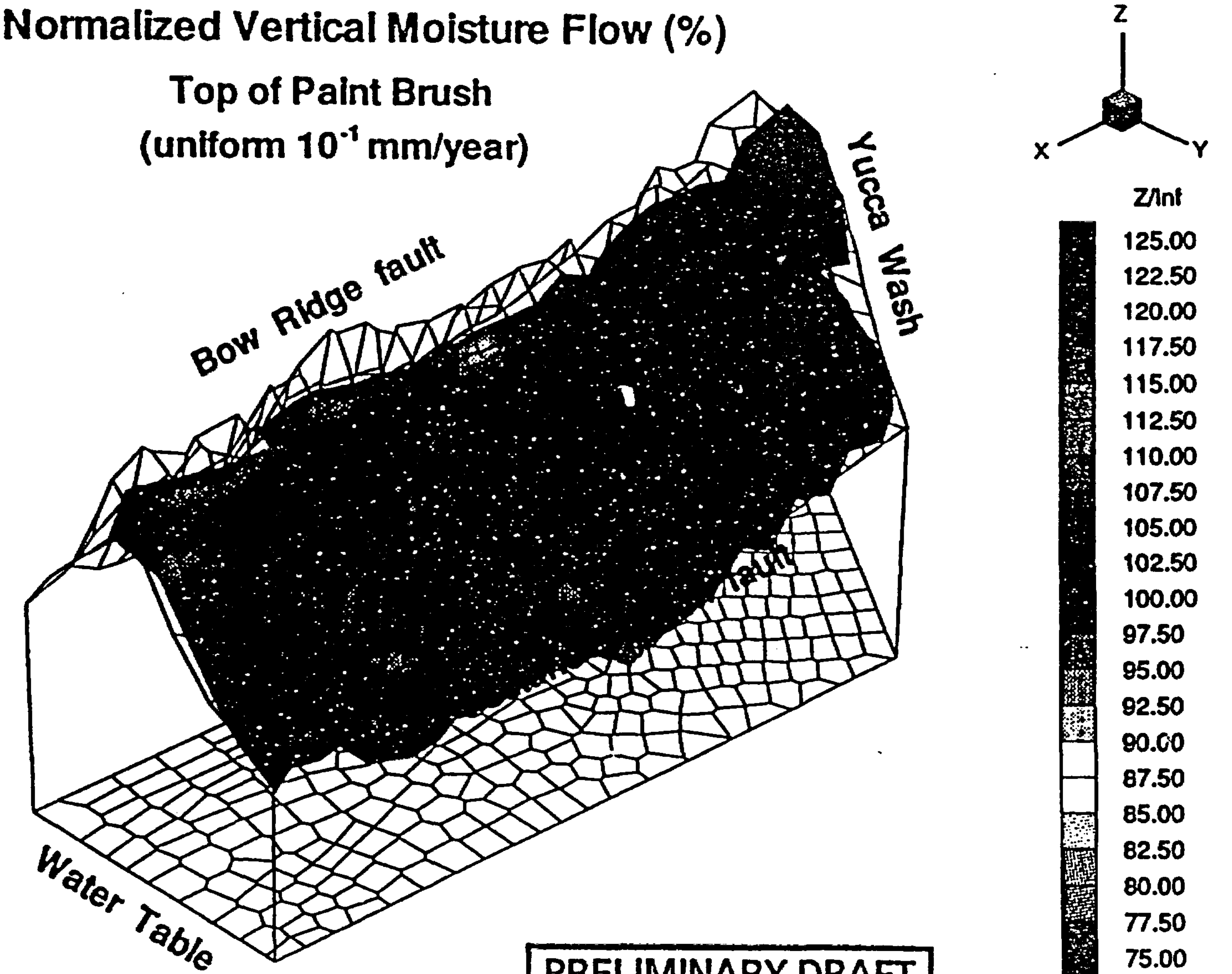
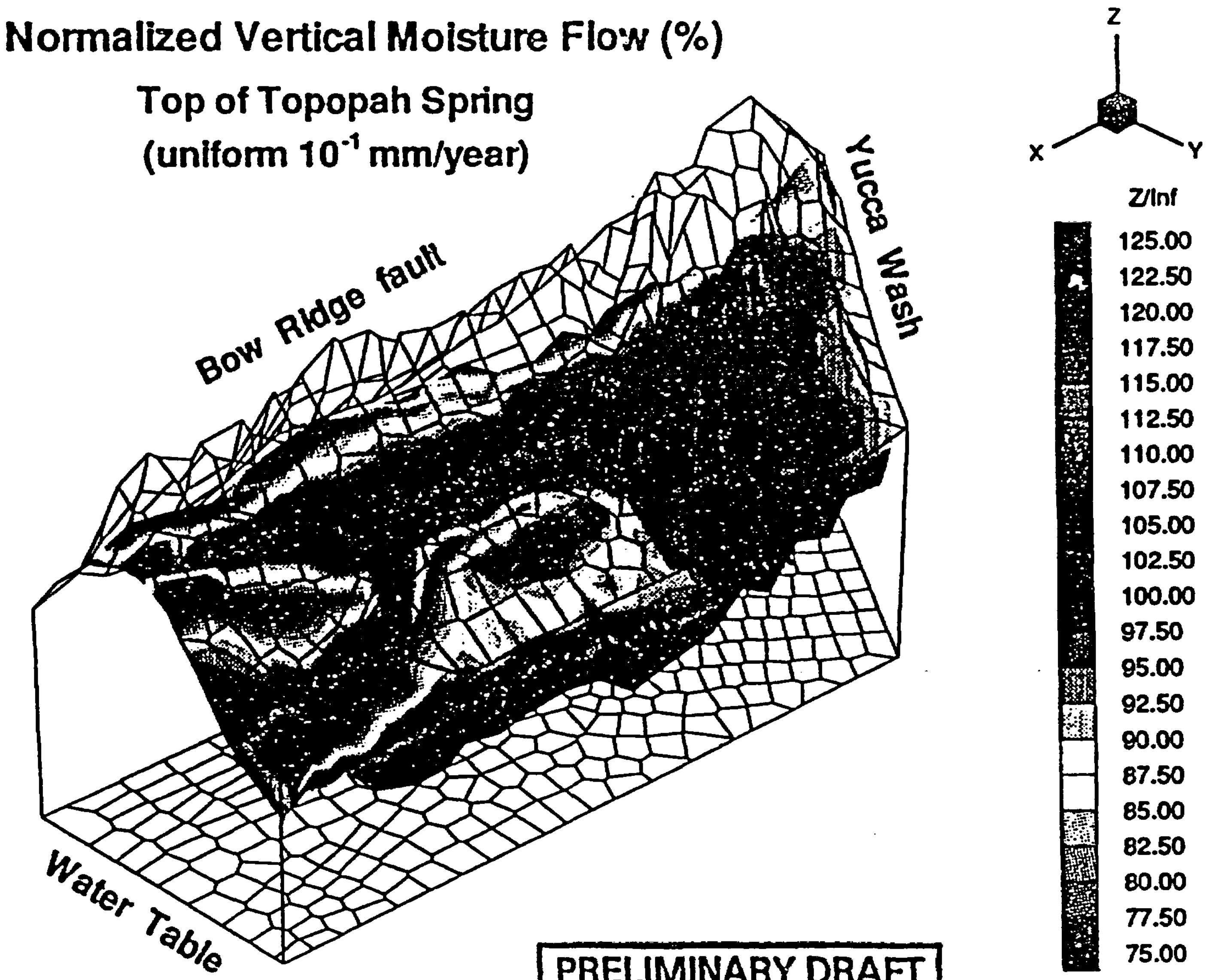

Bow Ridge fault
Yucca Wash
Water Table
Z
X
Y
SL
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
PRELIMINARY DRAFT
INFORMATION ONLY

Normalized Vertical Moisture Flow (%)

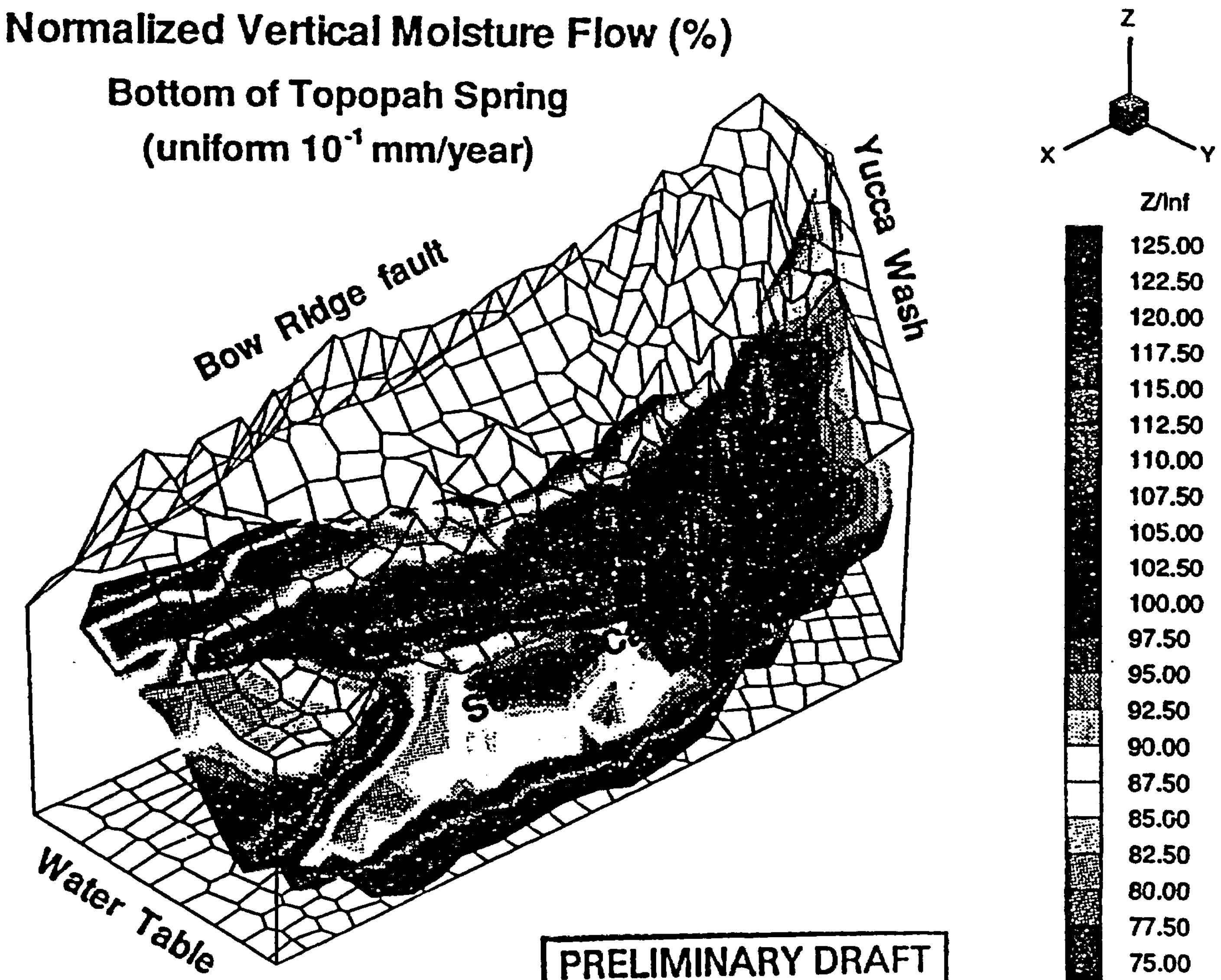
Top of Paint Brush
(uniform 10^{-1} mm/year)



PRELIMINARY DRAFT
INFORMATION ONLY



PRELIMINARY DRAFT
INFORMATION ONLY

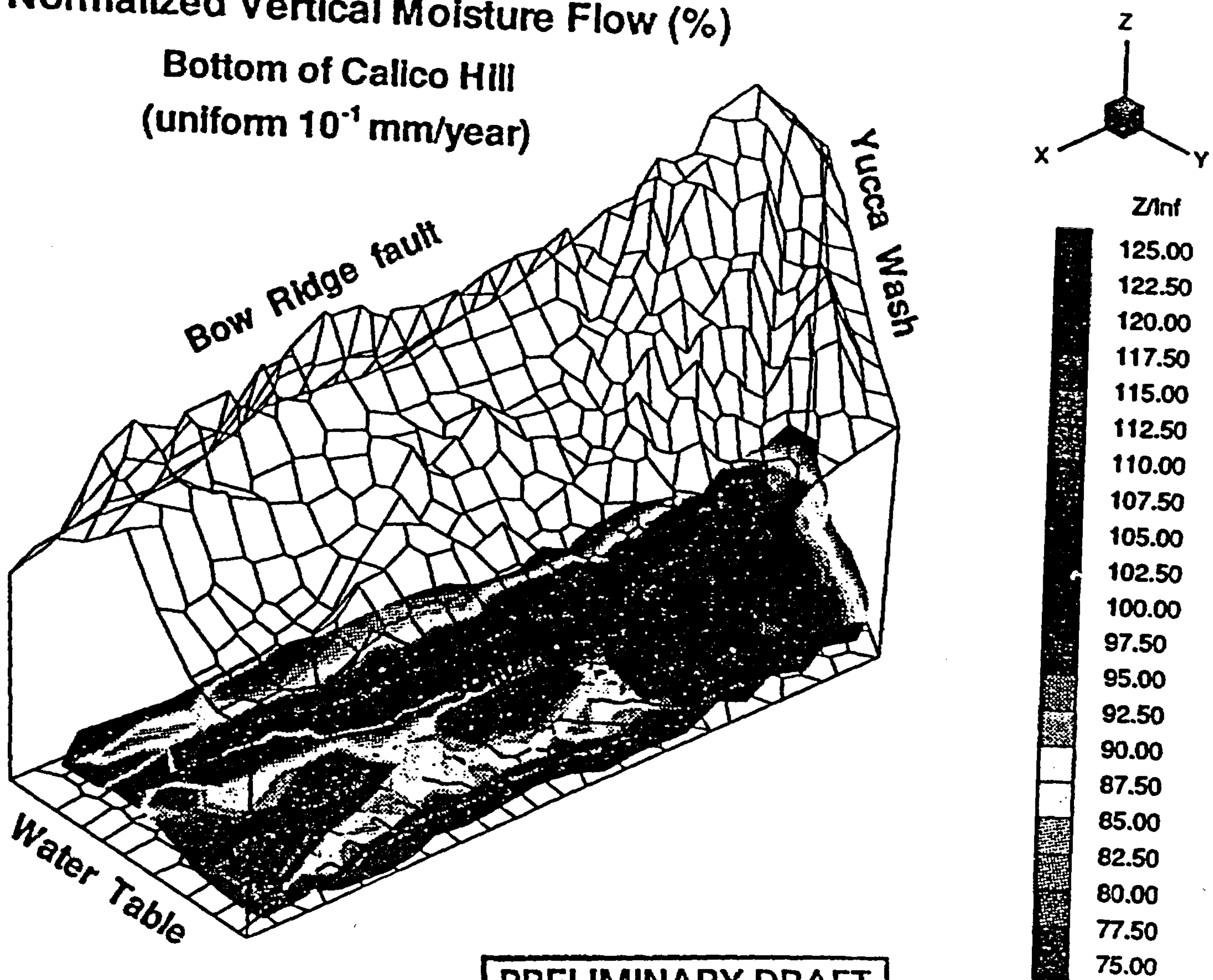


PRELIMINARY DRAFT
INFORMATION ONLY

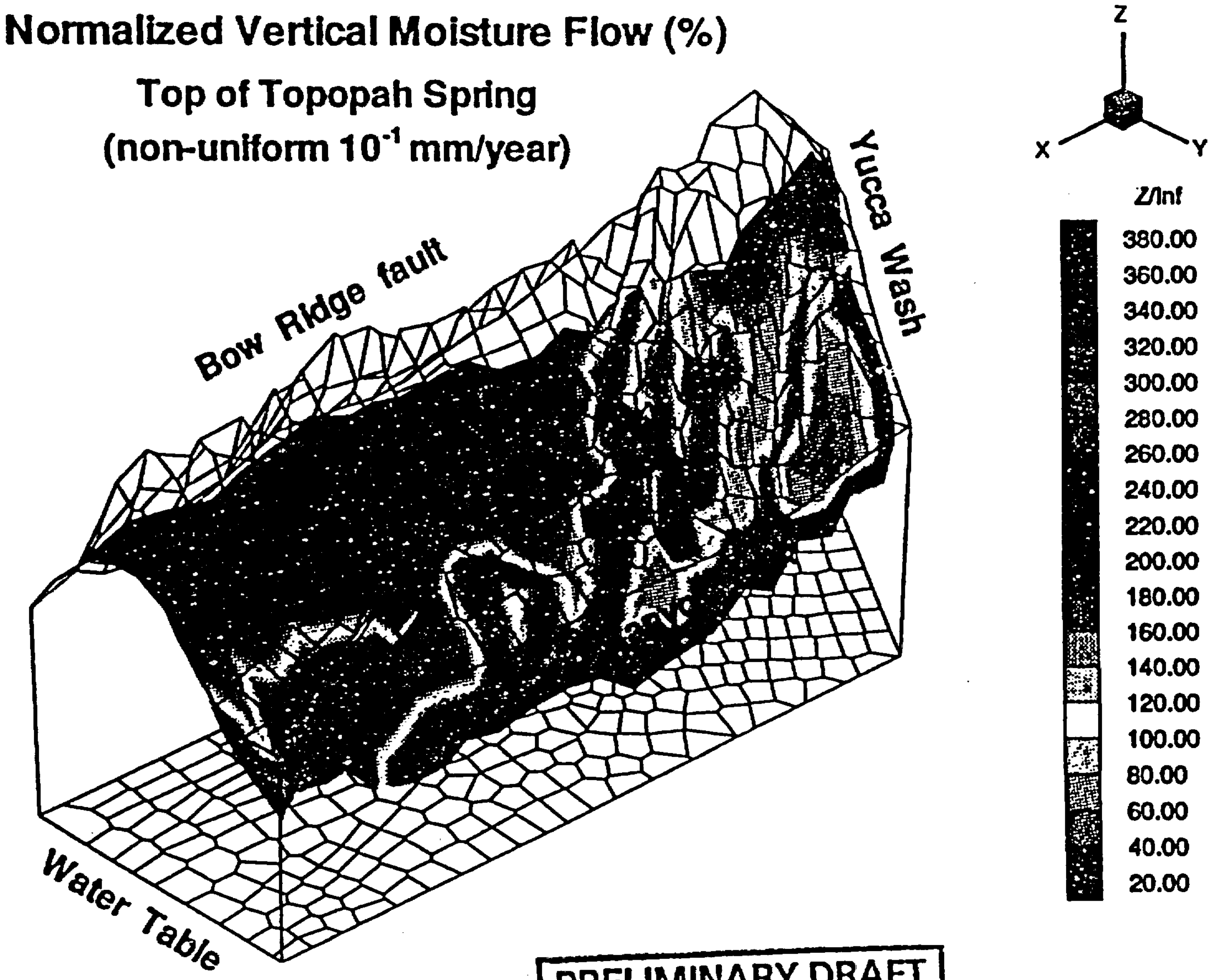
Normalized Vertical Moisture Flow (%)

Bottom of Calico Hill

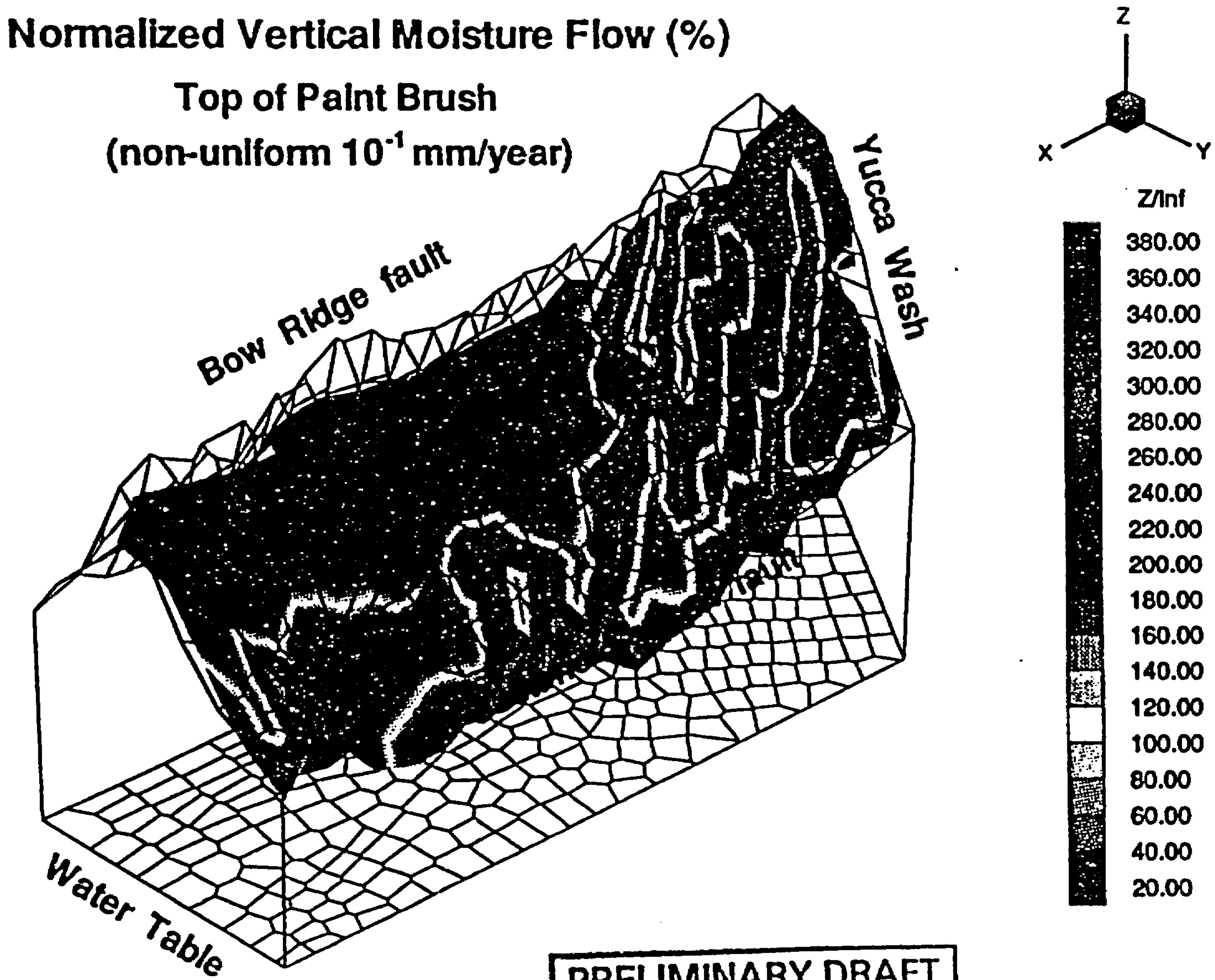
(uniform 10^{-1} mm/year)



PRELIMINARY DRAFT
INFORMATION ONLY



PRELIMINARY DRAFT
INFORMATION ONLY

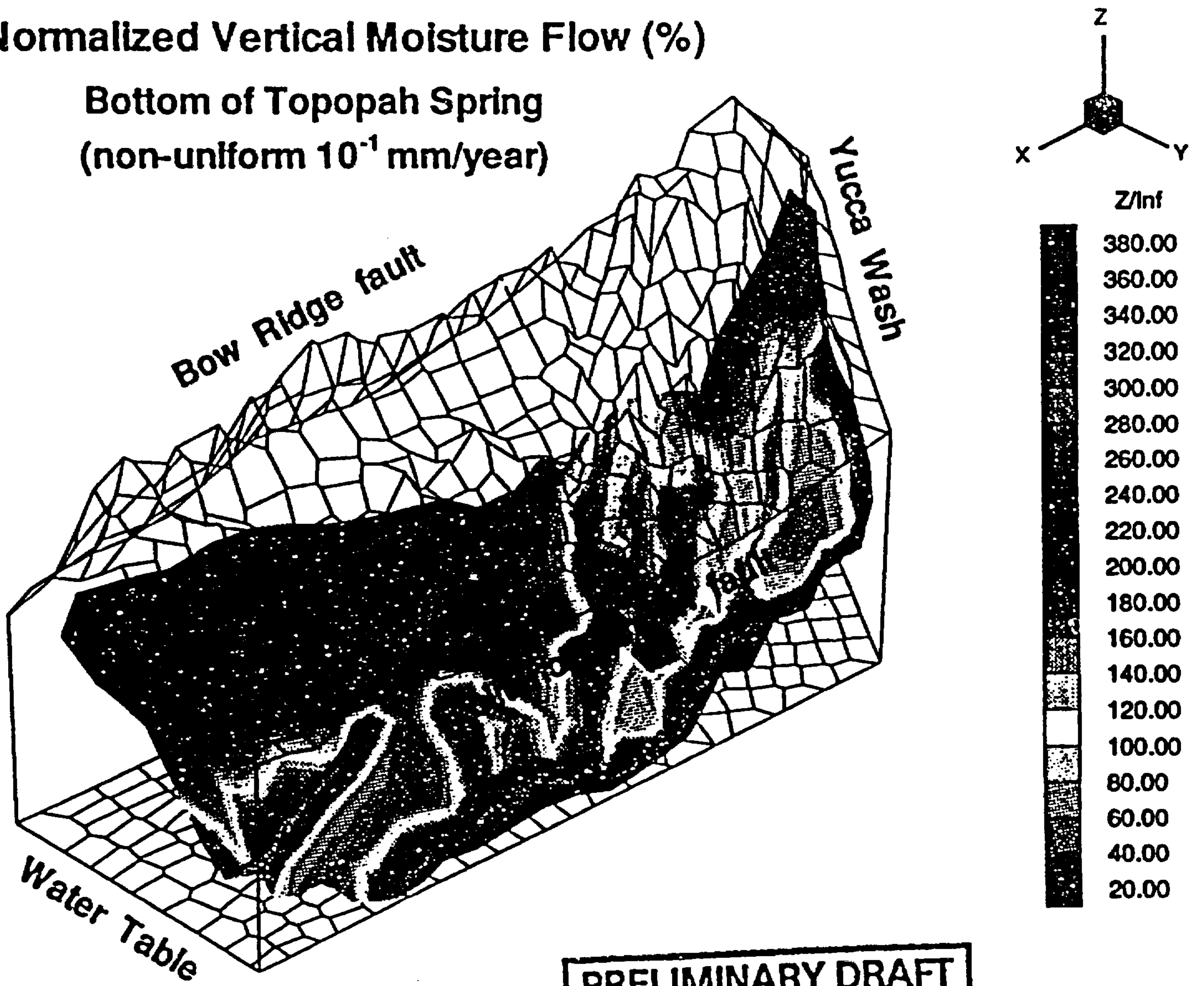


Normalized Vertical Moisture Flow (%)
Top of Paint Brush
(non-uniform 10⁻¹ mm/year)
Bow Ridge fault
Yucca Wash
Water Table
Z
X
Y
Z/Inf
380.00
360.00
340.00
320.00
300.00
280.00
260.00
240.00
220.00
200.00
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00

Normalized Vertical Moisture Flow (%)

Bottom of Topopah Spring

(non-uniform 10^{-1} mm/year)

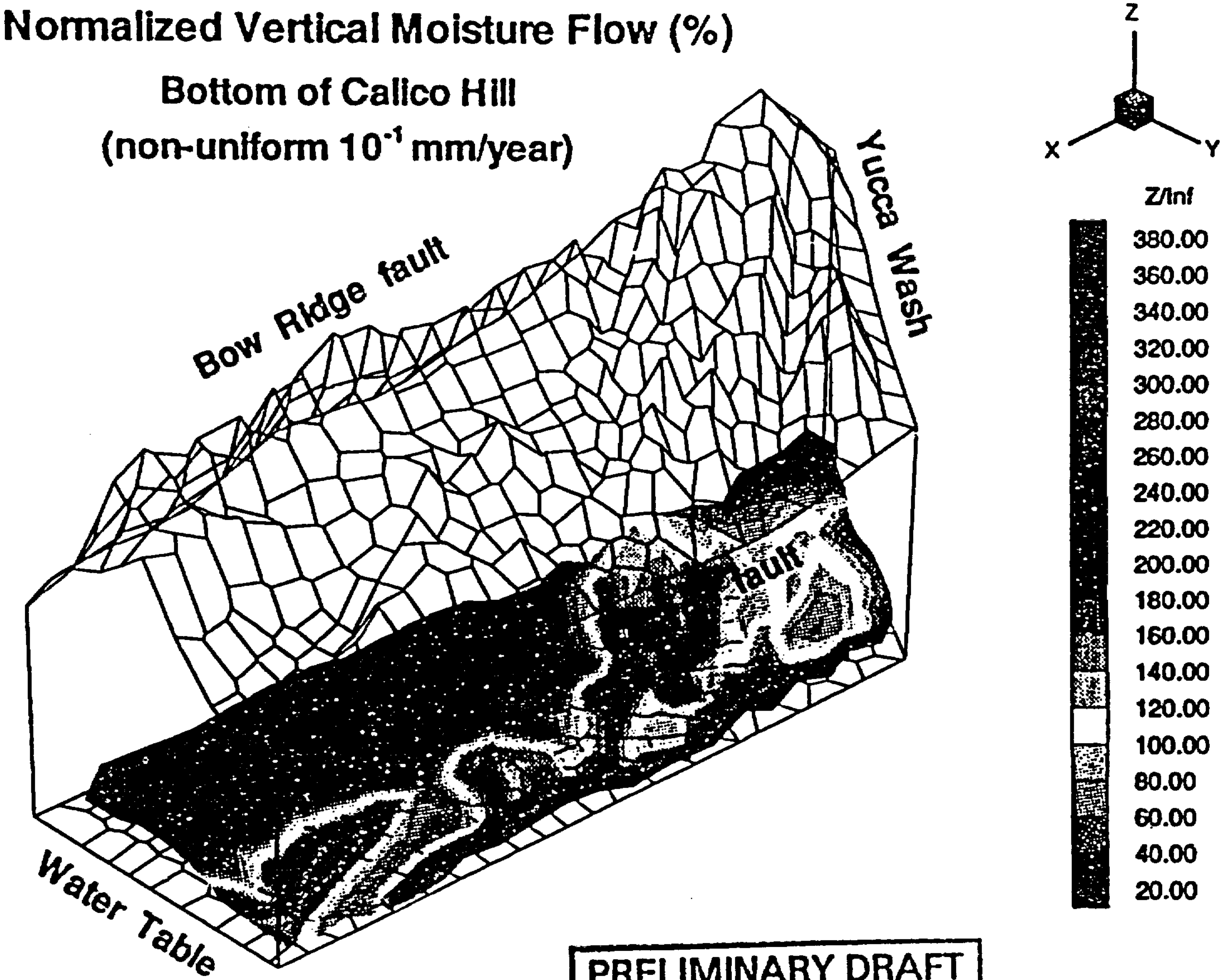


PRELIMINARY DRAFT
INFORMATION ONLY

Normalized Vertical Moisture Flow (%)

Bottom of Calico Hill

(non-uniform 10^{-1} mm/year)



PRELIMINARY DRAFT
INFORMATION ONLY

What are we doing now?

