0:00:09.936,0:00:11.120
[Keri Kodama (host):]
All right.

0:00:11.760,0:00:17.600
Hi, everyone. Welcome to the Water Resources
Research Center spring seminar series once again.

0:00:18.240,0:00:25.760
Maybe some folks, the folks were asking last
time about, you know, the geological aspects of

0:00:25.760,0:00:29.920
field transport. So, hope you were able to
make it here for this talk and maybe have

0:00:29.920,0:00:37.200
some of your questions answered from last time.
So we have Gary Beckett and Iris van der Zander,

0:00:37.200,0:00:43.840
and they will be presenting on field transport
considerations in the Hawaiian basalts system.

0:00:44.960,0:00:50.800
So, Gary Beckett was formerly a research associate
at San Diego State University, where he worked

0:00:50.800,0:00:57.840
with Dr. David Huntley on examining and testing
multi-phase processes under field conditions. And

0:00:58.800,0:01:04.080
Dr. Iris van der Zander works at the Hawaiʻi
Department of Health and supports the Safe

0:01:04.080,0:01:09.280
Drinking Water Branch and Hazard Evaluation and
Emergency Response Office on the Red Hill project.

0:01:09.280,0:01:11.840
[Iris Van Der Zander (speaker):]
Thank you, Keri, for the introduction.

0:01:13.600,0:01:15.760
Okay, thank you everybody, for joining.

0:01:17.600,0:01:28.160
Today we're going to talk about two important
acts—aspects in contamination transport in the

0:01:28.160,0:01:34.480
Hawaiian basalt system. So it's first of all
we're going to look at the geology, and then

0:01:35.600,0:01:45.520
we're going to look at the transport of the fuel
itself. I'm going to start with some pretty basic

0:01:46.800,0:01:54.240
stuff so people can follow along, and Gary Beckett
will then get into the more complicated details

0:01:54.240,0:02:02.000
about models and fluid transport. But I wanted
to start to get everybody's on the same page

0:02:02.720,0:02:08.720
with what we actually can see in the field
and how complicated fluid transport can be.

0:02:11.280,0:02:17.040
My background is I'm a geologist, I am currently
a geologist at the Safe Drinking Water Branch

0:02:17.040,0:02:26.000
since this Monday, previously, I was with the DOH
HEER office. I was also involved in the Red Hill

0:02:26.000,0:02:35.840
project more math—marginally and looking at some
data and lab reports. But I was part of the team.

0:02:36.800,0:02:45.520
So the key questions when we are looking at
contaminant transport, or fuel transport

0:02:46.480,0:02:55.200
in a system, in this case, the basaltic system is
where is the fuel? How does it move? What happens

0:02:55.200,0:03:01.680
to it? And how toxic it is? Today, we're
going to focus on two items in the middle:

0:03:01.680,0:03:09.840
how does it move and what happens to it, which is
all—often referred to as the transport and fate.

0:03:14.240,0:03:22.640
So when you're looking at the geology, it can be
very complicated. What I have often discovered in

0:03:23.200,0:03:30.560
reports I was reviewing is people say when they're
drilling somewhere that they're hitting a basaltic

0:03:30.560,0:03:38.160
rock and refusal is encountered, and they assume
everything is solid. In reality, that's not the

0:03:38.160,0:03:43.040
case. When you take a look at this picture here
on the left hand side, this is what you can see

0:03:43.040,0:03:53.840
at a typical outcrop in Hawaiʻi of basalt, you
can see that there is a lot of cracks, which can

0:03:53.840,0:04:02.800
happen during cooling, cooling cracks, or you can
have weathering, you are creating little pathways.

0:04:02.800,0:04:09.760
For example, when fluids go there and they can be
widened by the fuel transport or you can have on

0:04:09.760,0:04:15.040
the other hand from the fluids, some minerals
coming out and plug some of these channels up.

0:04:18.480,0:04:21.920
So, first message to take away is:

0:04:21.920,0:04:28.560
Basalt is not a solid piece of rock where nothing
can go through. There are preferential pathways.