- Completing reports on:
  - (1) moisture flow
  - (2) decoupling of TOUGH
  - (3) grid effects
- Performing 3-D simulations to investigate areas where 1-D, 2-D and 3-D flows occur at Yucca Mountain
- Performing simulations to match observed behavior in UZ-14.

Where are we going?

- Incorporation of geothermal gradient
- Incorporation of gas flow
- Development of a new numerical grid incorporating the ESF
- Model sensitivity ("enough data")
- Periodic release of model data to Performance Assessment personnel (retardation, thermal loading studies, etc.)

Why is the work technically sound?

- Quarterly modeling meetings
- Publications in IHLRW meetings and refereed journals
- Periodic peer review (LBL, USGS, DOE, NRC, NWTRB, ACNW)
- Documentation through USGS QA program

Summary

- 3-D site-scale model is operational and is being used to predict conditions at new boreholes and for sensitivity studies
- Major purpose of model to *integrate* the available data and to *guide* in the site-characterization process
- The model is under continuous development with current incorporation of gas flow, geothermal gradient and the ESF

Site Scale Unsaturated Zone Modeling

Edward M. Kwicklis
U.S. Geological Survey
Denver, Colorado

ACNW Working Group Meeting
Las Vegas, Nevada
December 14, 1993

Objectives

- o Develop credible quantitative models of the natural flow system
- o Integrate site data and analyses
- o Guide the site-characterization effort
- o Estimate fluid fluxes
- o Test hypotheses concerning the hydrologic behavior of the site
- o Produce estimates of hydrologic parameters

Site Unsaturated Zone Modeling and Synthesis (SP 8.3.1.2.2.9)

- o Conceptualization of the Unsaturated Zone Hydrologic System (Activity 8.3.1.2.2.9.1)
- o Selection, Development and Testing of Hydrologic-Modeling Computer Codes (Activity 8.3.1.2.2.9.2)
- o Simulation of the Natural Hydrogeologic System (Activity 8.3.1.2.2.9.3)
- o Stochastic Modeling and Uncertainty Analysis (Activity 8.3.1.2.2.9.4)
- o Site Unsaturated-Zone Integration and Synthesis (Activity 8.3.1.2.2.9.5)

Outline:

- o Introduction
  - Objectives
- o Description of profiles
  - Porosity, saturation and water potential
  - Assessment of measurement error
- o Regression relations
  - van Genuchten functions
  - Regression results
- o Application of regression results to UZ boreholes
  - Water potentials
  - Effective hydraulic conductivities
  - Liquid water fluxes
  - Comparison of predicted and measured $K_e(S)$
- o Isotope data
  - Tritium
  - ^{14}C
- o Conclusions

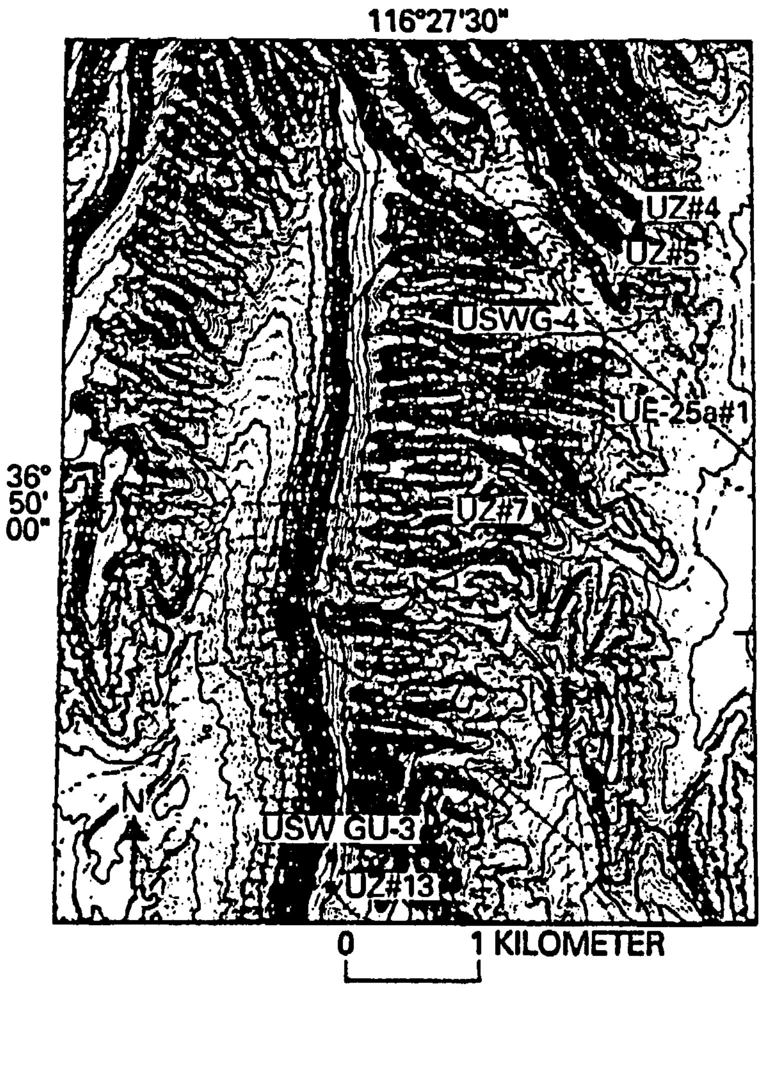
Objectives:

o Examine the internal consistency of data collected to date from laboratory and field measurements.

o Estimate liquid water fluxes through the nonwelded and bedded units in the unsaturated zone.

o Better understand recharge mechanisms and redistribution of infiltration beneath the surface of Yucca Mountain.

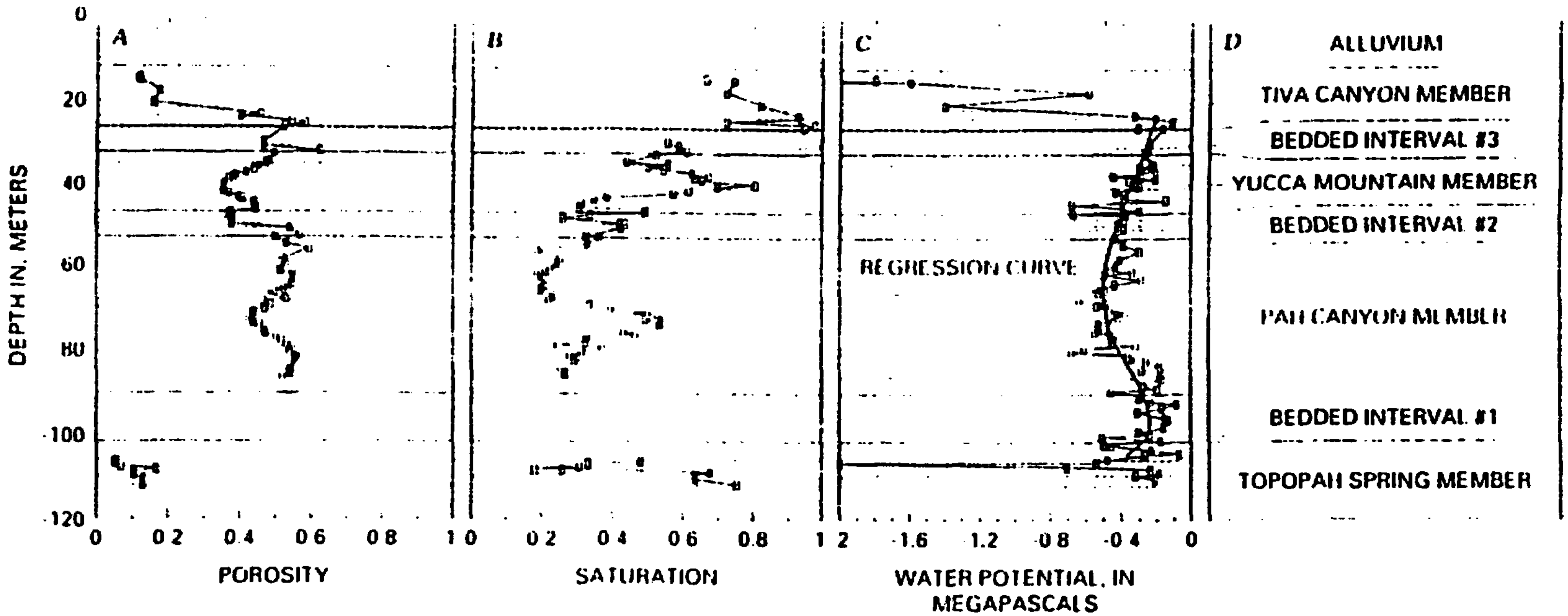
Borehole locations



Description of profiles

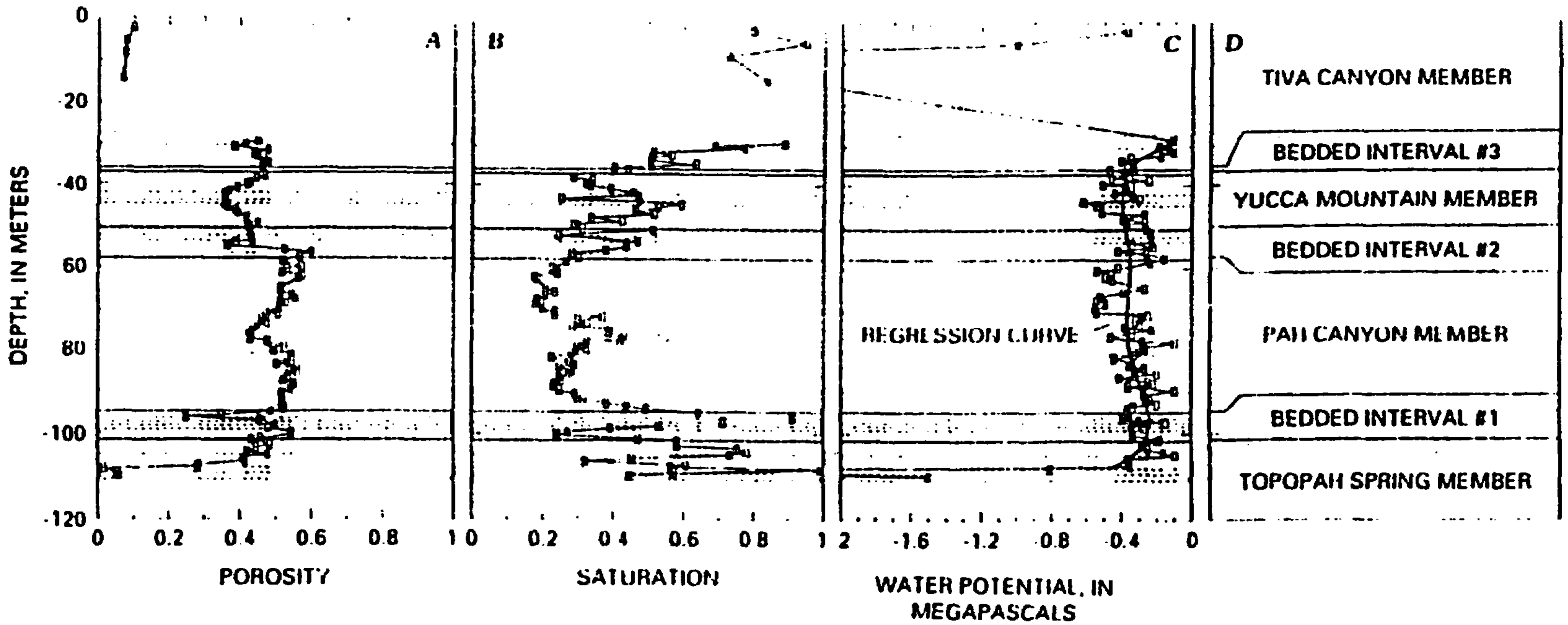
- o Provide an overview of the ϕ, S and ψ profiles in each hole.
- o Highlight trends, differences and similarities between holes.
- o Emphasize the role of the microstratigraphy in controlling the distribution of S and ψ.

Data for UZ #4



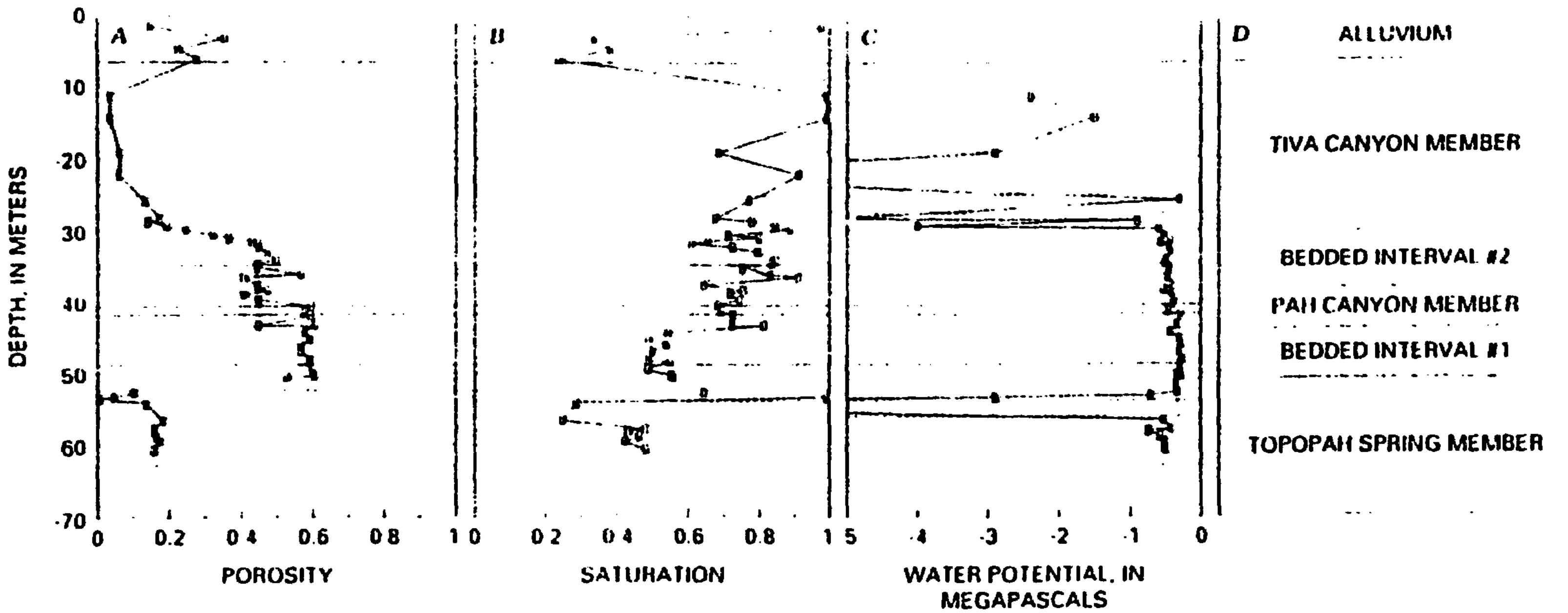
A
B
C
D
DEPTH IN. METERS
0
20
40
60
80
100
120
0
0 2
0.4
0 6
0 8
1 0
0 2
0 4
0 6
0.8
1 2
1.6
1.2
0 8
0 4
0
POROSITY
SATURATION
WATER POTENTIAL, IN MEGAPASCALS
REGRESSION CURVE
ALLUVIUM
TIVA CANYON MEMBER
BEDDED INTERVAL #3
YUCCA MOUNTAIN MEMBER
BEDDED INTERVAL #2
PAH CANYON MEMBER
BEDDED INTERVAL #1
TOPOPAH SPRING MEMBER

Data for UZ #5



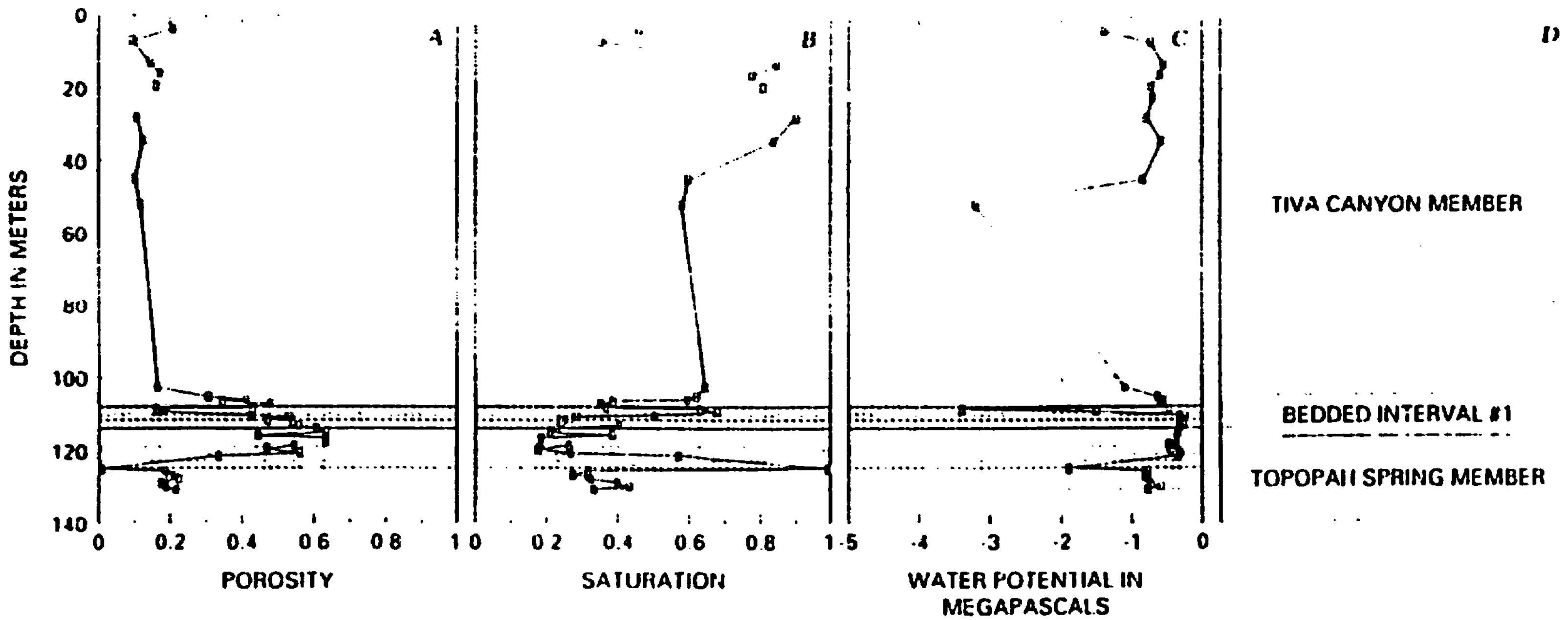
PRELIMINARY DRAFT
INFORMATION ONLY

Data for UZ #7



PRELIMINARY DRAFT
INFORMATION ONLY

Data for UZ #13

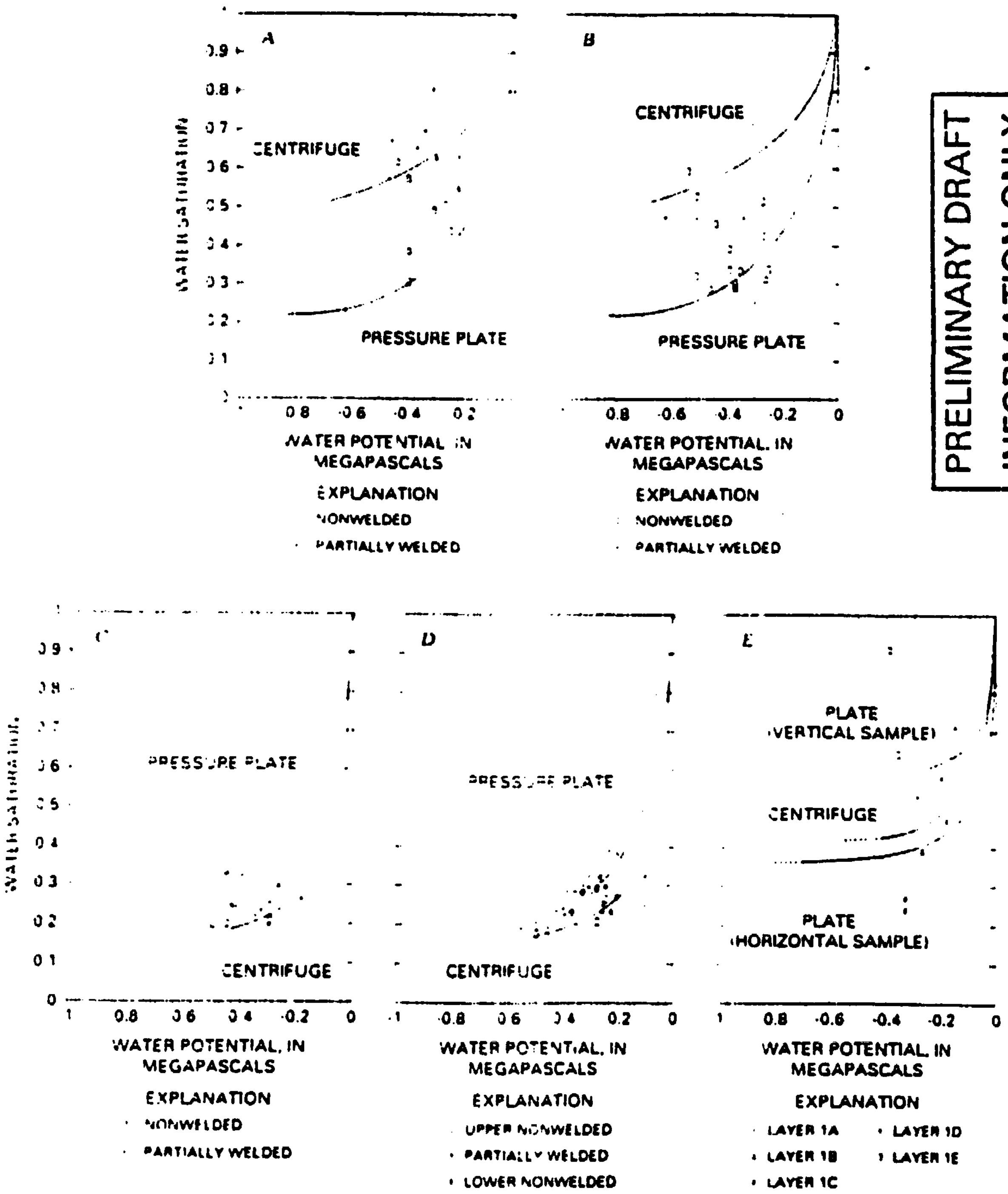


PRELIMINARY DRAFT
INFORMATION ONLY

Examination of ϕ, S and ψ profiles shows

- o Stratigraphy changes with geographic location.
- o Even stratigraphic horizons of geologically similar origin show variability in ϕ, and presumably other properties as well.
- o Microstratigraphy, as reflected in ϕ, significantly influences local values of S and to a lesser extent ψ.

Comparison of scatterplots of S versus ψ with measured moisture retention data (a) Yucca Mountain Member UZ #4 (b) Yucca Mountain Member UZ #5 (c) Pah Canyon Member UZ #4 (d) Pah Canyon Member UZ #5 (e) Bedded Interval #1 UZ #5



Measurement Error

- o When sample ϕ is small, small measurement error in either ϕ or θ_g can produce large errors in S.

- o Inherent accuracy of psychrometer not better than 100 kPa.
  - Additional error possible due to lack of vapor-liquid equilibrium.

- o Plots of S versus ψ data for microstratigraphic units exhibit considerable scatter, reflecting both measurement error and heterogeneity.

Regression Analysis

- o Compensate for relatively few measurements of $S(\psi)$ and $K_e(S)$ at UZ boreholes.
- o Account for media heterogeneity, as reflected in ϕ-profiles.
- o Examined data set of Peters et al (1984) for correlations between K, ϕ and van Genuchten parameters α, β, S_s and S_r.

van Genuchten expression relating S, ψ and K_e:

$$S_e = (1 + (\alpha|\psi|)^{\beta})^{-\lambda} \tag{1}$$

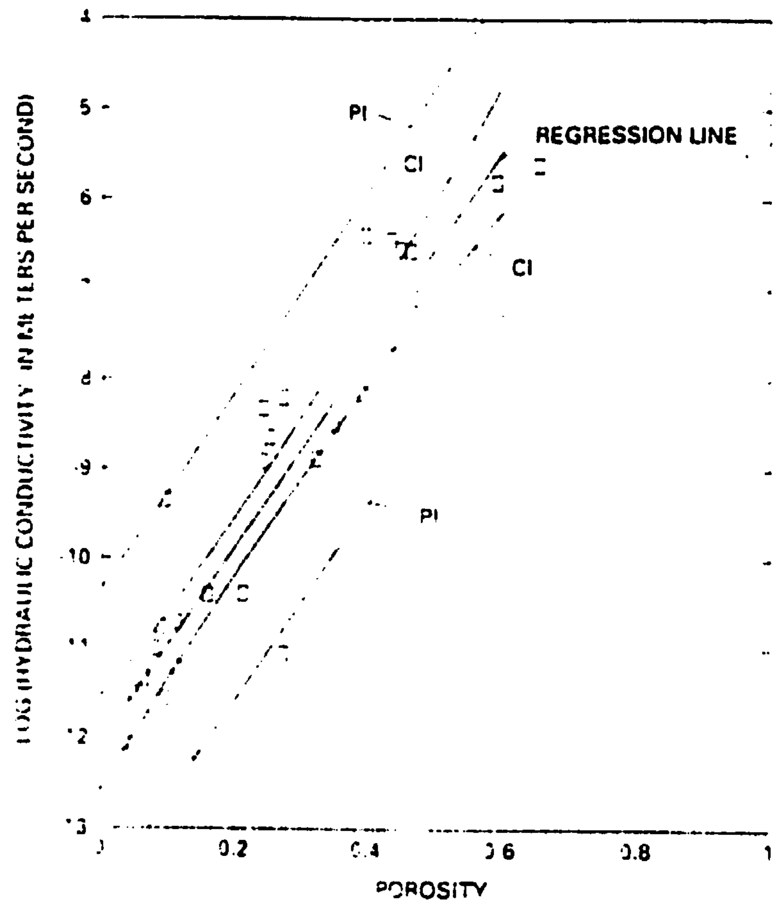
$S_e = (S - S_r)/(S_s - S_r)$ is scaled liquid water saturation;
S_r is residual liquid water saturation;
S_s is the satiated liquid water saturation; and
α, β and λ are fitting parameters ($\lambda = 1 - 1/\beta$).

ψ were estimated by inverting equation 1:

$$\psi = -1/\alpha \, (S_e^{-1/\lambda} - 1)^{1-\lambda} \tag{2}$$

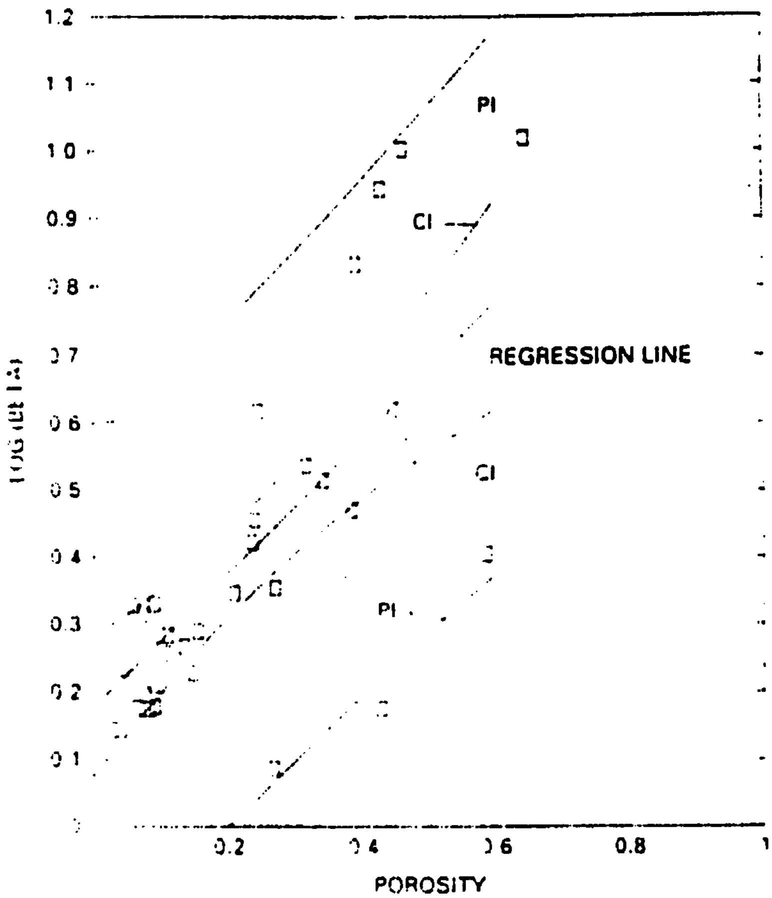
K_e were estimated using:

$$K_e = KS_e^{0.5}[1 - (1-S_e^{1/\lambda})^{\lambda}]^2 \tag{3}$$

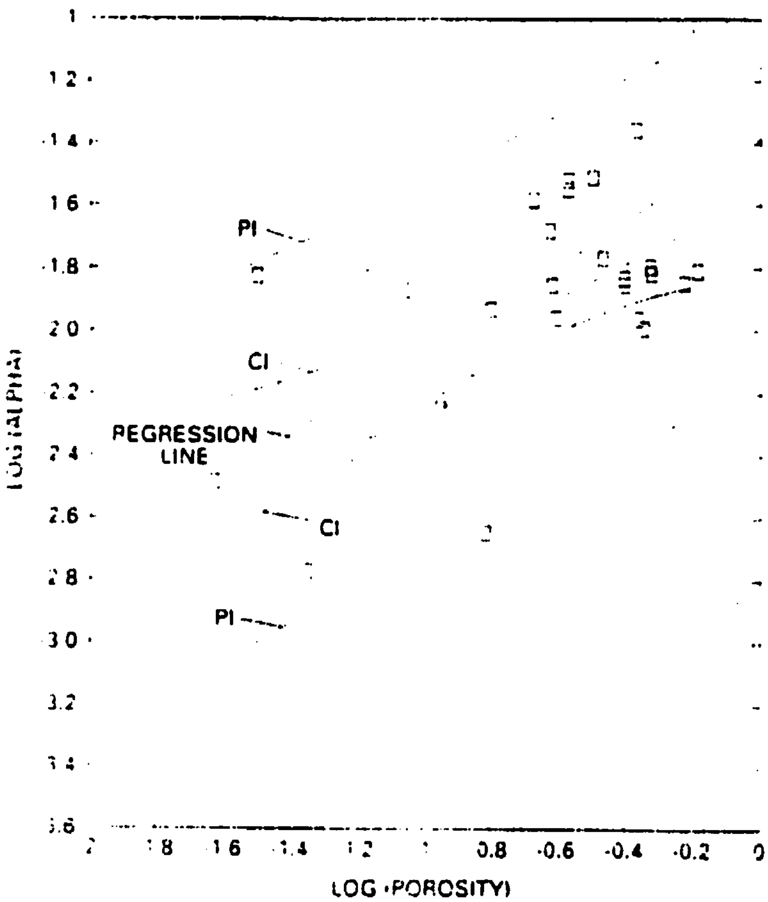


Log K versus ϕ data from Peters et al. with calculated regression line, and 95% confidence and prediction intervals.

PRELIMINARY DRAFT
INFORMATION ONLY



Log β versus φ data from Peters et al. with calculated regression line, and 95% confidence and prediction intervals.



Log α versus log ϕ data from Peters et al. with calculated regression line, and 95% confidence and prediction intervals.

PRELIMINARY DRAFT
INFORMATION ONLY

Summary of Regression Results

- o Statistically significant relations (at a 0.05 level of significance were established between

  -log K versus ϕ ($r^2 = 0.885$)

  -log β versus ϕ ($r^2 = 0.463$)

  -log α versus log ϕ ($r^2 = 0.344$)

  -log K versus log α, log β ($r^2 = 0.652$)

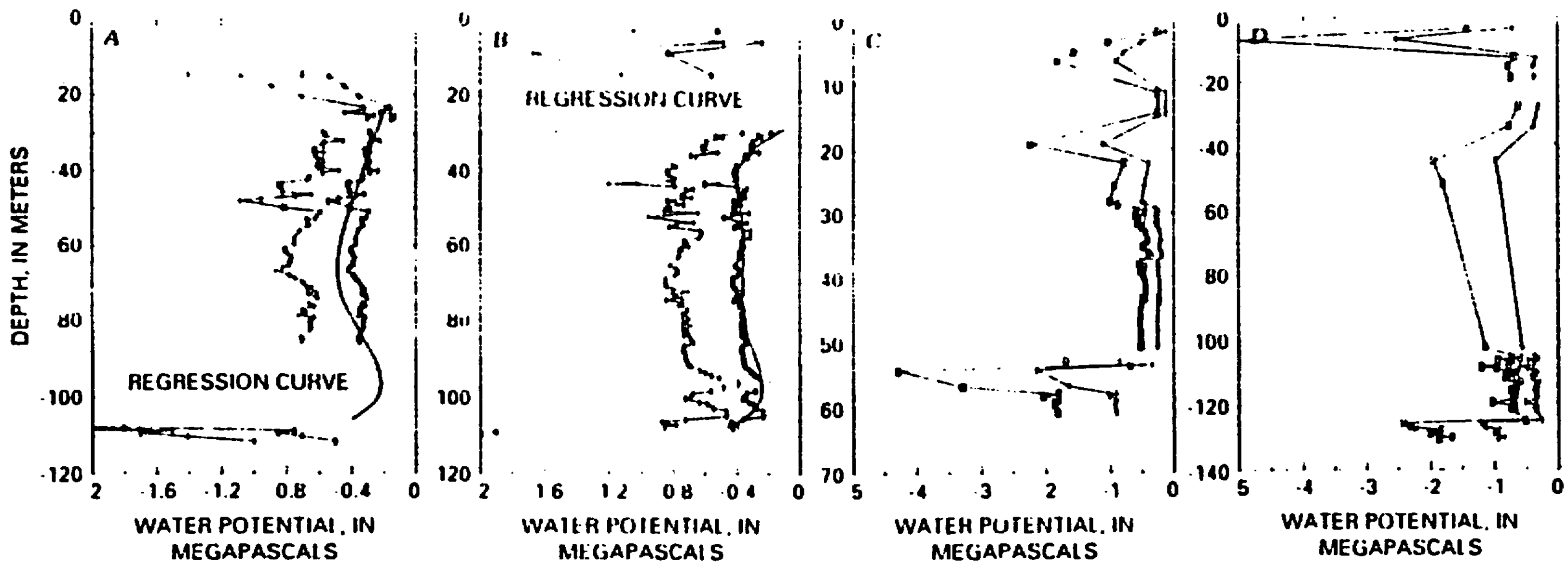
- o No correlation between S_r and ϕ, or between log β and log α.

- o Slope of θ_{max} versus ϕ is 0.785, suggesting full saturation not achieved.

Application of regression results to UZ #4, UZ #5, UZ #7 and UZ #13

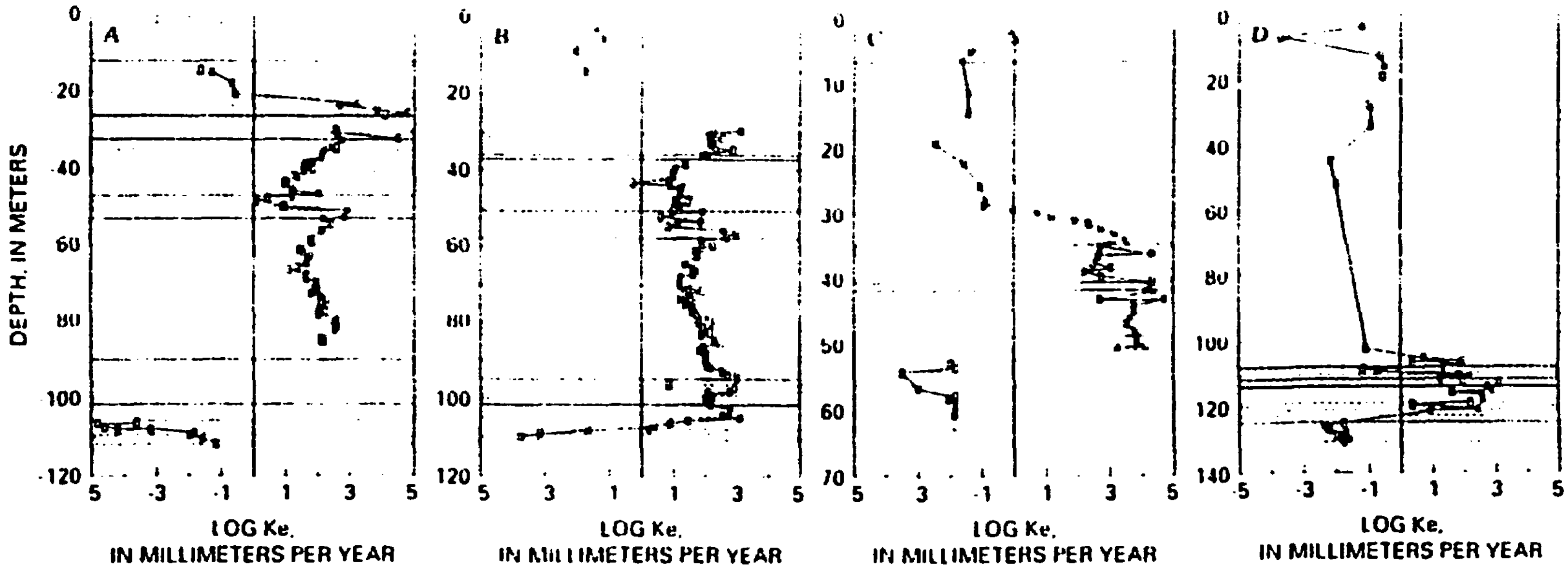
- o Regression relations were used with measured ϕ and S to estimate ψ.
- o Regression relations were used with measured ϕ and S to estimate K_e.
- o K_e were used with estimated and measured ψ to estimate flux.

Predicted ψ versus depth profiles for (a) UZ #4 (b) UZ #5 (c) UZ #7 and (d) UZ #13. Also shown are regression curves fit to measured ψ data for UZ #4 and UZ #5.



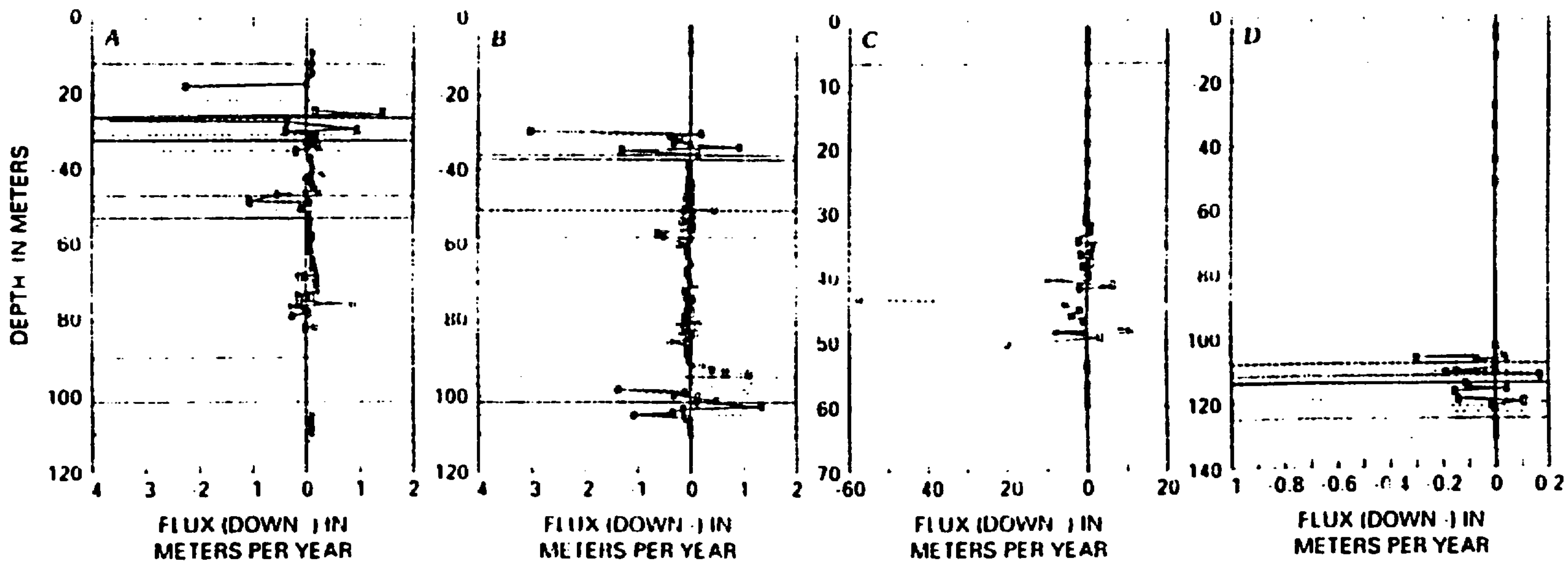
PRELIMINARY DRAFT
INFORMATION ONLY

Estimated log effective hydraulic conductivity versus depth profiles for (a) UZ #4 (b) UZ #5 (c) UZ #7 and (d) UZ #13.



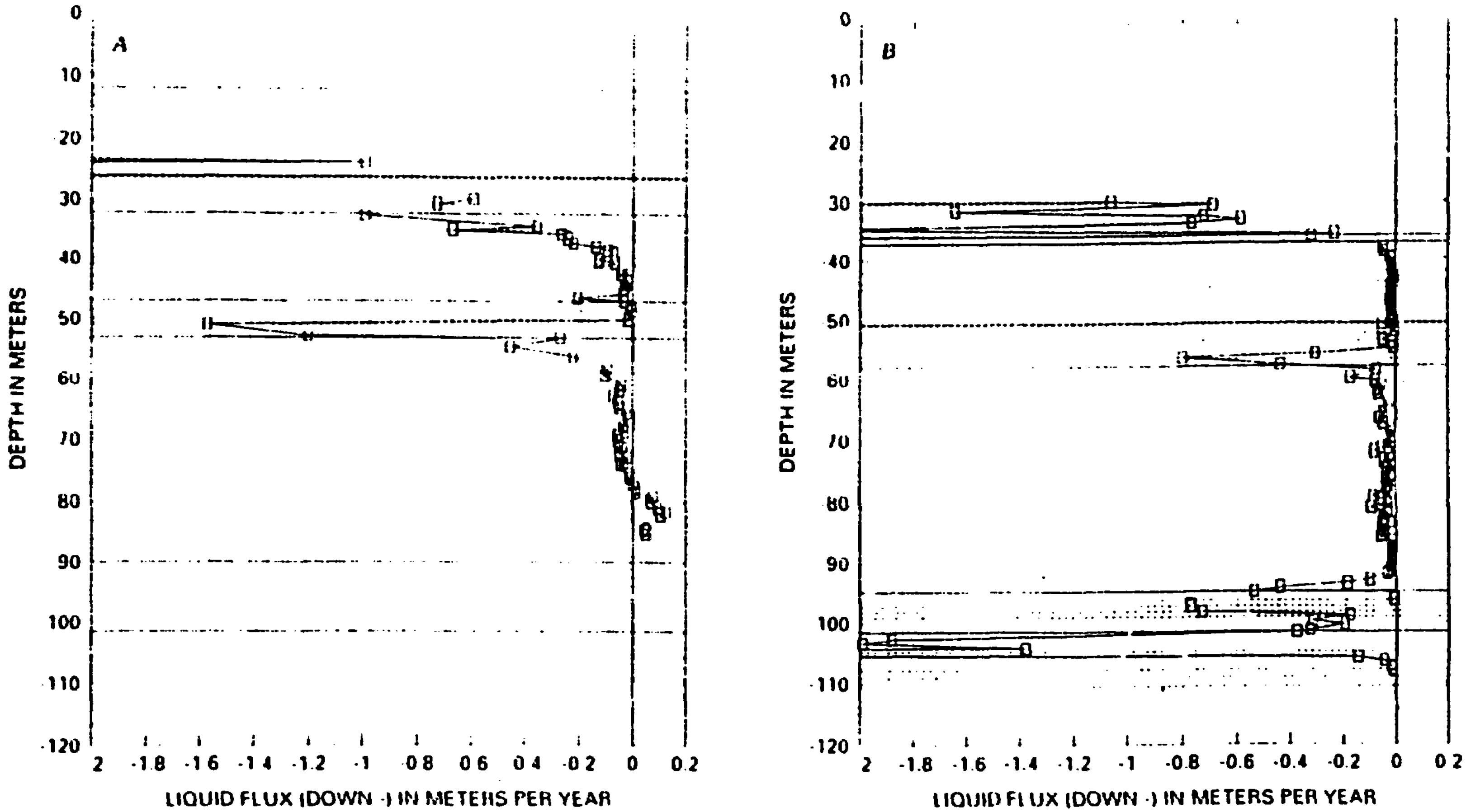
PRELIMINARY DRAFT
INFORMATION ONLY

Estimated liquid flux versus depth profiles calculated with predicted ψ values (a) UZ #4 (b) UZ #5 (c) UZ #7 and (d) UZ #13.



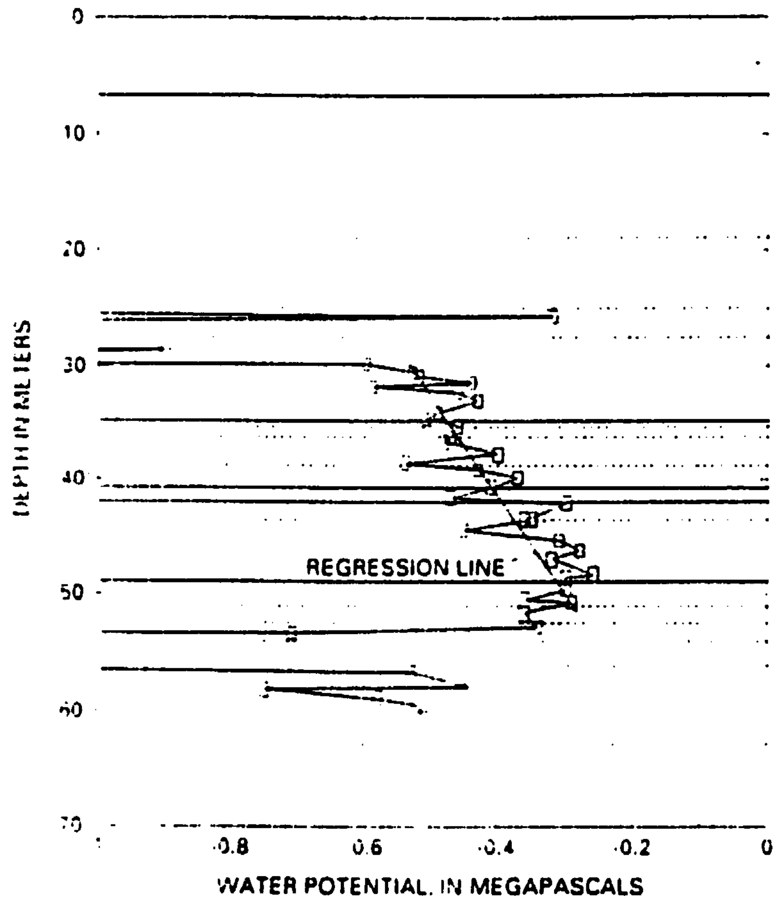
PRELIMINARY DRAFT
INFORMATION ONLY

Estimated liquid flux versus depth profiles calculated using 5th order polynomial fits to the measured water potential data (a) UZ #4 and (b) UZ #5.



PRELIMINARY DRAFT
INFORMATION ONLY

ψ versus depth profile at UZ #7, with fitted line (r^2=0.69) to water potential data between -29.8 to -51.6 m.



PRELIMINARY DRAFT
INFORMATION ONLY

Assessment of uncertainty in $K_e(S)$

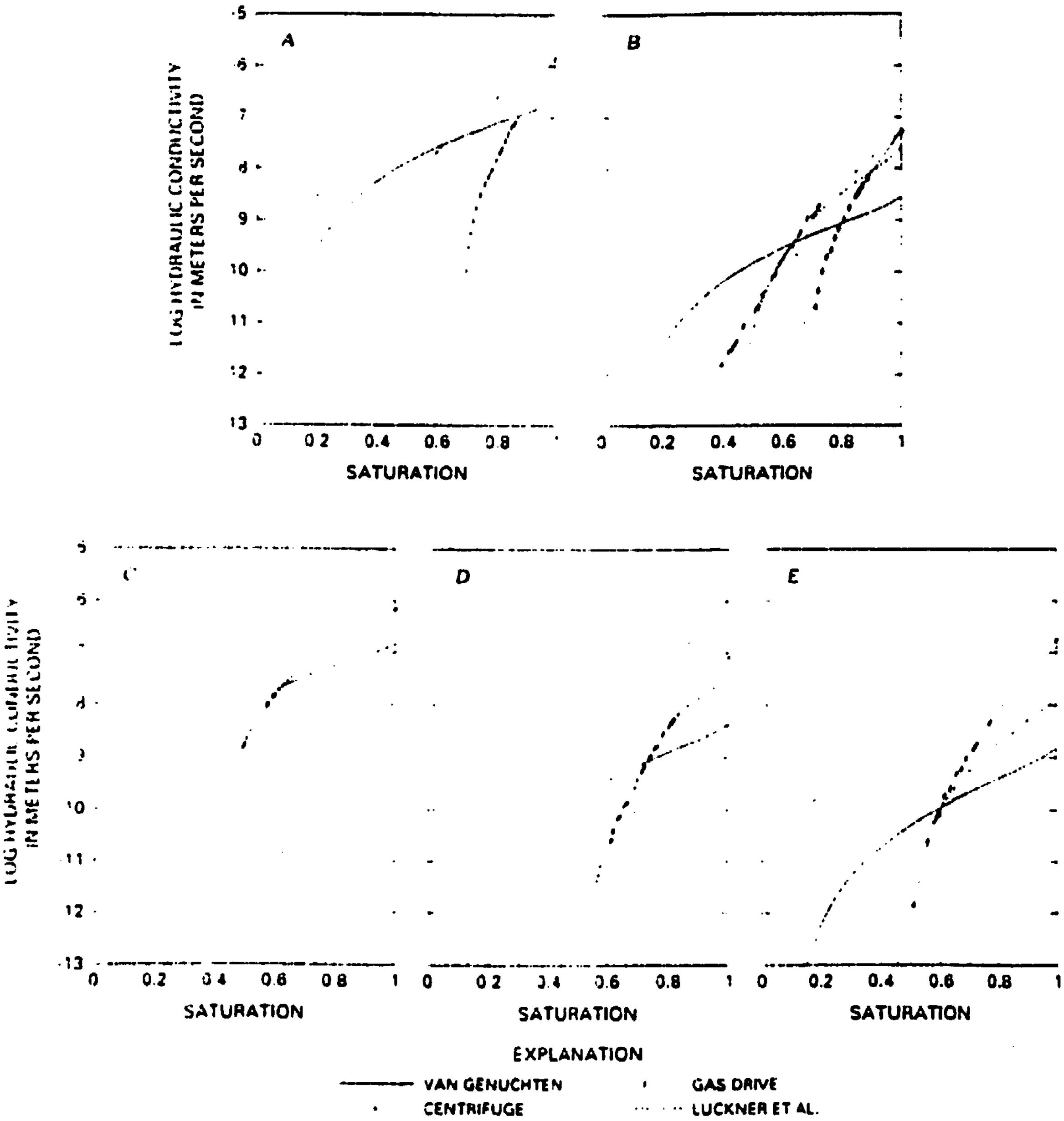
- o Compare $K_e(S)$ curves predicted for selected samples on the basis of ϕ with measured $K_e(S)$ curves.