0:04:33.920,0:04:41.920
What we also see often is something called
clinker zones and what this is here,

0:04:41.920,0:04:46.640
on the left side you can see it's
a zone of rubble that is usually

0:04:47.840,0:04:56.400
below a flow, in this case an ʻaʻā flow, and that's
just part of how the flow moves. It cools on the

0:04:56.400,0:05:02.800
top and on the bottom. And because it is
still liquid inside and cools on a top and bottom,

0:05:03.360,0:05:12.160
you have pieces of rubble breaking off that the
flow moves on with time. So, you have a network of

0:05:12.160,0:05:19.120
rubble below the flow, where you can have actual
lot of pukas in between where fluids or

0:05:20.400,0:05:33.920
water or fuel water mixture can move along. But
what can also happen is that there is this zone

0:05:33.920,0:05:42.240
can weather and you can have clay minerals
develop and the zone can be plugged up. So,

0:05:43.680,0:05:51.200
geology is inherently unfair, you cannot really
predict what happens and whatnot, and when you go

0:05:51.840,0:05:58.880
from one area to the next, you move like 10 feet
over you can have a completely different geology.

0:06:01.600,0:06:04.240
You can have also flow contacts. So,

0:06:05.600,0:06:15.360
when one flow develops, you can have weathering
on top and then the next flow comes in and moves

0:06:15.360,0:06:22.320
over it in between you can have gaps and again
along those gaps, you can have fluid transport.

0:06:25.920,0:06:32.960
Let's go to the different flow types. What
we often see is ʻaʻā flows and they're typically

0:06:32.960,0:06:38.800
pretty massive in the core like you see here. They're
typically you can identify them by stretched

0:06:39.360,0:06:49.280
vesicles but you don't see a lot of
interconnected network of vesicles and

0:06:50.320,0:06:55.680
quite a bit of space. However, because they're
so massive, you can have cracks developing in

0:06:55.680,0:07:03.920
between and again this is where fluid can move. On
the other hand, you can have pāhoehoe flows

0:07:04.800,0:07:11.360
and those typical shows a lot of vesicles
then, that can be interconnected or not.

0:07:13.760,0:07:21.120
Those vesicles can act like a quasi-sponge. So,
it can be an important to storage reservoir and

0:07:21.120,0:07:26.800
if those vesicles are connected, you can
have quite a bit of flow going through it.

0:07:28.320,0:07:34.400
So pāhoehoe flow have quite a bit of
potential as storage or transport medium.

0:07:37.040,0:07:40.400
Let's go to the big pictures. We can also have

0:07:41.680,0:07:48.400
lava tubes on different scales. Here on the right-
hand side we can see a medium-sized lava flow—

0:07:49.520,0:07:58.080
lava tube and you can have not only lava flows
through it and drain out afterwards, it can stay

0:07:58.080,0:08:05.680
open and you can have fuel and water transport
through these kinds of features. They can be

0:08:05.680,0:08:13.440
quite large, as everybody knows that visited the
Thurston Lava Tube on the Big Island. They can

0:08:13.440,0:08:20.640
can be small- or medium-sized, but they can also be
filled like in the example on the left-hand side.

0:08:21.680,0:08:29.920
So, the message from from all of this is a
reminder that when we are looking at models,

0:08:31.040,0:08:35.920
all these features are very different—
difficult to incorporate into models, but

0:08:36.720,0:08:43.040
we need to be aware that these features
exist and how this can influence models.

0:08:46.640,0:08:53.360
As the next consideration we are
going to look at fuel, specifically

0:08:53.360,0:09:01.760
the physical and chemical processes that are
involved in fuel or contaminant transport.

0:09:04.160,0:09:10.880
As everybody knows that has poured some oil
on water, they're not supposed to mix. So,

0:09:10.880,0:09:16.800
if this happens, then we shouldn't get fuel
in the water, right. You should have basically fuel

0:09:16.800,0:09:21.840
that shears off the top and there should
never ever get anything into the water.

0:09:23.280,0:09:31.120
So, the question is also at Red Hill, does this
happen or does this not happen? On on the bottom

0:09:31.120,0:09:40.080
here, what can also happen is once you stir
such a mixture up, you can get a very different

0:09:43.520,0:09:52.080
mixture of fuel and water, you can actually get
little bubbles in there or a foam type mixture.

0:09:52.080,0:10:01.120
And that has important implications on how the
contaminant can be transported in the water.

0:10:03.440,0:10:09.760
Something like this, for example can be imagined
to happen at the Red Hill Shaft when you turn

0:10:09.760,0:10:17.840
pumps off, pumps on in, you stir it, this
mixture up. So you're training basically,

0:10:18.720,0:10:31.840
the fuel into the water. And other potential
is the solution. The problem is, as we know,

0:10:33.520,0:10:40.800
like dissolves in like so we can usually
only dissolve something that is nonpolar

0:10:40.800,0:10:46.320
into a nonpolar solvent. And what's something
that's polar in a polar solvent, otherwise you

0:10:46.320,0:10:55.280
don't get a homogeneous mixture. I have some
example here of a polar compound like water

0:10:56.960,0:11:02.800
where you have different polarities. So
any compound that has polarity is going

0:11:02.800,0:11:10.640
to be solved. On the other hand, see here on
the right, a nonpolar, you have hydrocarbon

0:11:11.920,0:11:15.680
that has no polarity. So do
you going to solve this in there.