- o Accounts for the combined uncertainty in $K_e(S)$ that results from

  - imperfect correlations between K, β, S_s, S_r and ϕ, and

  - questionable validity of van Genuchten $K_e(S)$ function to Yucca Mountain tuffs.

Comparison between measured and predicted effective hydraulic conductivity curves (a) Tiva Canyon Member (b) Yucca Mountain Member (c) Pah Canyon Member (d) Bedded Interval #1 and (d) Topopah Spring Member.



Comparison of predicted and measured $K_e(S)$ curves indicate

- o Predicted $K_e(S)$ curves underestimate measured K_e at high S and overestimate K_e at low S.
  - possibly related to underestimation of true S_r and measurement of K at incomplete saturation in Peters et al data set.

Estimates of flux for selected stratigraphic intervals at UZ #4 and UZ #5.

Stratigraphic Interval	Sample ID[a]	Sample borehole + depth	S_{avg} UZ#4	S_{avg} UZ#5	K_s UZ#4 mm/y	K_s UZ#5 mm/y	$d\psi/dz$ +1 UZ#4	$d\psi/dz$ +1 UZ#5	Flux UZ#4 mm/y	Flux UZ#5 mm/y
Tiva Canyon Member (nonwelded)	2A	UE25a#1 -65.07m to -65.23m	.962 (2)	.555 (6)	2.1E4	1.5E-9	1.94	5.85	4.0E4	<<.01
Yucca Mountain Member (partially welded)	5-2	UZ #5 -42.43m to -42.58m	.655 (6)	.398 (3)	1.7E1	5.2E-2	1.80	0.90	3.0E1	4.7E-2
Pah Canyon Member (partially welded)	4-5	UZ #4 -84.49m to -84.64m	.390 (18)	.333 (14)	2.7E-1	1.5E-2	-.35[a] variable	0.78	-9.5E-2	1.2E-2
Topopah Spring Member (air-fall)?	5-9	UZ #5 -105.55m to -105.64m	-	.484 (4)	-	1.0E-2	-	3.68	-	3.7E-2

negative values for the gradient and flux indicate upward flow.

PRELIMINARY L...
INFORMATION ONLY

Comparison of results with isotope data

Tritium Data

- o Based on the tritium peak at -4.5 m depth, a flux of 35.1 mm/yr occurred within within the allumium in Pagany Wash at UZ #4 over the period 1963-1984.

- o Based on the tritium peak at -3.5 m depth, a flux of 23.6 mm/yr occurred within the alluvial wash at UZ #7 over the same 21 period.

- o Tritium peaks at UZ #4 and UZ #5 are consistent with interpretations of fracture flow through the Tiva Canyon Member and lateral flow along Bedded Interval #2.

Comparison of results with isotope data

^{14}C Data

- Based on ^{14}C ages of 1000 and 4900 yrs at 100 m depth and using $\theta_{avg} = 0.20$, average downward fluxes of approximately 20 and 4 mm/yr can be calculated at boreholes UZ #4 and UZ #5.

Summary and Conclusions

- o Limitations of some existing data have been identified.

- o Correlations have been identified between some important hydrologic variables.

- o Flux profiles have been created which indicate large, relatively recent influxes of water beneath the wash at UZ #4 and UZ #5.

- o The near-static equilibrium water potential profile at UZ #7 suggests that the vitric caprock of the Topopah Springs Member may be an important capillary barrier.

- o Flow above and within the nonwelded and bedded units at UZ #4 and UZ #5 is multidimensional and transient.

DOE/YMPO HYDROCHEMICAL CHARACTERIZATION OF THE UNSATURATED ZONE

By Albert Yang

Advisory Committee on Nuclear Waste Working Group on Unsaturated Zone Hydrology, Dec 14, '93, Las Vegas, Nevada

HYDROCHEMICAL CHARACTERIZATION OF THE UNSATURATED ZONE (SCP SECTION 8.3.1.2.2.7)

OBJECTIVES:

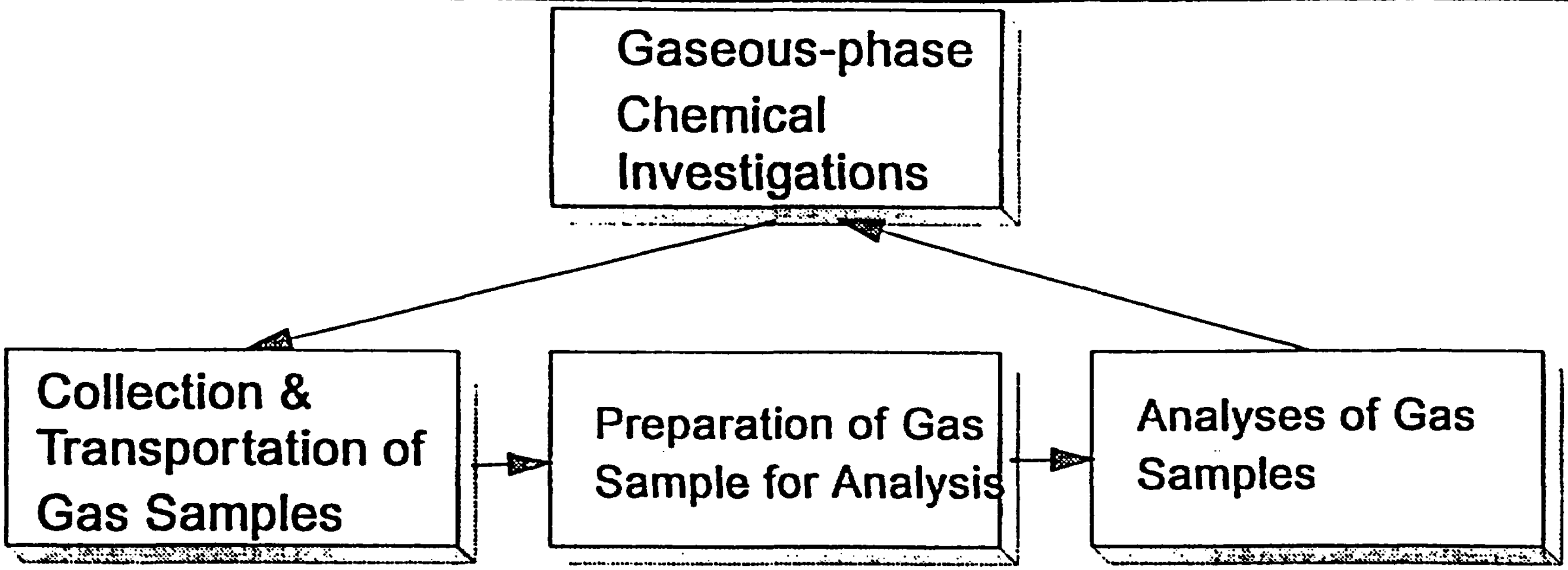
- TO UNDERSTAND THE GAS TRANSPORT MECHANISM, DIRECTION, FLUX AND TRAVEL TIME WITHIN THE UNSATURATED ZONE

- TO DESIGN AND IMPLEMENT METHODS FOR EXTRACTING PORE FLUIDS FROM THE TUFF

- TO PROVIDE INDEPENDENT EVIDENCE OF FLOW DIRECTION, FLUX, AND TRAVEL TIME OF WATER IN THE UNSATURATED ZONE

- TO DETERMINE THE EXTENT OF THE WATER-ROCK INTERACTION, AND TO MODEL GEOCHEMICAL EVOLUTION OF THE WATER IN THE UNSATURATED ZONE

HYDROCHEMICAL METHODS FOR GASEOUS-PHASE INVESTIGATIONS

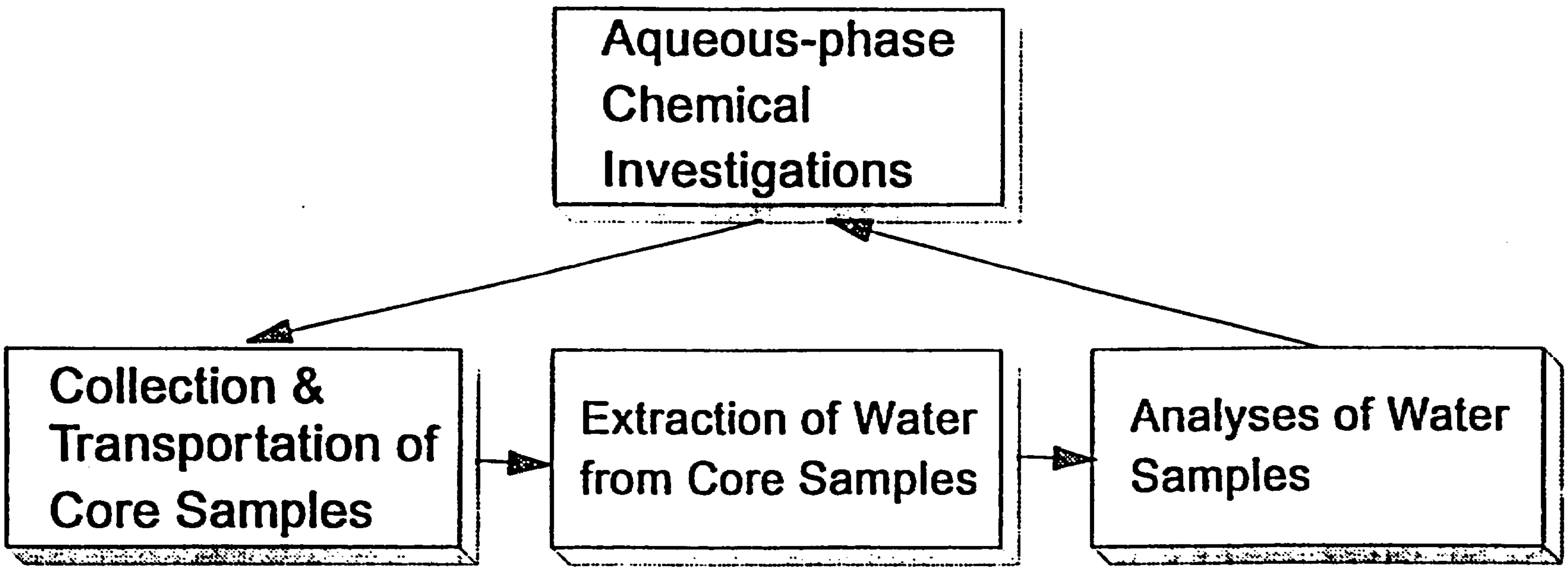


Carbon dioxide
  C-14,C-13/12
Sulfur Hexafloride
Water Vapor
  H-3, D/H, O-18/16

Release of CO_2 from
  molecular sieve
Transfer of water from
  cold trap to glass vials

C-14 by gas counting
H-3 by liquid scintillation
Stable isotopes by Mass
  spectrometer
Tracer gases by GC

HYDROCHEMICAL METHODS FOR AQUEOUS-PHASE INVESTIGATIONS



Collection & Transportation of Core Samples

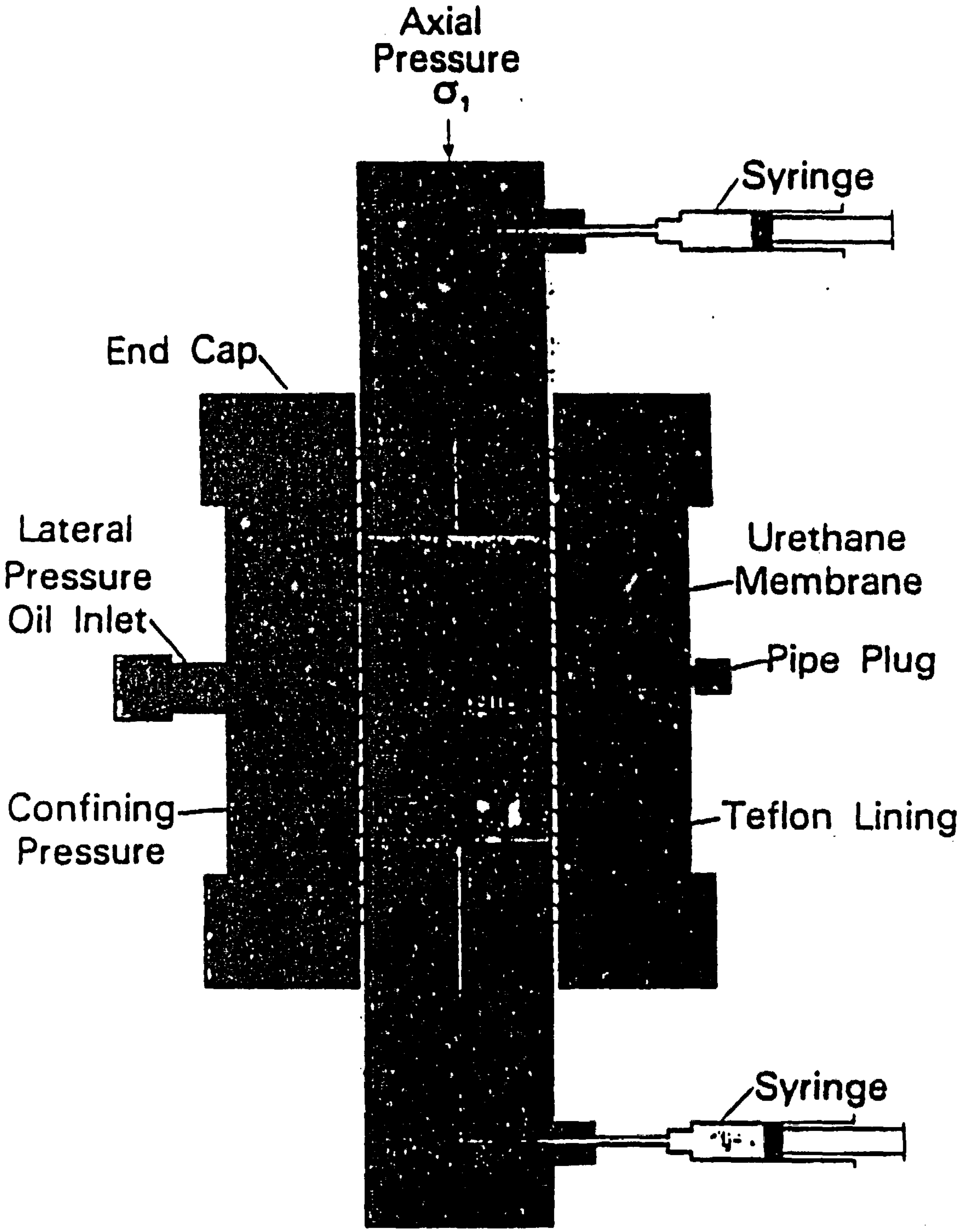
- Sealing of core samples
- Transport of sealed cores to Denver via overnight mail

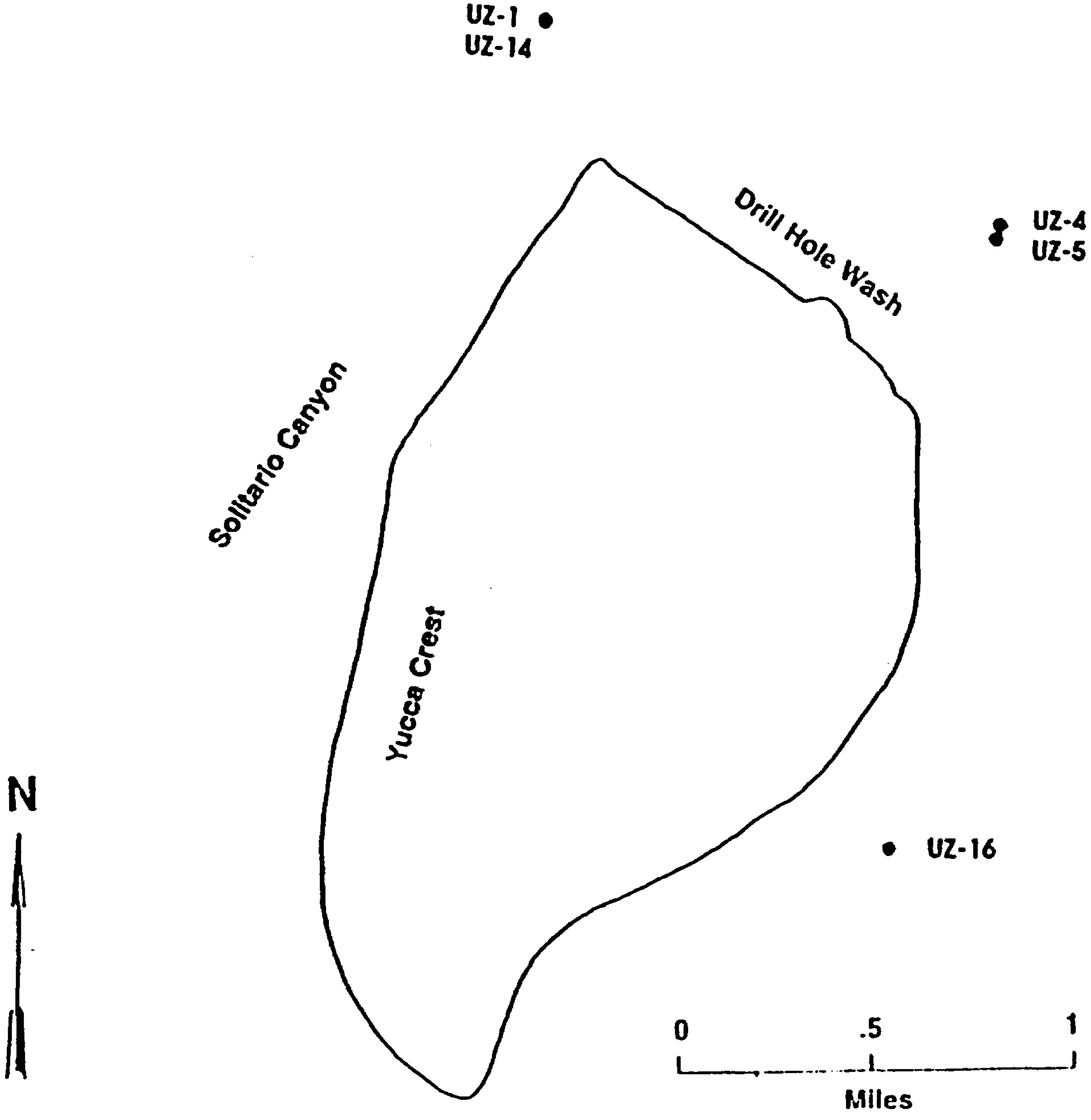
Extraction of Water from Core Samples

- Extract pore water by uniaxial compression
- Vacuum distillation of residual pore water

Analyses of Water Samples

- C-14 by TAMS
- H-3 by Liquid scintillation
- Stable isotopes by Mass spectrometer
- Chemistry by ICP & IC

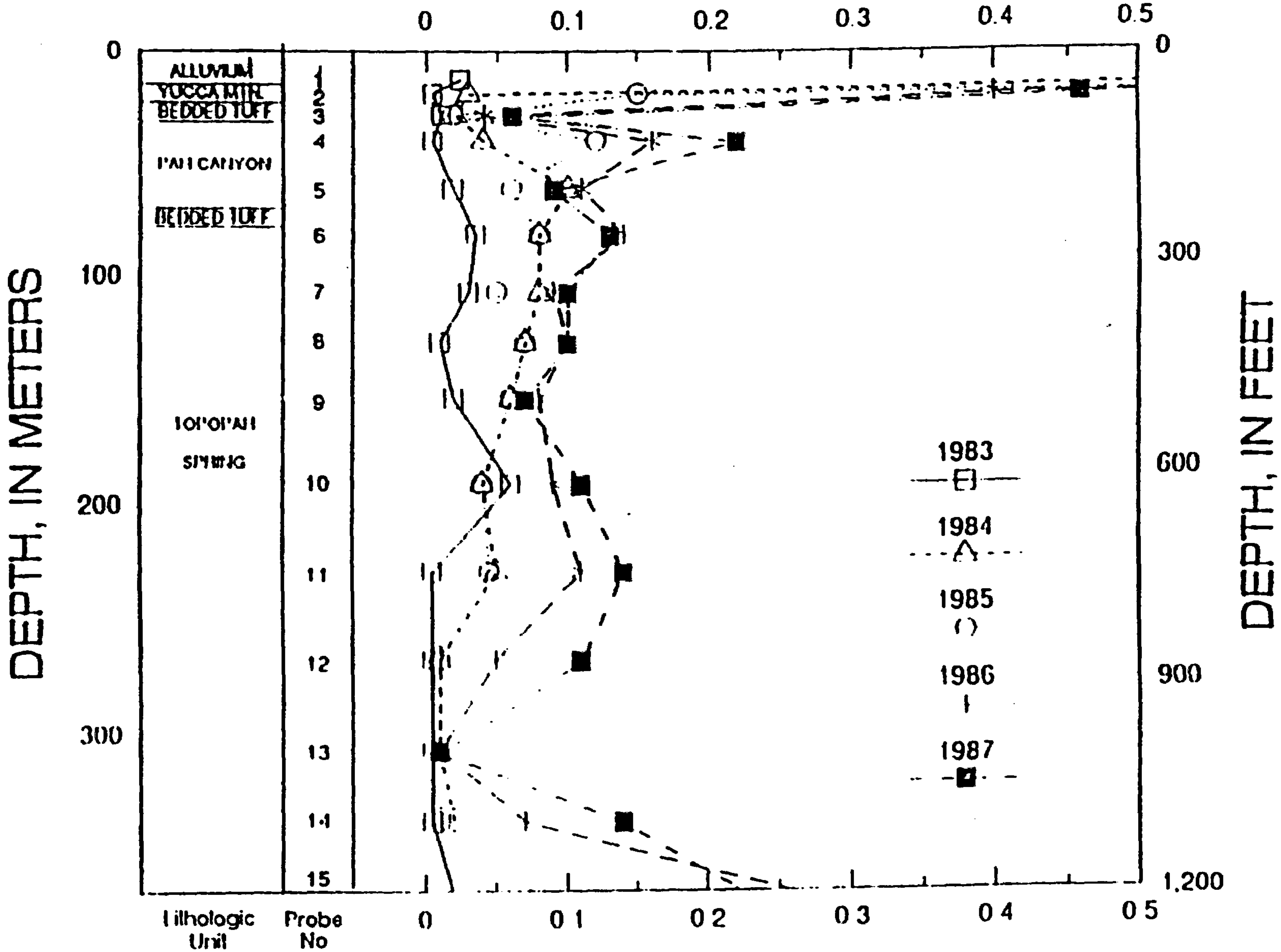

Axial
Pressure
σ_1
Syringe
End Cap
Lateral
Pressure
Oil Inlet
Urethane
Membrane
Pipe Plug
Confining
Pressure
Teflon Lining
Syringe



SC1UZ144 125 NW/10 19 93

AVERAGE TERRESTRIAL ISOTOPIC ABUNDANCE

ELEMENT	ISOTOPES	AVERAGE TERRESTRIAL ABUNDANCE (%)	COMMENTS
HYDROGEN	^{1}H	99.984	
	^{2}H	0.0148	
	^{3}H	10^{-14} TO $^{-16}$	RADIOACTIVE $t_{1/2}$=12.35 yr
CARBON	^{12}C	98.89	
	^{13}C	1.11	
	^{14}C	$\sim 10^{-10}$	RADIOACTIVE $t_{1/2}$=5730 yr
OXYGEN	^{16}O	99.76	
	^{17}O	0.037	
	^{18}O	0.203	



PRELIMINARY ... ORMATION ...

Figure 6. Percent CO_2 by depth, 1983-87. UZ-1

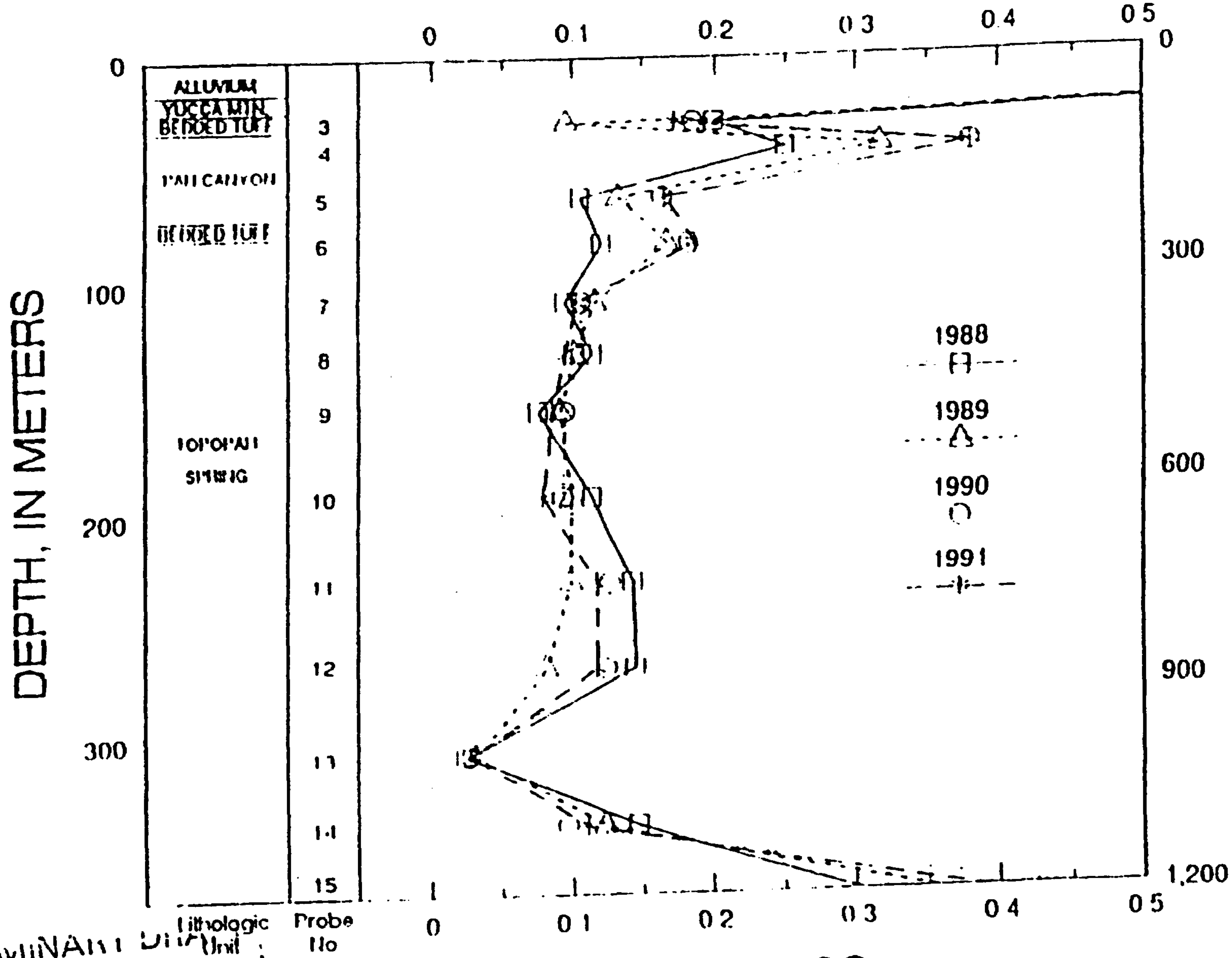
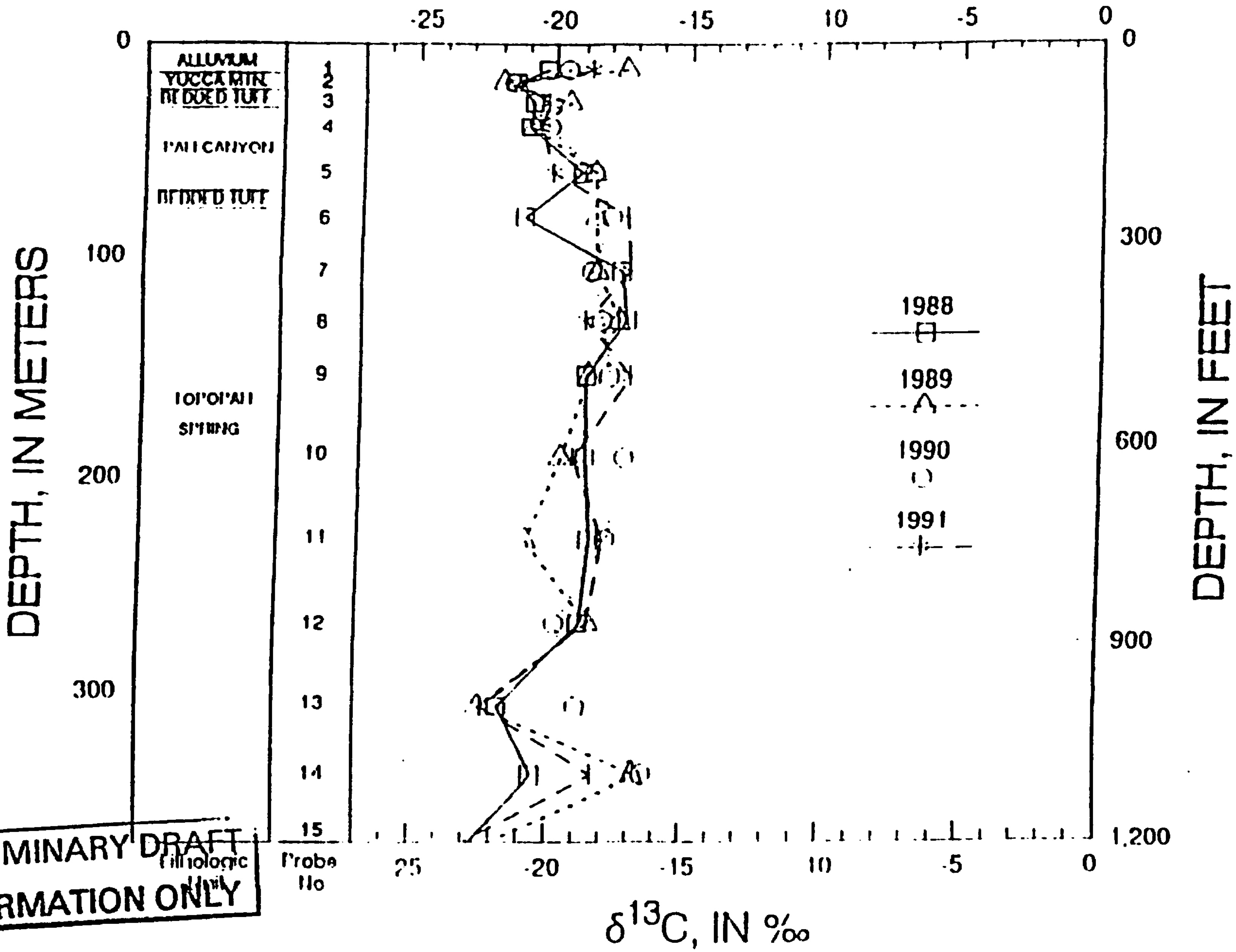
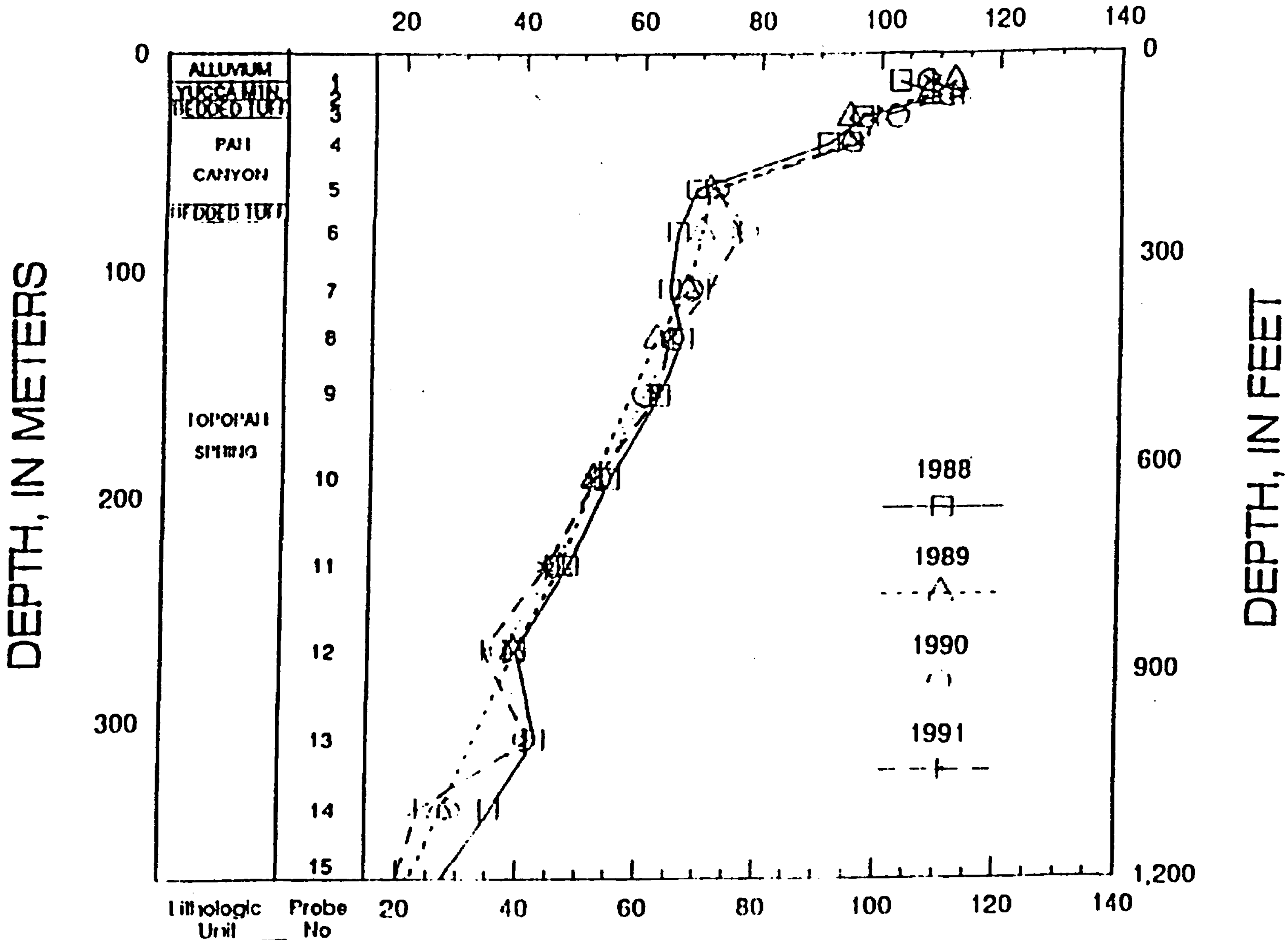


Figure 7. Percent CO_2 by depth, 1988-91. UZ-1



PRELIMINARY DRAFT
INFORMATION ONLY

Figure 9. $\delta^{13}C$, in ‰ by depth, 1988-91. UZ-1



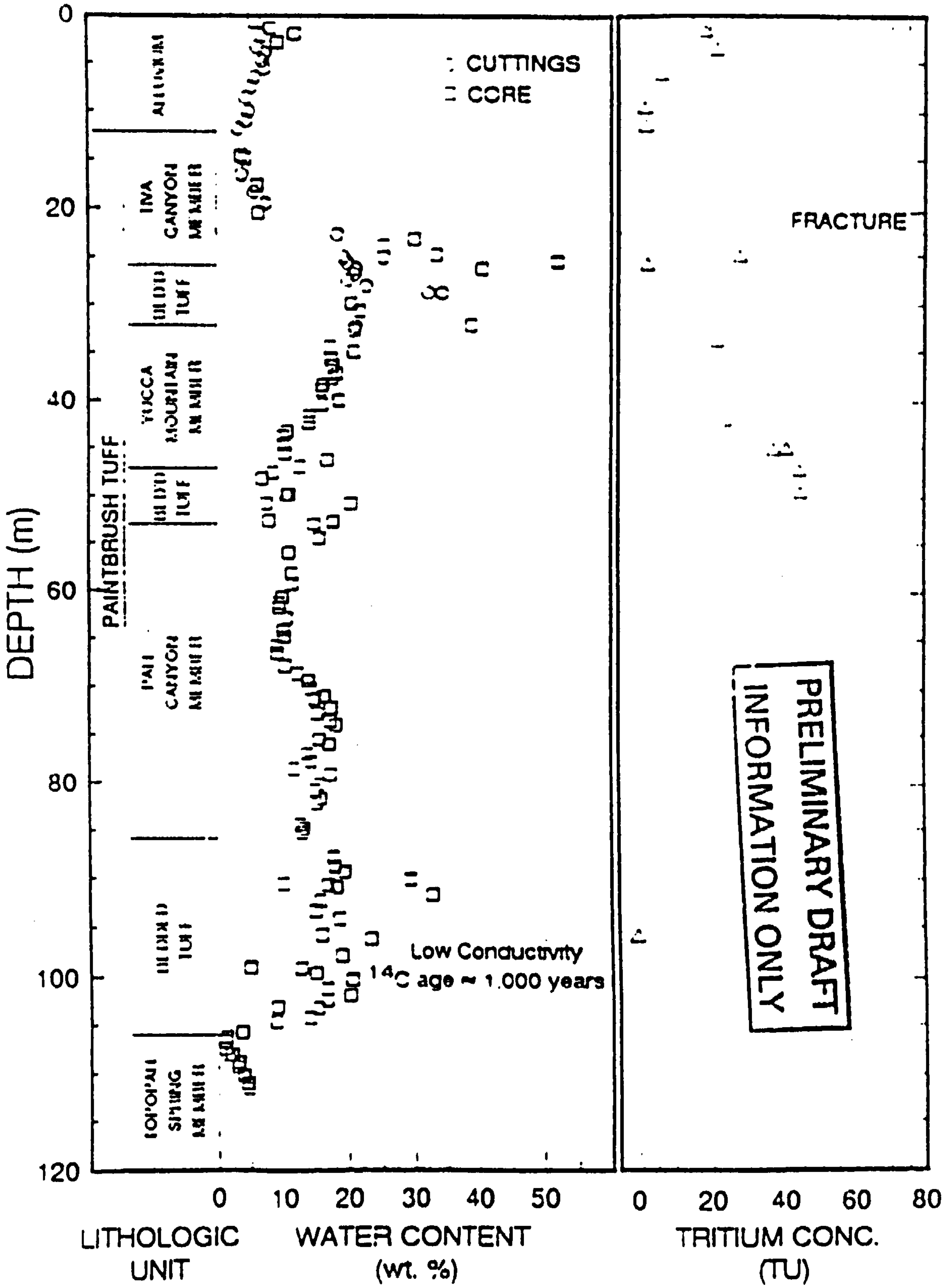
PRELIMINARY DRAFT
INFORMATION ONLY

Figure 11. ^{14}C activity, in % modern by depth, 1988-91. UZ-1

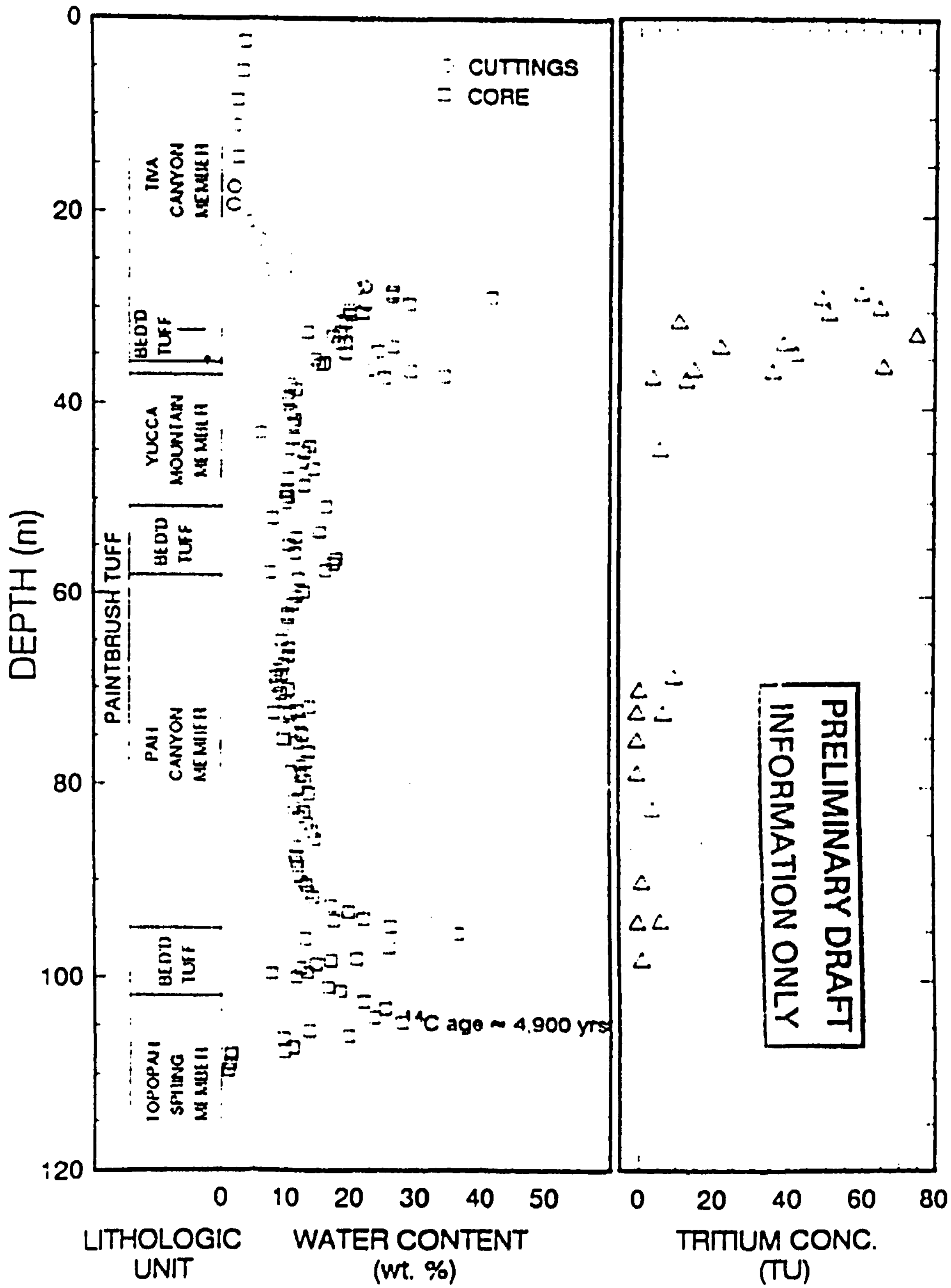
DEFINITION OF TRITIUM UNIT(TU)

- Tritium unit is a concentration unit of tritium in water: that is one atom of tritium in 10^{18} atoms of hydrogen or 3.24 pCi per liter of water.

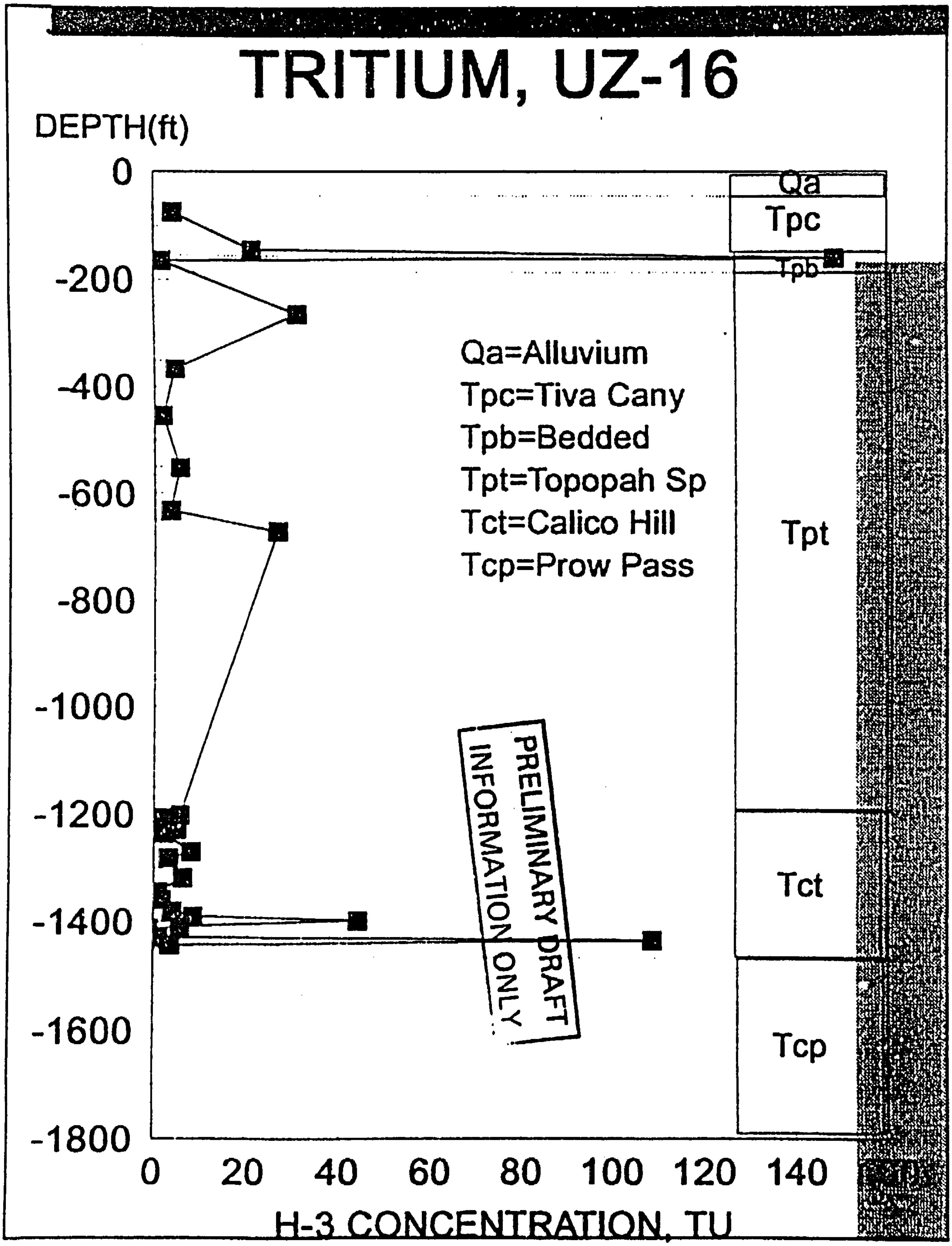
UZ-4


DEPTH (m)
PAINTBRUSH TUFF
ALLUVIUM
TIVA CANYON MEMBER
BEDDED TUFF
YUCCA MOUNTAIN MEMBER
BEDDED TUFF
PAH CANYON MEMBER
BEDDED TUFF
TOPOPAH SPRING MEMBER
CUTTINGS
CORE
FRACTURE
Low Conductivity
14C age ~ 1,000 years
PRELIMINARY DRAFT
INFORMATION ONLY
LITHOLOGIC UNIT
WATER CONTENT (wt. %)
TRITIUM CONC. (TU)

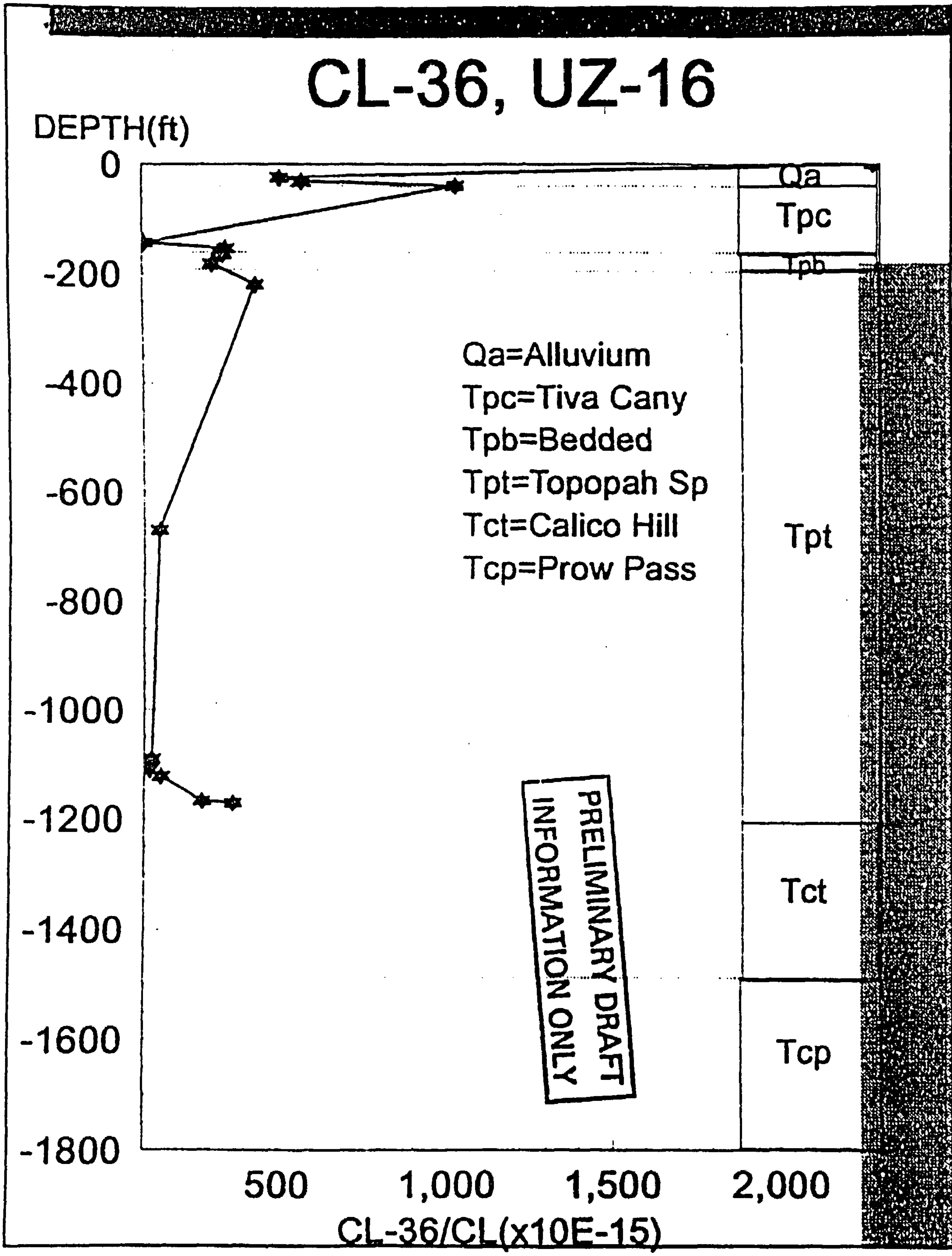
UZ-5



DEPTH (m)
0
20
40
60
80
100
120
CUTTINGS
CORE
PAINTBRUSH TUFF
TIVA CANYON MEMBER
BED'D TUFF
YUCCA MOUNTAIN MEMBER
BED'D TUFF
PAH CANYON MEMBER
BED'D TUFF
TOPOPAH SPRING MEMBER
^{14}C age ~ 4,900 yrs
0 10 20 30 40 50
0 20 40 60 80
LITHOLOGIC UNIT
WATER CONTENT (wt. %)
TRITIUM CONC. (TU)
PRELIMINARY DRAFT
INFORMATION ONLY