0:11:17.520,0:11:26.320
You wouldn't expect this very much to happen.
But one possibility is if you have an alteration

0:11:26.320,0:11:35.600
of your initial hydrocarbons. So, this can happen
for example, during biodegradation, where you are

0:11:35.600,0:11:43.200
adding oxygen onto compounds and your microbes
start munching on these compounds, they get

0:11:43.200,0:11:51.760
smaller and oxygen can be added. What this does
is basically it can turn molecule into a solvent,

0:11:51.760,0:11:59.360
which has a polar end and a nonpolar end and then a
worst case, this can lead to nonpolar compounds

0:12:00.000,0:12:09.840
going into the water because the
oxygen can bind to the water molecules.

0:12:13.280,0:12:15.520
I touched on biodegradation.

0:12:16.960,0:12:27.280
Let's take a look what can happen. Biodegradation
is often very simplified, especially in terms of

0:12:29.600,0:12:38.000
does it not—does petroleum naturally degrade. Often it is
shown that a hydrocarbon, when bacteria start

0:12:38.000,0:12:50.720
degrading it, turns into water and carbon dioxide.
While this might be true, it is not that simple.

0:12:50.720,0:12:56.560
There are many many steps that go in between
as you can see, for example, in this formula

0:13:00.400,0:13:06.480
this is an example of compound of hydrocarbons
and you're adding oxygen. First of all

0:13:06.480,0:13:12.240
nothing is gonna happen if you don't add any
activation energy or an enzyme, you have to

0:13:13.360,0:13:19.840
basically get over an initial activation
energy to get the process started.

0:13:21.040,0:13:28.320
After that, you can at some point get carbon
dioxide and water and you're creating energy.

0:13:28.320,0:13:37.120
This energy can be in the form of heat, which
also can be used as a tracer, when you will have

0:13:38.160,0:13:45.760
some biodegradation going on in terms of fuel
degradation. However, as you can see here on the

0:13:45.760,0:13:55.360
bottom, oxidation of this compound requires
75 electrons and therefore it's—it's not a

0:13:55.360,0:14:06.400
very simple process, these electrons have to move
around. So, the process is much more complicated.

0:14:07.280,0:14:13.760
You cannot—you have, can have different types
of degradation. You can have aerobic degradation,

0:14:13.760,0:14:18.640
where you utilize oxyges—oxygen, or
you can have anaerobic degradation

0:14:20.080,0:14:28.080
of different compounds and with different electron
acceptors. It depends very much on what conditions

0:14:28.800,0:14:33.440
you have present at a site. Do you have
enough oxygen? Do you—don't have enough

0:14:33.440,0:14:39.920
oxygen? After a while, you're depleting the oxygen even
if it is present, and you have to go to other

0:14:40.480,0:14:48.640
electron acceptors. But what is also important
is the process that I showed in the beginning.

0:14:49.680,0:14:58.240
We're going to CO_2 and water involves many steps
in between and along this pathway you can have

0:14:58.240,0:15:05.360
many intermediate compounds, which might be called
polar compounds that Barbara Bekin's talked about

0:15:05.920,0:15:17.360
the other day. They can be ketones, alcohols, and
so forth. So, their reaction is not necessarily

0:15:17.360,0:15:27.360
complete. We don't necessarily know what happens
in between. In addition, biodegradation happens in

0:15:27.360,0:15:33.680
competition but also syntrophic. So, different
populations of bacteria can work together

0:15:33.680,0:15:39.840
or they can work against each other
and take important components away.

0:15:45.200,0:15:49.520
Okay, so, in summary, weathering of
hydrocarbons is a multistep process.

0:15:52.000,0:15:54.400
We also can have different

0:15:56.560,0:16:06.800
microbes degrading at different rates, anaerobic
degradation like methanogenesis is usually pretty

0:16:06.800,0:16:13.520
slow, if you have oxygen involved, it can be
faster, but all of this depends also on

0:16:14.480,0:16:22.880
do you have the right substrate there that
the microbes can use to degrade the fuel.