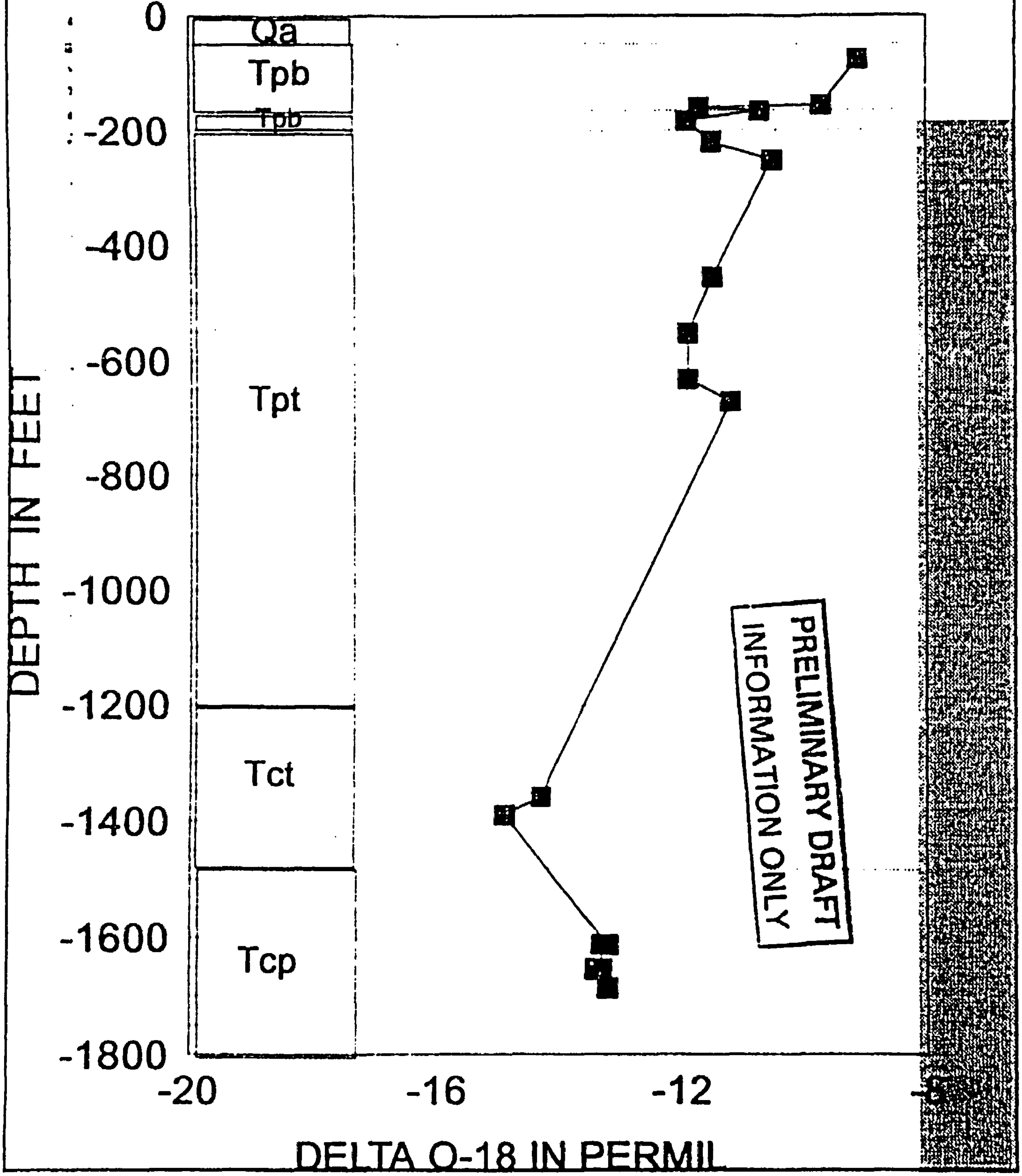


TRITIUM, UZ-16
DEPTH(ft)
0
-200
-400
-600
-800
-1000
-1200
-1400
-1600
-1800
0
20
40
60
80
100
120
140
H-3 CONCENTRATION, TU
Qa=Alluvium
Tpc=Tiva Cany
Tpb=Bedded
Tpt=Topopah Sp
Tct=Calico Hill
Tcp=Prow Pass
Qa
Tpc
Tpb
Tpt
Tct
Tcp
PRELIMINARY DRAFT
INFORMATION ONLY

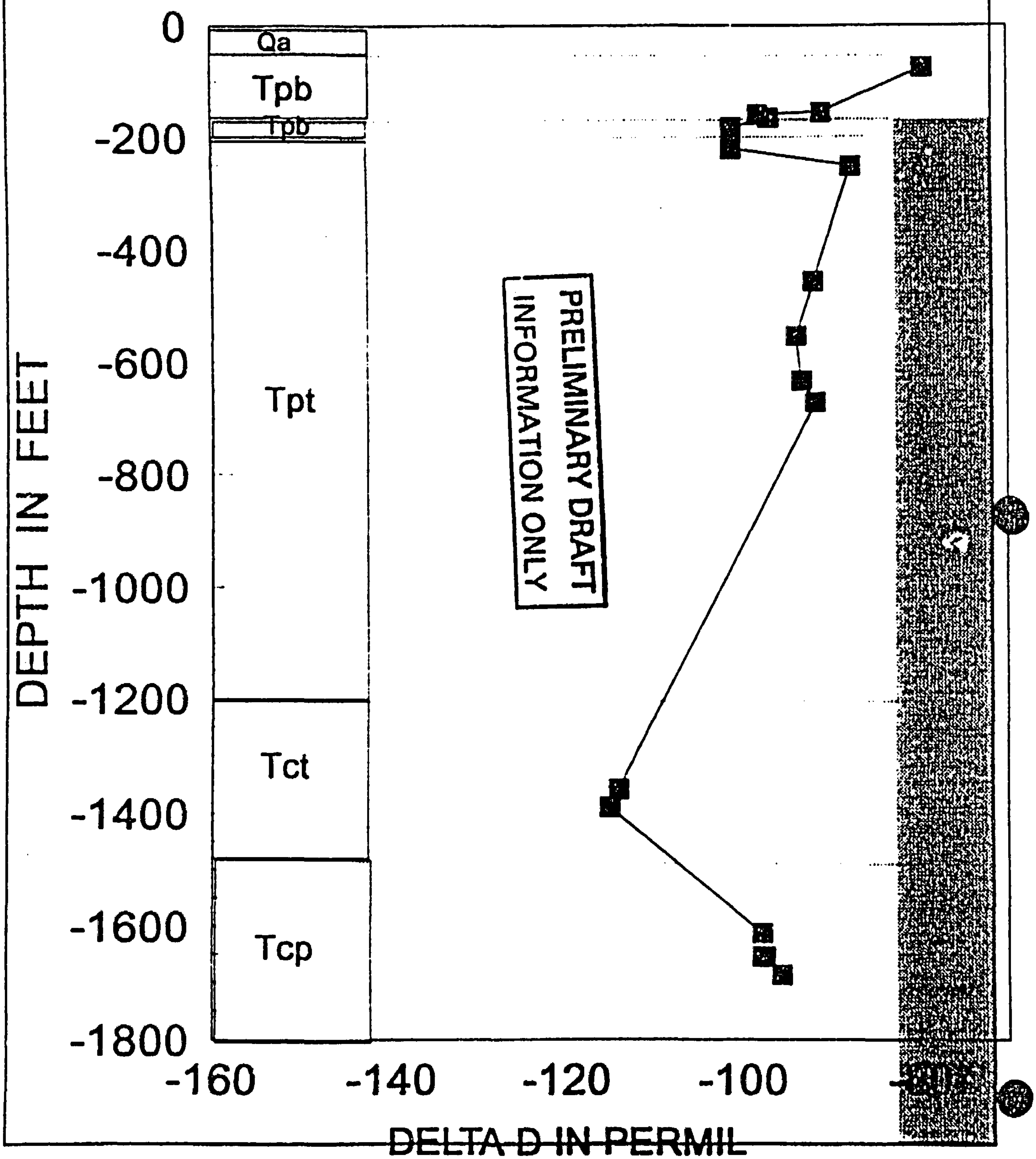


Source:Fabrica-Martin et al, FOCUS '93

OXYGEN-18 DATA, UZ-16

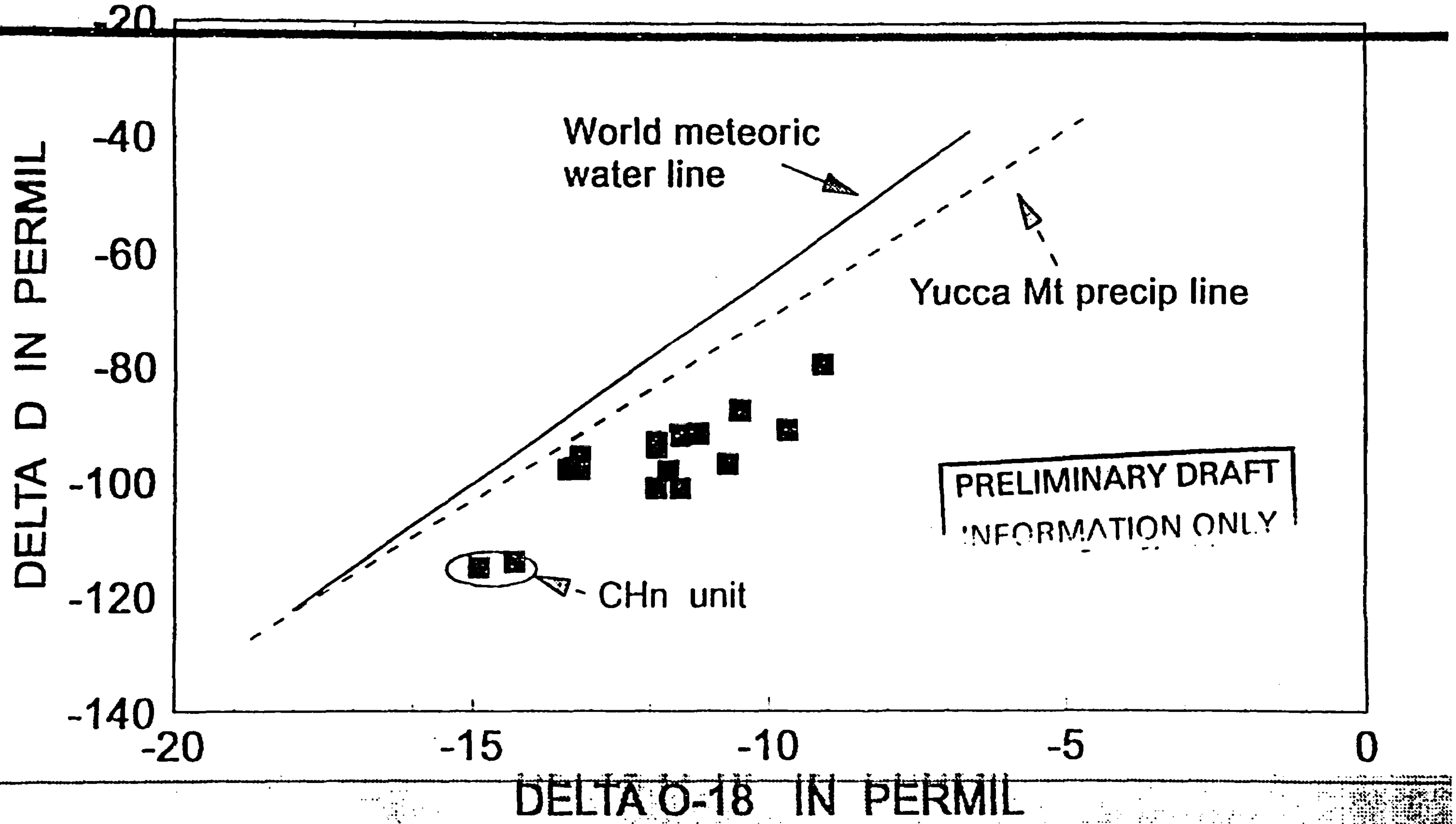


DELTA D ,UZ-16



0
-200
-400
-600
-800
-1000
-1200
-1400
-1600
-1800
DEPTH IN FEET
Qa
Tpb
Tpb
Tpt
Tct
Tcp
PRELIMINARY DRAFT
INFORMATION ONLY
-160
-140
-120
-100
DELTA D IN PERMIL

STABLE ISOTOPE DATA OF UZ-16 PORE WATER, DEUTERIUM VS OXYGEN-18 PLOT



Sources of Carbon in Ground Water

- (1)Dissolution of carbonate by carbonic acid:
  - $CaCO_3$ + CO_2 + H_2O = Ca^{++} + 2 HCO_3^-
  - Ao=0% 100% 50%
  - C-13=0‰ -25 ‰ -12.5‰
- (2) Weathering of silicate rocks by carbonic acid:
  - $CaAl_2(SiO_4)_2 + 2CO_2 + H_2O = Ca^{++} + 2HCO_3^- + ...$
  - Ao= 100% 100%
  - C-13= -25‰ -25‰

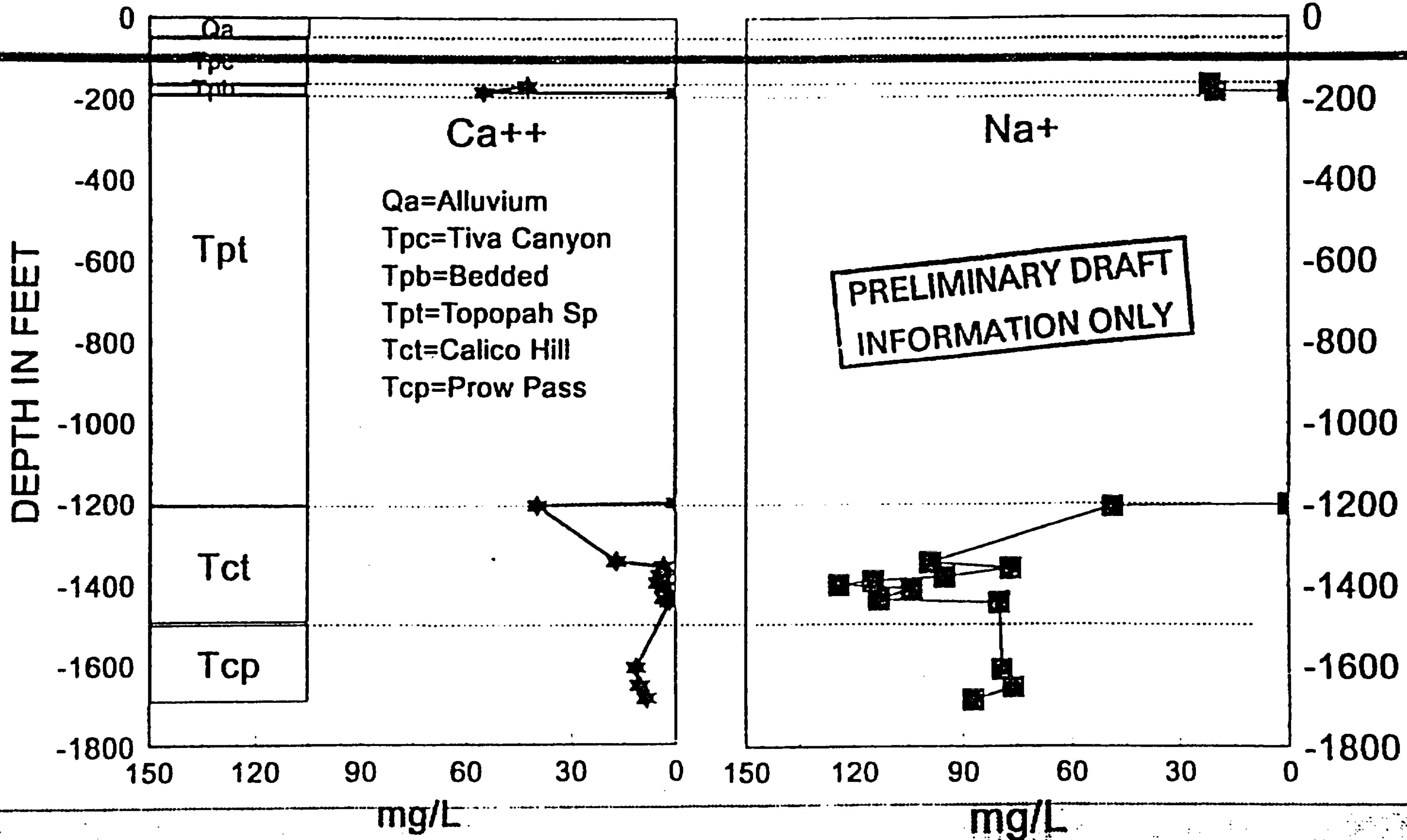
Note: Ao=Initial C-14 activity

ISOTOPIC REACTIONS (ISOTOPIC FRACTIONATIONS)

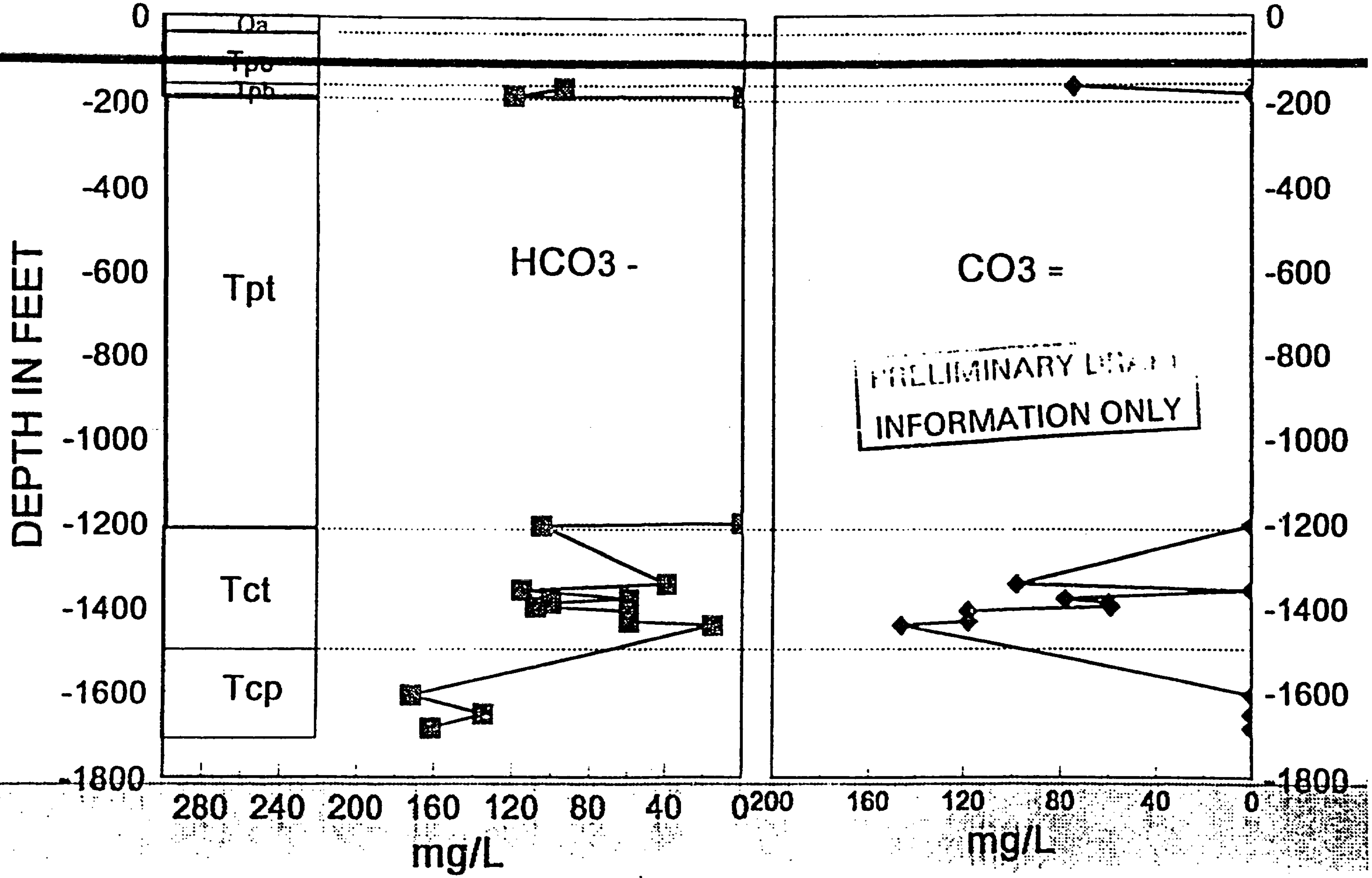
- CO_2(gas) = CO_2 (aqueous)
- CO_2(aqueous) = HCO_3^-
- HCO_3^- = CO_3^-
- CO_3^- = Solid Carbonate

Note: Isotopic exchange reactions may not reach equilibrium for each compound.

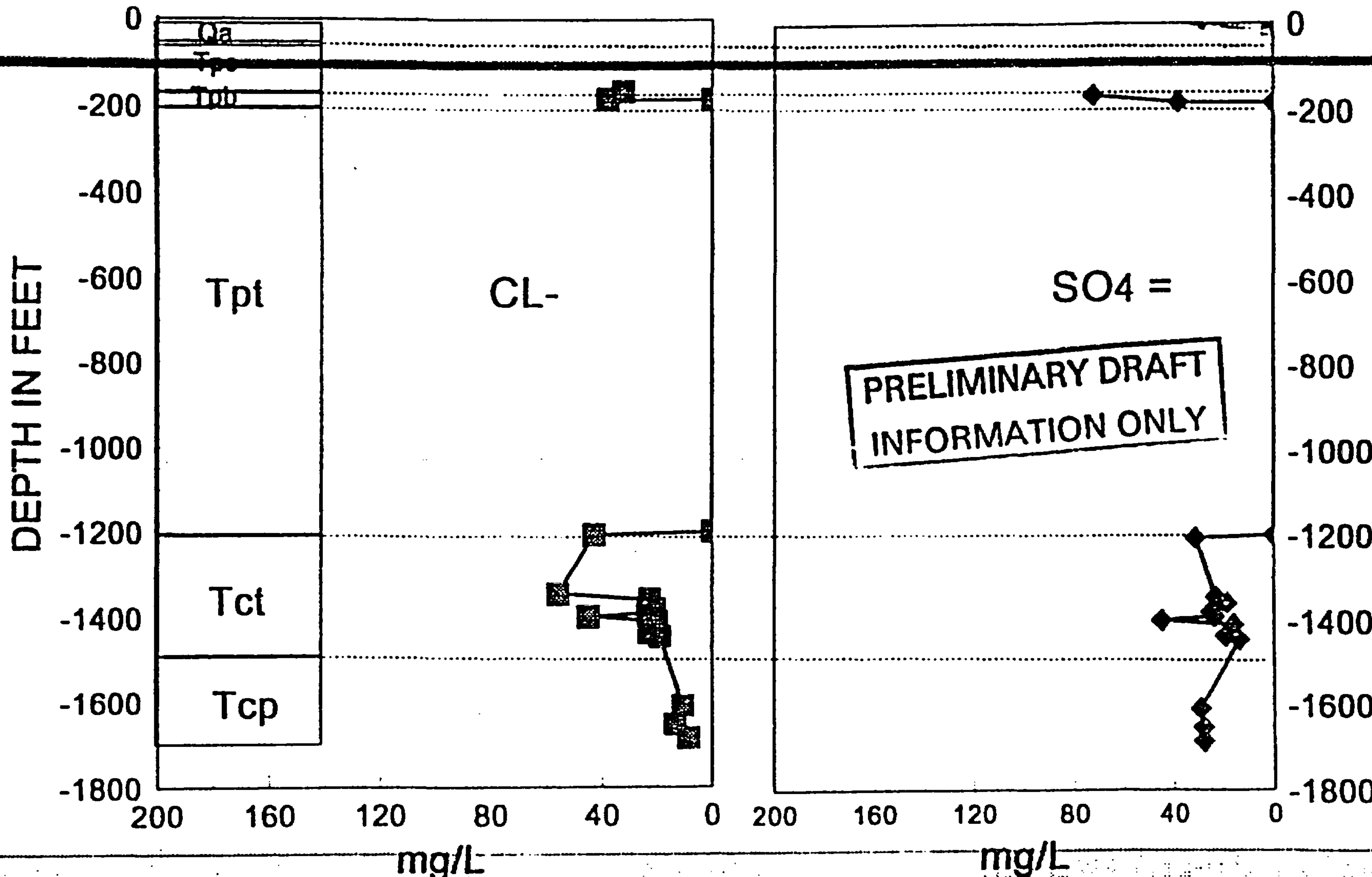
Chemical Compositions of Water from UZ-16 Bore Hole



Chemical Compositions of Water from UZ-16 Bore Hole



Chemical Compositions of Water from UZ-16 Bore Hole



INITIAL C-14 ACTIVITY MODELS

Model	A0	Computed (no decay)	Observed	Age
Original Data	33.05	7.75	.80	18771.
Mass Balance	52.33	12.27	.80	22570.
Vogel	85.00	19.93	.80	26580.
Tamers	53.46	12.54	.80	22747.
Ingerson and Pearson	52.33	12.27	.80	22570.
Mook	53.80	12.62	.80	22800.
Fontes and Garnier	46.51	10.91	.80	21596.
Eichinger	47.57	11.15	.80	21782.
User-defined	100.00	23.45	.80	27924.

Summary and Conclusions

- Gas-phase C-14 data in UZ-1 indicate faster transport of CO_2 in Topopah Spring unit than in Tiva Canyon or bedded units. However, gas transport mechanism is likely by gas diffusion.
- The H-3 data from UZ-4, UZ-5 and UZ-16 indicate preferential flow path (also indicated by Cl-36 data). High H-3 value in Calico Hill need to be further investigated since pore water chemistries and stable isotopic data indicate paleowater.
- Pore-water chemistries from UZ-16 cores indicate calcium bicarbonate type young water near top 200 feet, and sodium carbonate type old water in the Calico Hill Unit.

Summary and Conclusions(Continued)

- Stable isotopic data from UZ-16 cores indicate Calico Hill unit water is very light in both deuterium and oxygen-18 values, an indication of paleowater.
- Plot of UZ-16 pore-water stable-isotopic data on Deuterium versus oxygen-18 diagram indicate all data are to the right-hand side of the Yucca Mountain Precipitation line(YMPL), and parallel to the YMPL.This indicate infiltrating water lost some water by evaporation before percolating into depth.

Presentation to the
Advisory Committee on Nuclear Waste
December 14, 1993
Las Vegas, Nevada

Subject: DOE/YMPO Surface-Based Data Collection Studies in Unsaturated Zone Percolation

Presenter: Joseph P. Rousseau, P.E.