0:16:25.600,0:16:36.240
You're required to have microorganism presence
and you can also produce oxygen containing

0:16:36.240,0:16:49.120
products as I showed earlier. You can create so-called
solvents that might be able to pull fuel

0:16:49.120,0:16:57.120
compounds that are normally nonpolar into a polar
solvent like water. So, they act like a solvent.

0:17:00.080,0:17:07.520
Biodegradation also depends on many factors,

such as you have to have wide—water available.

0:17:09.360,0:17:17.840
You need to transport these substrates for the
different microbes from one place to the other.

0:17:18.480,0:17:21.840
You have to have the right
substrate there for example,

0:17:25.280,0:17:32.240
iron reducing microbes need iron,
and you have the sulfate reducing

0:17:32.240,0:17:39.680
microbes that require sulfate, and so forth.
You can have also a variety of compounds

0:17:40.320,0:17:48.000
in your fuel. So, it depends how good
these microbes can degrade long chains or

0:17:48.000,0:17:57.120
short chains, it depends on what your combination
of microbes are, which do you have present.

0:17:59.440,0:18:05.680
And then you can have different growth rates,
which is not only dependent on your microbes,

0:18:05.680,0:18:13.840
but also on the availability of food or oxygen.

0:18:15.040,0:18:20.800
In addition, you have these dynamics of
your communities of microbes. which can compete

0:18:20.800,0:18:27.600
or support each other. And last, but not least,
you have different conditions in the aquifer

0:18:27.600,0:18:42.160
such as different oxygen compositions, but also
the—it depends on how fast your aquifer moves.

0:18:42.160,0:18:52.240
These are different models, what can happen in a
plume, but what I just want to point out, the popular

0:18:54.000,0:18:58.720
concept is right now that you have
in a center, you have a methanogenic

0:19:00.000,0:19:06.960
area where you have anaerobic bacteria,
because everything else has been depleted,

0:19:06.960,0:19:14.080
oxygen has been depleted, sulfate has been
depleted, and so forth, but you can also have

0:19:15.120,0:19:24.560
degradation happening at the fringes. It is not
quite clear how exactly degradation happens.

0:19:26.880,0:19:33.520
But these are two competing models that are here
right now and that most people are talking about.

0:19:34.960,0:19:43.040
This can be used for example, to identify a source,
so if you are looking for a tracer, you want to

0:19:43.040,0:19:52.640
look at methane for example. That usually tells
you where most likely your source zone is.

0:19:55.920,0:19:58.880
Take away from what I just presented is

0:19:59.920,0:20:07.280
studies have found that hydrology
affects biodegradation. So, if you

0:20:09.360,0:20:14.560
want to have microbes degrade
material, you have to ensure that different

0:20:17.040,0:20:24.400
fuel or different substrate is moved from one area
to the next, otherwise your microbes will starve.

0:20:25.680,0:20:31.040
But the question is, what kind of speed
do you need for the transport of these

0:20:31.040,0:20:37.280
substrates. So, it can't be too quickly
because then you're washing it basically away.

0:20:38.320,0:20:44.400
But it also cannot be too slow so
that your microbes don't starve.

0:20:45.440,0:20:53.760
So, this is something we are battling with as
well. In the end, you have to look at all these

0:20:53.760,0:21:00.720
different aspects that I just showed you, you
have to look at the geology, you have to look at,

0:21:01.520,0:21:11.680
okay, what—how do you transport water, material?
How does a compound evaporate? How

0:21:11.680,0:21:19.360
do different compounds separate from each
other based on, for example, their polarity,

0:21:19.360,0:21:25.200
and you have to all assemble this in a conceptual

site model. And the more you know what's going on,

0:21:25.200,0:21:29.840
the better it is. If you start with
assumptions, there's always room for error.

0:21:32.640,0:21:38.800
So you want to avoid as much as possible that
you are making too many assumptions. So you start

0:21:38.800,0:21:45.440
with a good conceptual site model like this and
then you go and start your model. And—but

0:21:45.440,0:21:50.960
you always have to go back and do some ground
truthing, compare it with the actual data.

0:21:52.160,0:21:58.560
And with that, I'm gonna transition
to Gary Beckett to take it from here.