Presenter's Title and Organization: Hydrologist, Project Chief
U.S. Geological Survey
Denver, Colorado

Presenter's Telephone Number: (303) 236-5183

Presentation Outline

- Study Objectives
- Borehole Siting Strategy and Criteria
- Overview of Percolation Studies - Approaches Being Used
- Deep UZ Percolation Processes

Presentation Outline (Continued)

- Some Aspects of In Situ Measurement of UZ Fluid Flow Potentials
- Preliminary Findings and Current Status of UZ-16 and Implications for Monitoring
- Achieving Study Goals

Purpose and Objectives

To characterize present day flux in the unsaturated zone at Yucca Mountain, NV through field and laboratory measurements of

- Matrix hydrologic properties
- In-situ permeability
- In-situ fluid flow potentials

Uniform flux vs. Concentrated flux

Borehole Siting Strategy

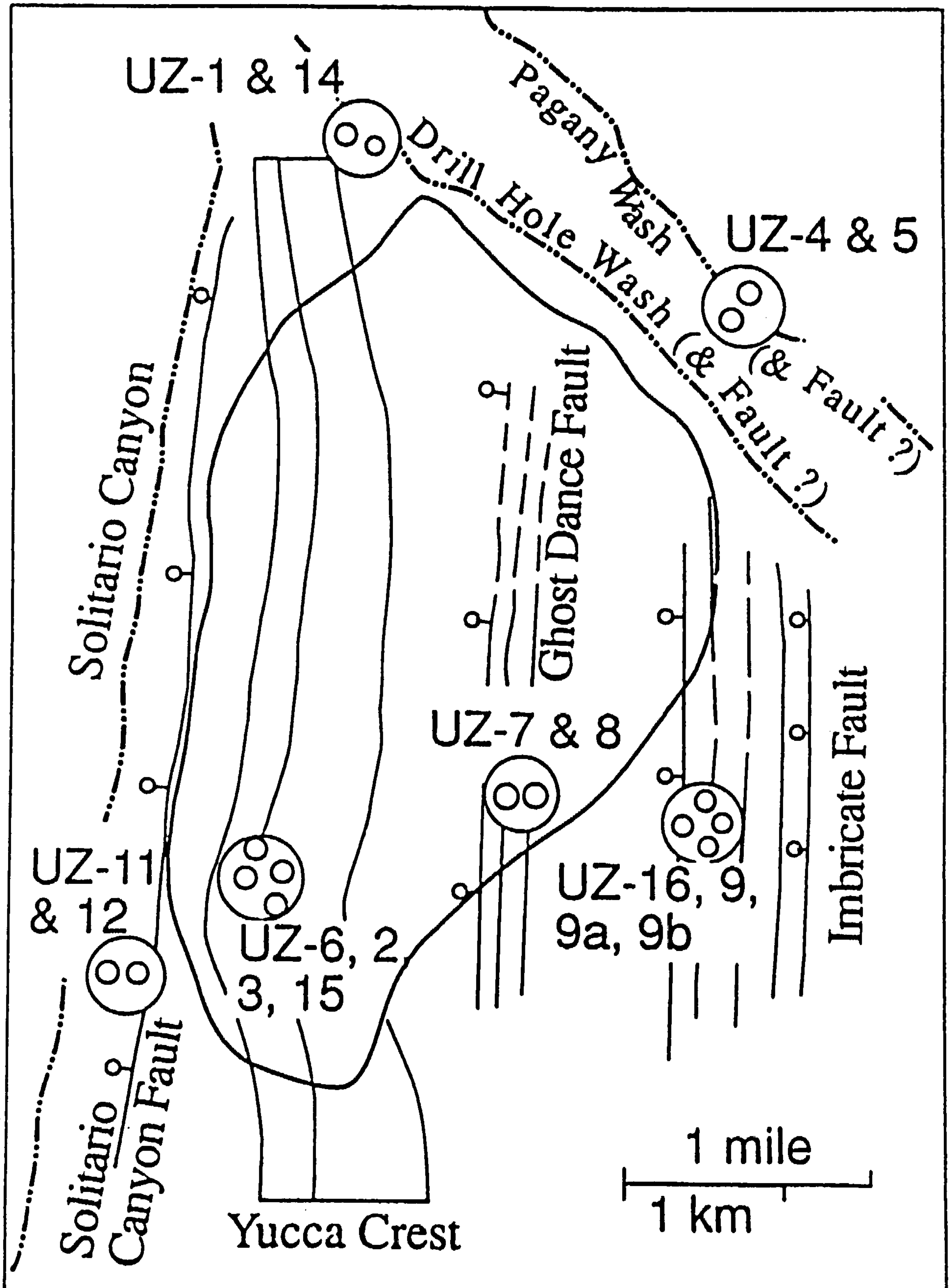
"...Target those areas of interest with the greatest potential to provide the evidence needed to assess the suitability of Yucca Mountain as a repository for high-level radioactive waste"

(YMP-USGS-SP 8.3.1.2.2.3)

Borehole Siting Criteria

- Large scale structural features
- Surface drainage features
- Topographic features

Features-Based Boreholes Yucca Mountain, Nevada



Overview of Percolation Studies

UZ Percolation Studies

Data source	Studies	Objectives	Scale (temporal and spatial)
UZ borehole & multiple borehole sites	Matrix hydrologic properties (core)	• Porosity • Relative permeability • Moisture retention • Saturation & water potential	Small
	Air permeability testing (borehole)	• Fracture & matrix permeability • Fracture inter-connectedness	Medium to large
	Fluid flow potentials (borehole)	• Pneumatic pressure, temperature & water potential • Flow directions & gradients • System stability • Diffusion & saturation permeability	Large
	Vertical seismic profiling (borehole)	• 3-D subsurface imaging • Geologic structure • Fault/fracture system continuity	Very large

UZ Percolation Studies

Data source	Studies	Objectives	Scale (temporal and spatial)
UZ borehole & multiple borehole sites	Chlorine 36 (cuttings)	• Dating of water	0-50years
	Hydrochemistry (core & borehole)	• Dating of water & gas • Pore-water chemistry • Gas chemistry	^{3}H 0-100 years ^{14}C 100 - 40,000 years
	Gaseous phase flow (borehole)	• Convective gas-flow processes	Large

Deep UZ Percolation Processes

- Matrix - Matrix Liquid Flow
  - Vertical
  - Lateral
- Matrix - Fracture Liquid Flow
- Vapor Transport
  - Diffusion
  - Convection

Some Aspects of

In Situ Measurement of

Unsaturated Zone - Fluid Flow Potentials

Pneumatic Pressure
(Convective Gas Flow)

- Barometric influences
  - diurnal, seasonal, storm related
  - pressure damping
  - pressure lagging

- Topographic influences
  - Yucca Crest / Solitario Canyon
  - inter-ridge depressions

- Bouyancy effects - temperature driven

- Equilibration time - rapid (few days to weeks)

Temperature
(Conductive Heat Flow)

- Liquid flux influences (rock thermal properties)

- Advective heat transfer
  - gas flow
  - liquid flow

- Latent heat of vaporization processes
  - heat sources
  - heat sinks

- Equilibration time - moderate (few months)

Water Potential
(Liquid and Vapor Flow)

- Vertical vs. lateral liquid flow
- Vapor (pressure) diffusion gradients
- Equilibration time moderate (few months) to very slow (years)
- Measurement - extremely sensitive to:
  - pressure disturbances
  - temperature disturbances

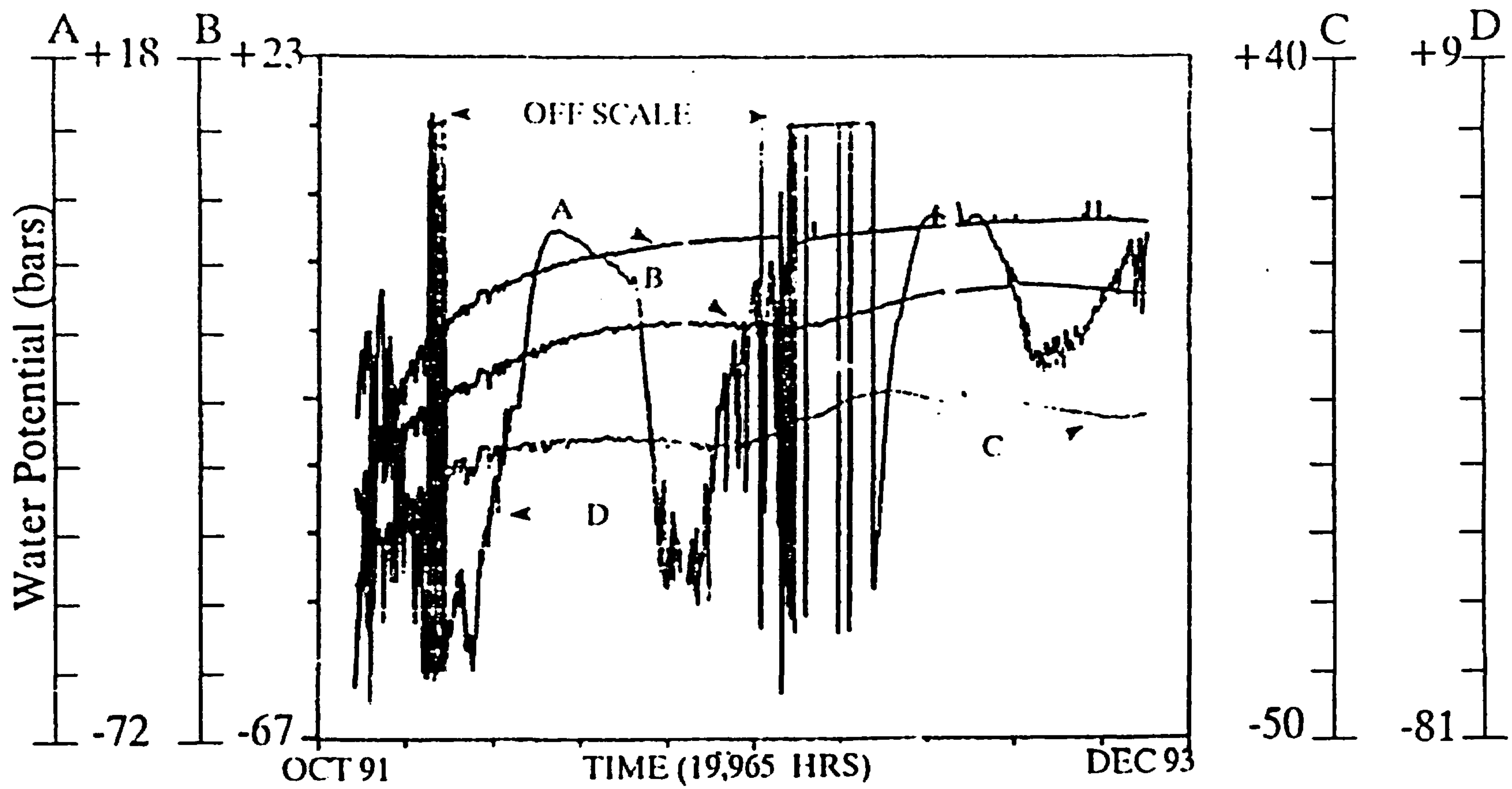
Monitoring Data

from

Hydrologic Research Facility Boreholes

Prototype Instrumentation Program

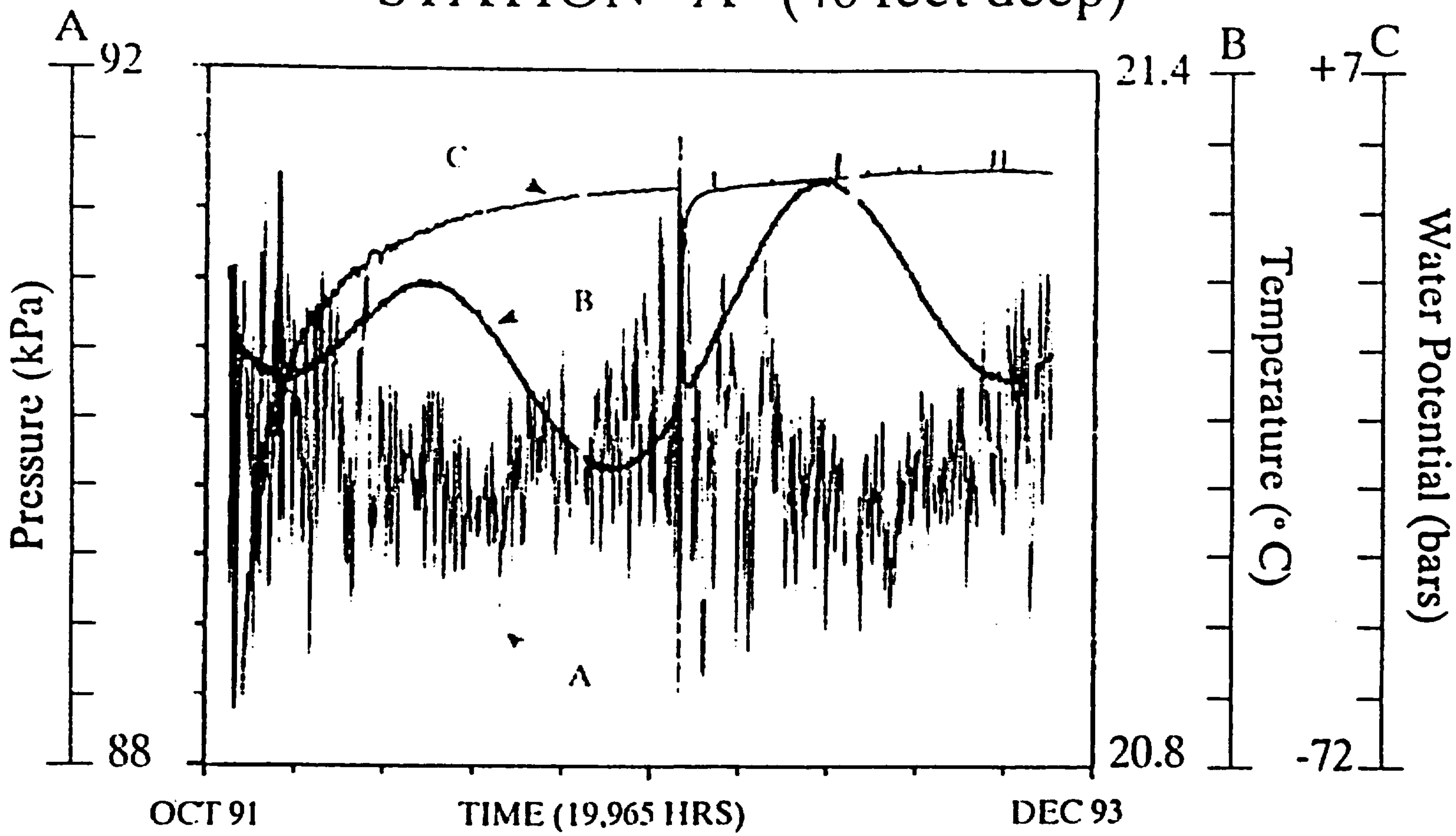
Hydrologic Research Facility - Borehole #1



Water potential curves for Stations: A (40 ft), B (30 ft), C (20 ft), D (10 ft) - TWO YEAR MONITORING PERIOD - Barometric pumping affects are most pronounced in the Station D record.

PRELIMINARY DRAFT
INFORMATION ONLY

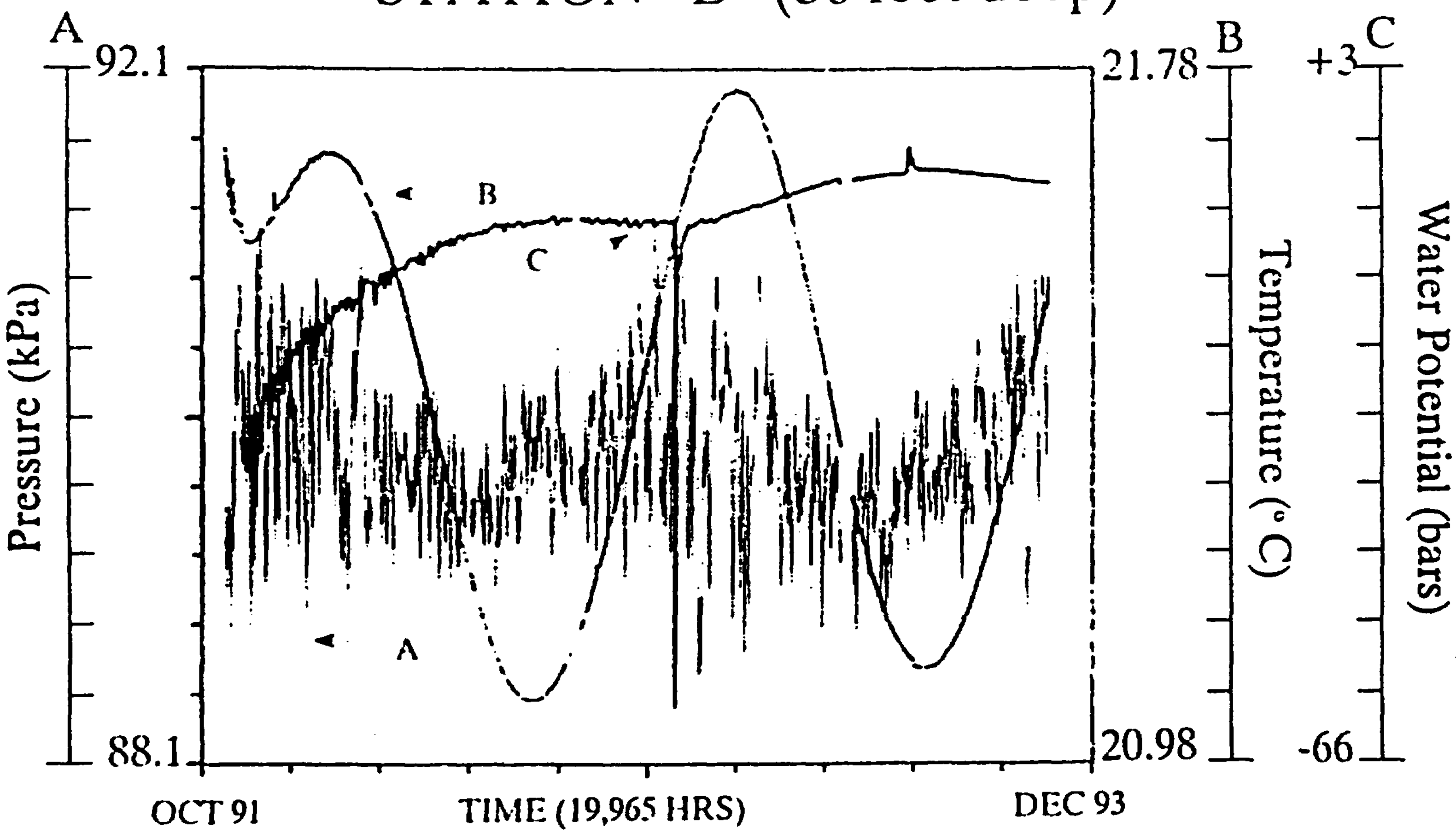
Hydrologic Research Facility - Borehole #1
STATION A (40 feet deep)



Pneumatic pressure, temperature, and water potential - TWO YEAR MONITORING PERIOD - Water potential equilibrium achieved after approximately twenty-three months of monitoring.

PRELIMINARY DRAFT
INFORMATION ONLY

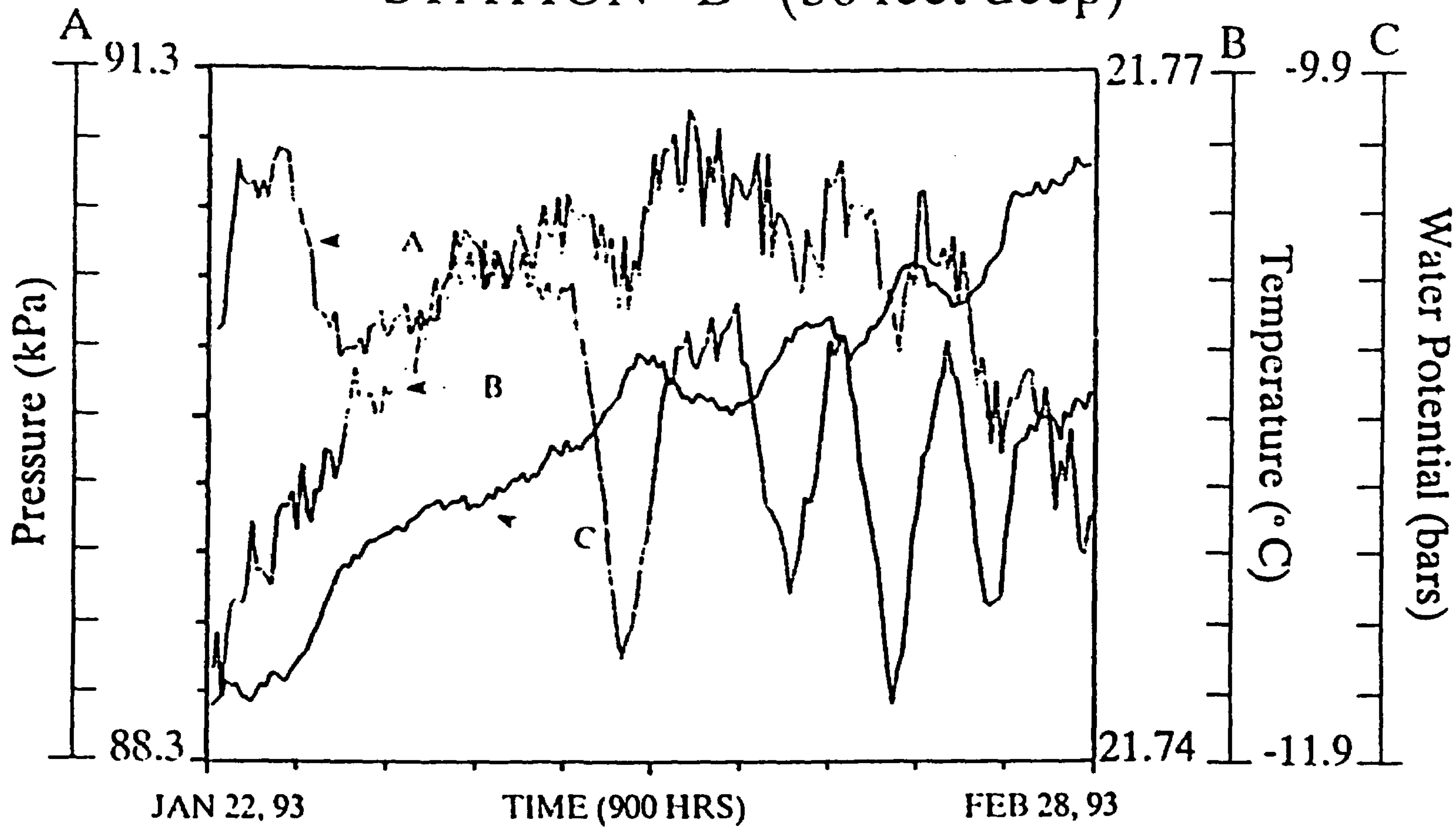
Hydrologic Research Facility - Borehole #1
STATION B (30 feet deep)



Pneumatic pressure, temperature, and water potential - TWO YEAR MONITORING PERIOD - Water potential equilibrium achieved after approximately ten months of monitoring.

PRELIMINARY DRAFT
INFORMATION ONLY

Hydrologic Research Facility - Borehole #1
STATION B (30 feet deep)



Temperature and water potential response to barometric pumping - 900 HR MONITORING PERIOD - Record illustrates mass transport of heat and vapor induced by pneumatic pressure changes.

PRELIMINARY DRAFT
INFORMATION ONLY

Preliminary Findings

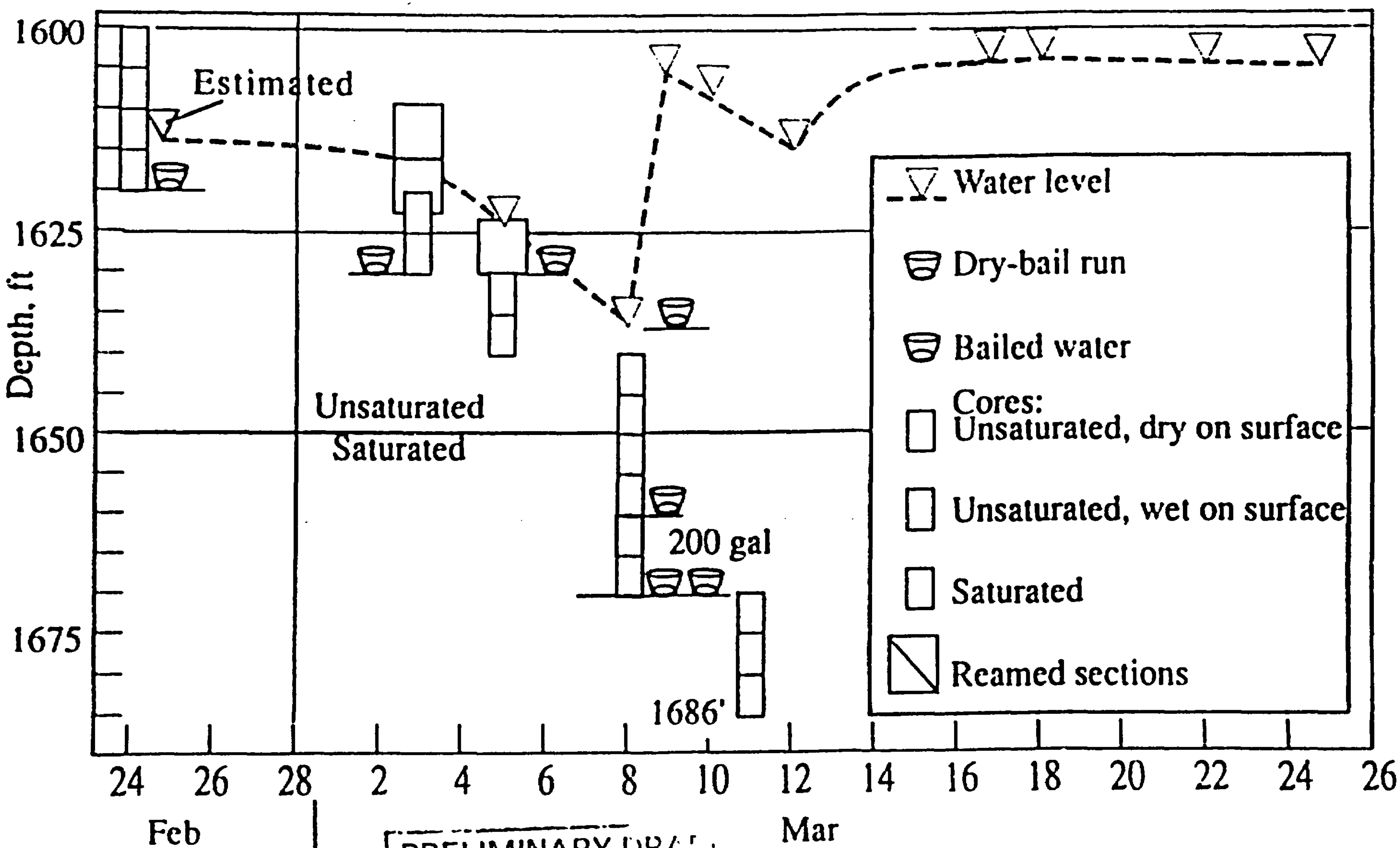
UE-25 UZ#16

Preliminary Findings

UZ-16 (dry drilled and cored to saturated zone)

- Imbricate faults almost vertical
- Fracture density in Topopah Spring much greater than earlier estimates
  - range: 50 to 250 per m^3
  - avg: 125 per m^3 vs 50 per m^3 (Montazer & Wilson, 1984)
- Water encountered in fractures in Prow Pass unit in non-saturated matrix environment

Water Levels During the Drilling of UZ-16



PRELIMINARY DRAFT
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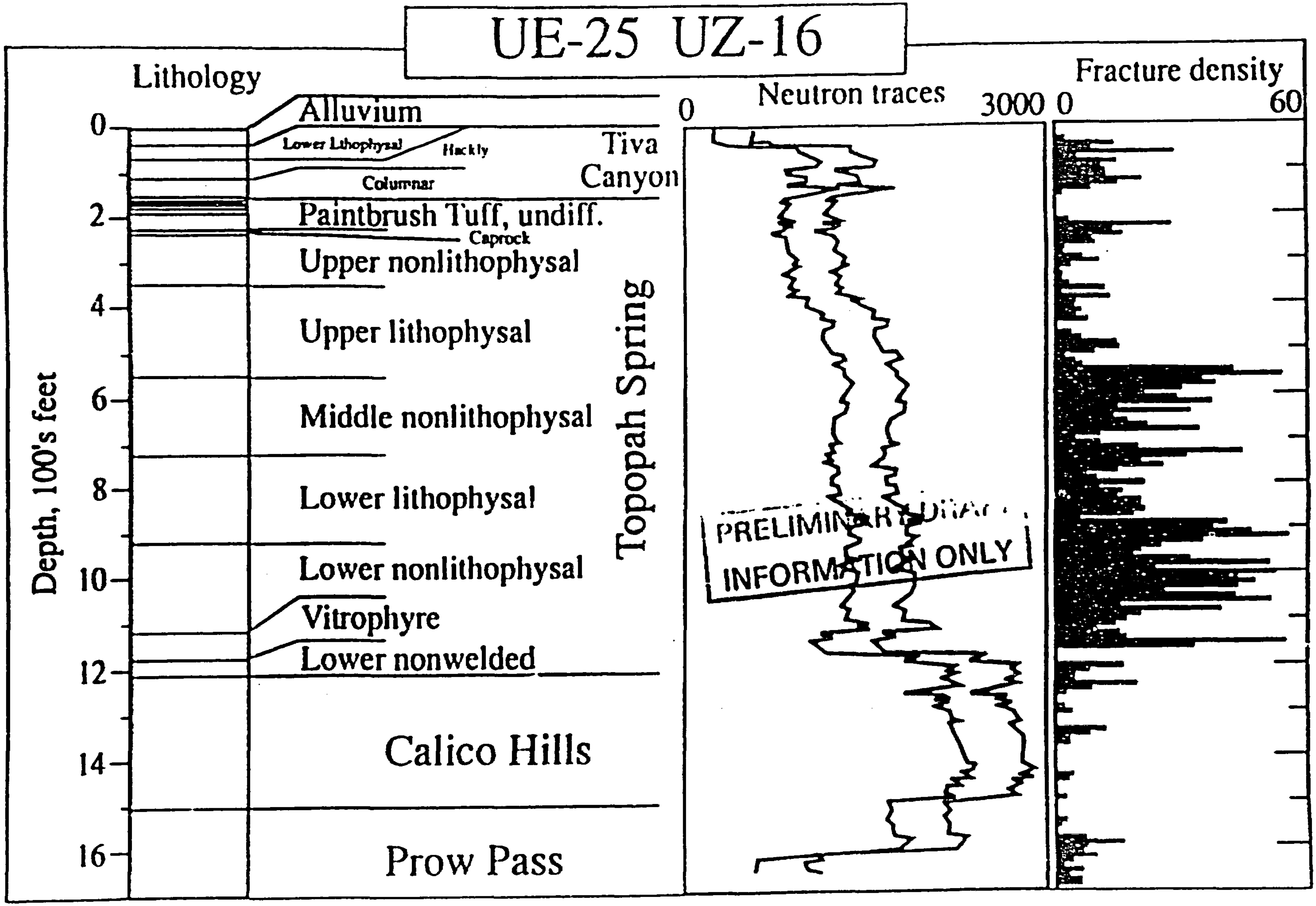
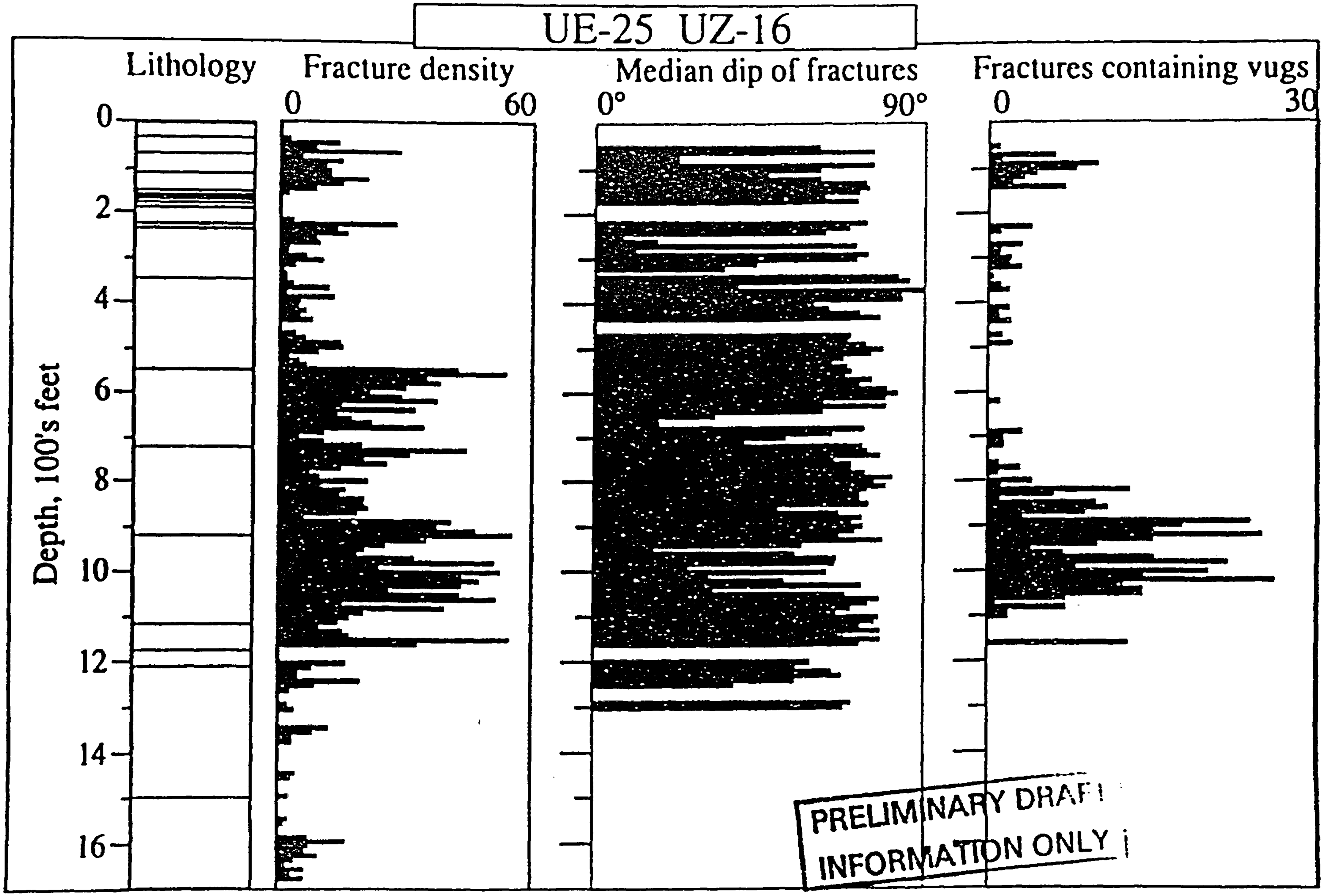
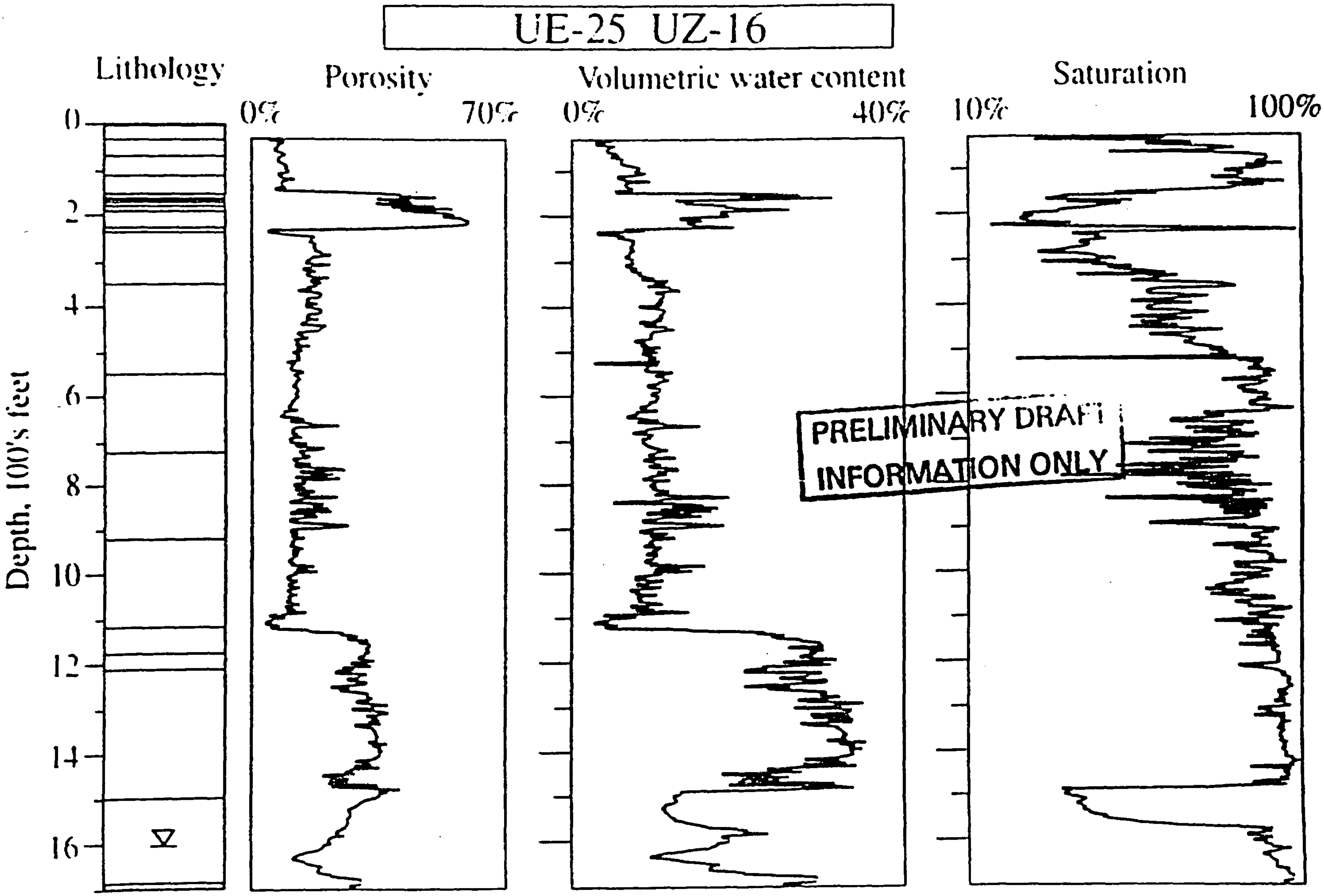
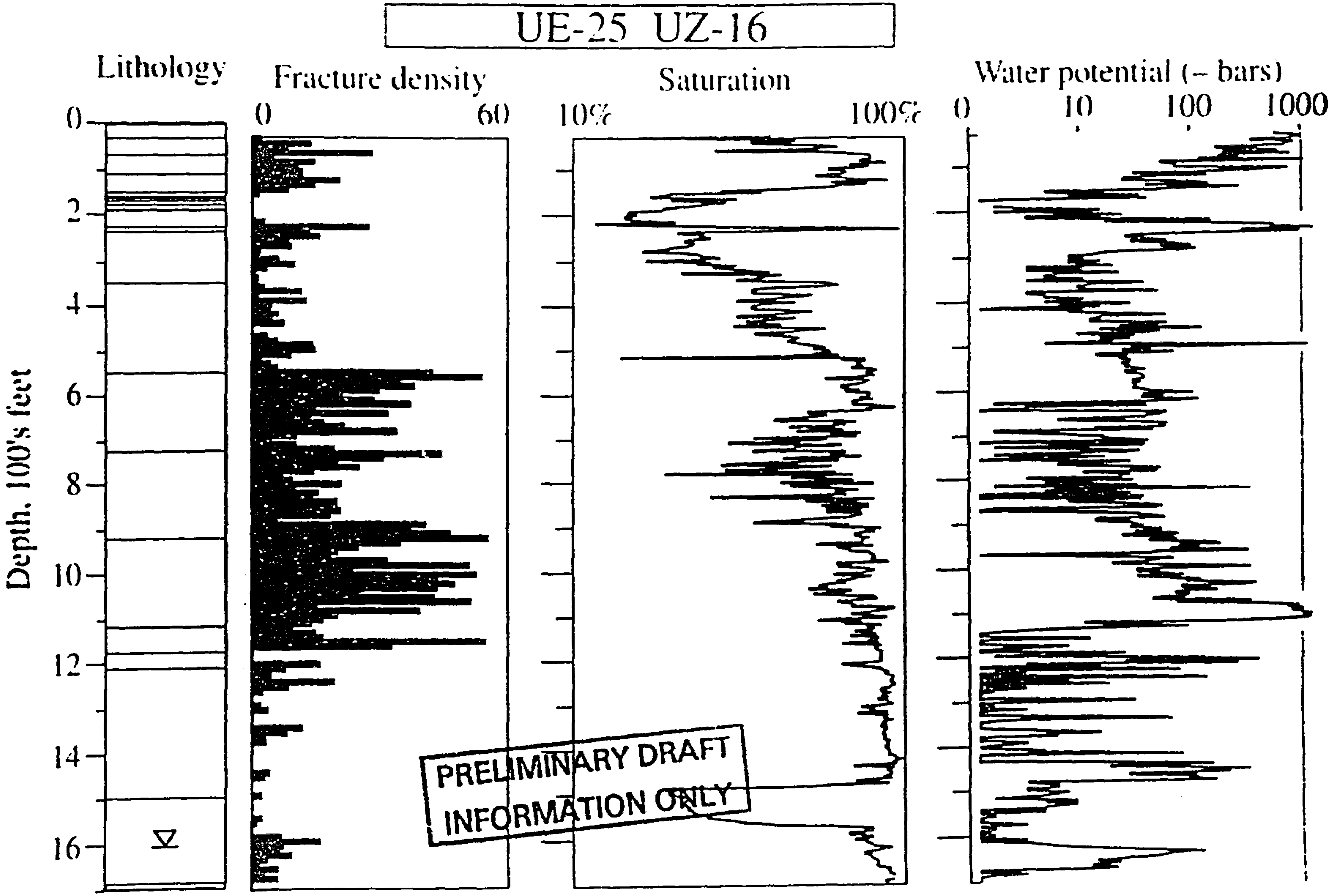


UE-25 UZ-16
Lithology
Depth, 100's feet
0
2
4
6
8
10
12
14
16
Alluvium
Lower Lithophysal
Hackly
Columnar
Tiva
Canyon
Paintbrush Tuff, undiff.
Caprock
Upper nonlithophysal
Upper lithophysal
Middle nonlithophysal
Lower lithophysal
Lower nonlithophysal
Topopah Spring
Vitrophyre
Lower nonwelded
Calico Hills
Prow Pass
Neutron traces
0
3000
Fracture density
0
60
PRELIMINARY
INFORMATION ONLY


UE-25 UZ-16
Lithology
Fracture density
0
60
Median dip of fractures
0°
90°
Fractures containing vugs
0
30
Depth, 100's feet
0
2
4
6
8
10
12
14
16
PRELIMINARY DRAFT
INFORMATION ONLY



UE-25 UZ-16
Lithology
Porosity
0%
70%
Volumetric water content
0%
40%
Saturation
10%
100%
Depth, 100's feet
0
2
4
6
8
10
12
14
16

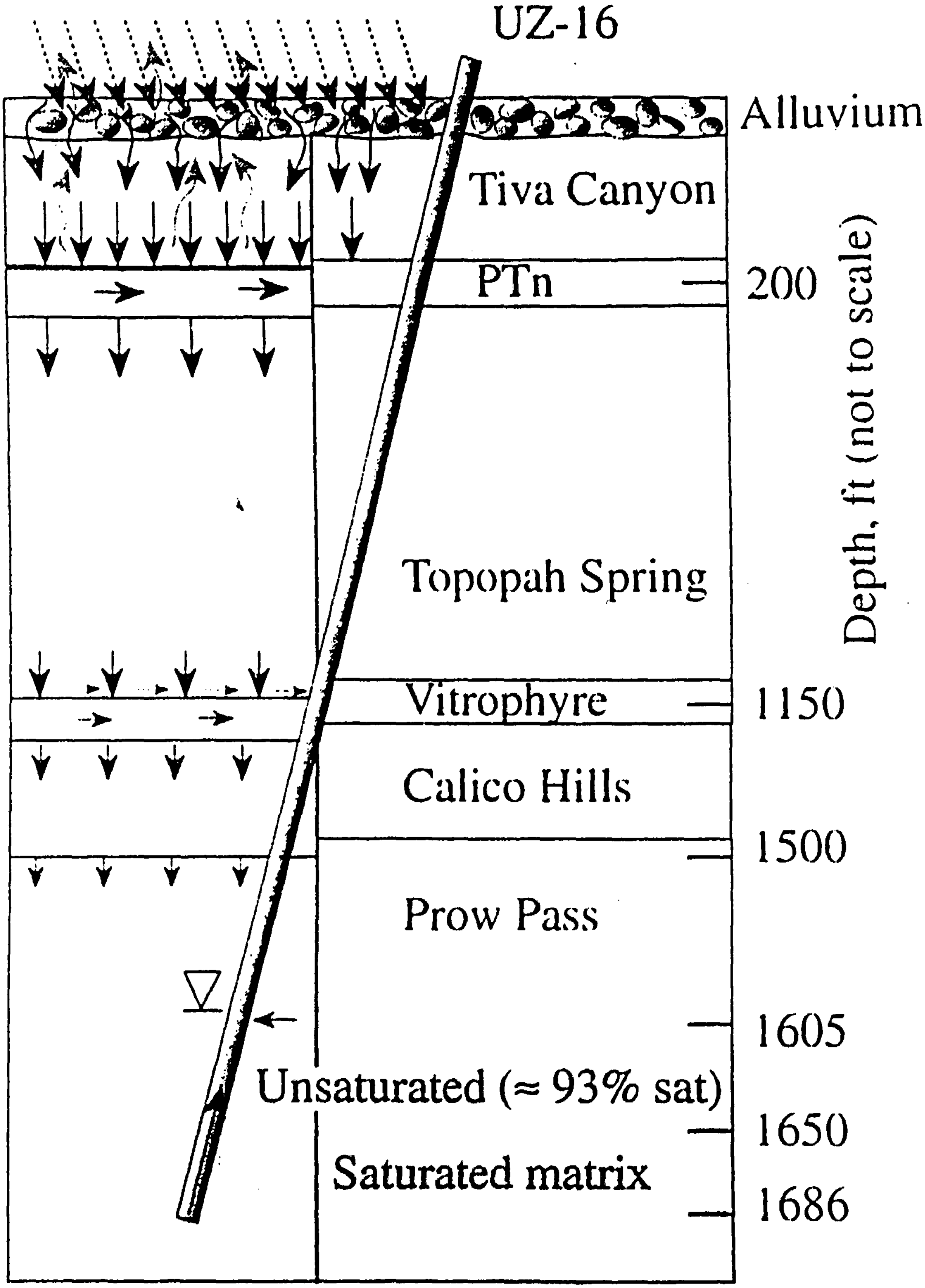


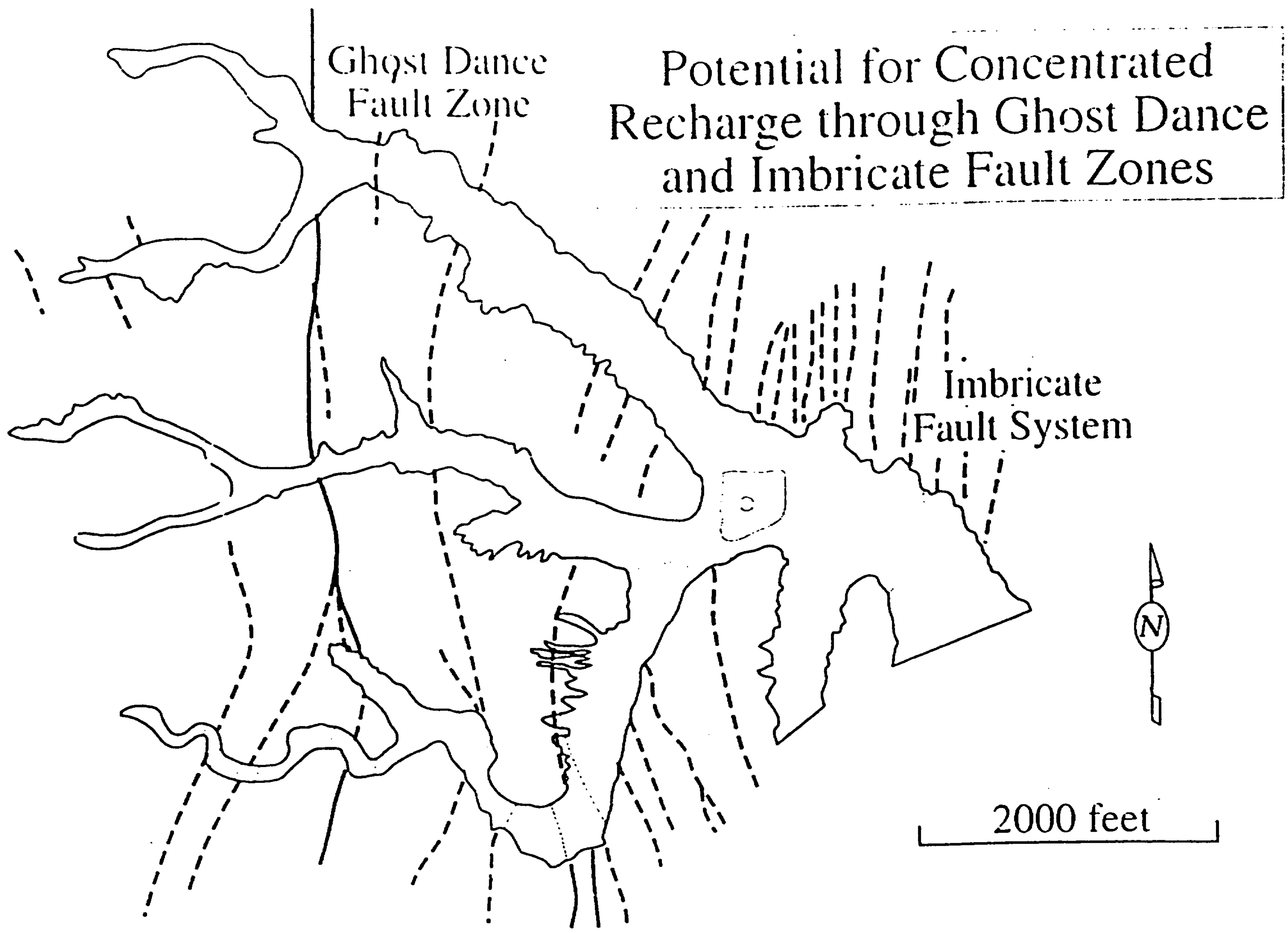
UE-25 UZ-16
Lithology
Fracture density
Saturation
Water potential (– bars)
0
60
10%
100%
0
10
100
1000
Depth, 100's feet
0
2
4
6
8
10
12
14
16
PRELIMINARY DRAFT
INFORMATION ONLY

Possible Interpretations

UE-25 UZ#16

Conceptualization of Percolation




Potential for Concentrated Recharge through Ghost Dance and Imbricate Fault Zones
Ghost Dance Fault Zone
Imbricate Fault System
N
2000 feet

Possible Interpretations for Unsaturated Matrix - Fracture Flow at UZ-16

Uniform Flux

- Fracture flow in unsaturated matrix sustained by high pressure heads and upward flow from the saturated Prow Pass

Concentrated Flux

- Fracture flow in unsaturated matrix sustained by downward fault flow derived from lateral inflow and/or near-surface infiltration

Possible Interpretations for Unsaturated Matrix - Fracture Flow at UZ-16

(Continued)

Perched Water

- Residual water from higher piezometric and/or standing water levels in the Prow Pass

* matrix may be locally saturated near interconnected fractures and/or near adjacent fault zones

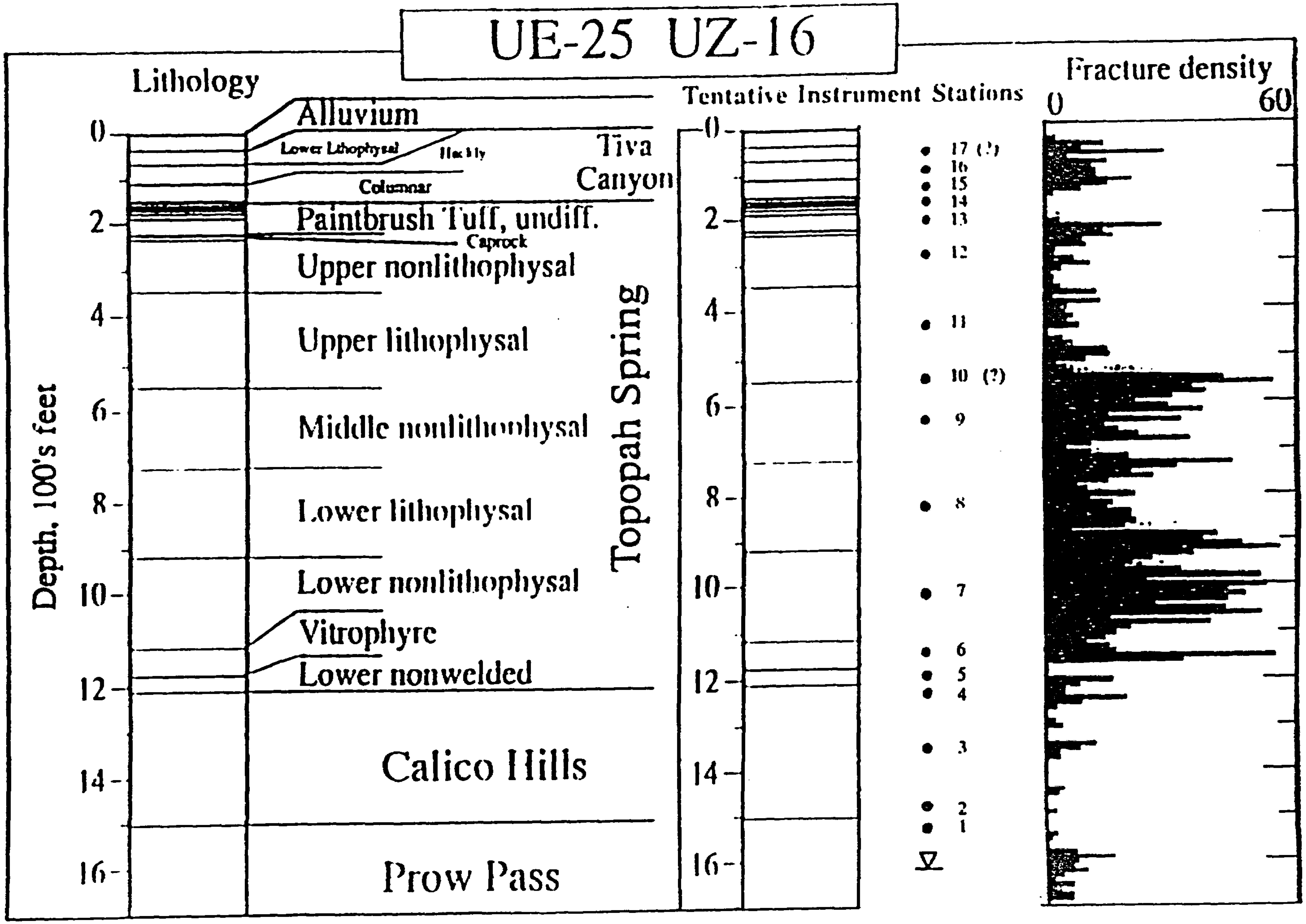
Tentative

Instrument Station Locations

for

UE-25 UZ#16

Borehole Site



Preliminary Predecisional Draft Material

Achieving Study Goals

Answer the question:

Is percolation a

a) uniform flux problem

b) concentrated flux problem

c) all of the above