0:22:02.240,0:22:08.960
[Gary Beckett (speaker):]
Thanks, Iris. I will start my video for a moment
here. But then I'm going to turn it off just to

0:22:08.960,0:22:15.360
preserve bandwidth and protect everybody's health
and safety in the room. So, folks, what I'm going

0:22:15.360,0:22:23.760
to cover is really just a very high-level overview
of some of the multiphase mechanics, how fuel

0:22:24.480,0:22:29.920
is transported, in general, and then more
specifically in hard rock environments. And

0:22:29.920,0:22:35.360
we'll talk a little about Red Hill, but not
a whole lot. This is more generalized. And

0:22:36.720,0:22:41.360
I look forward to some questions, hopefully at
the end. And I've tried to keep it as simple as

0:22:41.360,0:22:46.800
possible. But I think what you'll find pretty
quickly is multiphase processes aren't simple.

0:22:46.800,0:22:56.080
So with that, let me see if I can share
my screen. Does everybody see a slide?

0:22:58.080,0:23:04.400
Or does anybody not see a slide?
Okay. With that, we will continue

0:23:04.400,0:23:14.800
on. This cup was a taken from one of the
tap water, one of the sinks essentially in

0:23:14.800,0:23:22.320
the homes that was affected by particularly the
November 20 release at Red Hill, Hawaiʻi News

0:23:22.320,0:23:29.520
took this, but to Iris' point that when things
are emulsified, you can actually see it

0:23:29.520,0:23:33.520
right, dissolved phase—true
dissolved phase, you can't see.

0:23:34.160,0:23:39.200
So the problems that happened around
that timeframe were emulsified product.

0:23:42.160,0:23:48.560
You know, some of the factors that we'll talk
about today are specific to geologic context. Some

0:23:48.560,0:23:54.400
are specific to the fluids, meaning that fuels
the non-aqueous phase liquids, as we call them.

0:23:55.040,0:23:58.640
I'll talk a little bit about some
observations and complications.

0:23:58.640,0:24:02.080
And then again, we'll get into
some Red Hill observations.

0:24:03.200,0:24:08.320
The one thing I want people to take away and Iris
kind of hinted at it is that you really can't know

0:24:08.320,0:24:15.760
and describe everything. You can get your arms
around the general processes, you can understand

0:24:15.760,0:24:22.480
that there are things like lava tubes and cooling
fractures and whatnot, that all have an effect.

0:24:22.480,0:24:29.600
But describing where each one of those things are,
is impossible. So conservatism is important.

0:24:30.720,0:24:35.840
These are some observations by other folks
in literature, that pore scale processes are

0:24:35.840,0:24:40.080
important, really quite important, but you're
never going to see them at a macroscopic scale.

0:24:40.960,0:24:45.840
Homogenizing that scale can yield some
insights, but actually they're quite limited.

0:24:48.640,0:24:53.360
Many people, myself included, believe that
heterogeneity, especially in complex systems like

0:24:53.360,0:24:58.240
in Hawaiʻi's basaltic aquifers, just
can't model it deterministically.

0:24:59.600,0:25:04.240
Stochastics, meaning statistical
approaches should be used or considered.

0:25:05.200,0:25:10.800
That's abbreviated from Russell et al., that's
not a Science Foundation work, that's quite good.

0:25:12.160,0:25:15.520
Other interesting things in hard
rocks is small volumes of LNAPL

0:25:16.080,0:25:22.000
in fractures and in void spaces, can at
times produce significant LNAPL heads

0:25:22.720,0:25:27.840
and cause behaviors in transport and
distributions that are not expected.

0:25:30.880,0:25:35.120
The presence of potentially mobile
LNAPL beneath historical groundwater

0:25:35.120,0:25:42.240
surfaces are also a possibility under certain
release and driving pressure conditions.

0:25:42.240,0:25:45.440
That's abbreviated from Paul
Hardisty's work some years ago.

0:25:48.320,0:25:51.840
There's some math here, and I'm not
going to go into it in a lot of detail.

0:25:51.840,0:25:56.400
But it is really useful, especially anybody
that's had a hydrogeology class, we know what

0:25:56.400,0:26:01.600
Darcy's Law looks like. So, steady state flow
is proportional to the hydraulic conductivity "K,"

0:26:02.400,0:26:08.720
and the gradients "i" in the pore velocity is just
that divided by the effective porosity towards

0:26:08.720,0:26:16.320
water, a really simple equation, when you put
it into a multiphase context, same equation,

0:26:16.320,0:26:23.120
steady state flow of a phase LNAPL, if we
were interested in that is now proportional

0:26:23.120,0:26:28.000
to the permeability of the soil or the rock
materials, but also the relative permeability

0:26:28.000,0:26:35.920
of those materials towards that LNAPL in the
presence of water and/or air. It's proportional to

0:26:36.720,0:26:43.120
the fluid density and the viscosity as well.
These relationships, particularly the relative

0:26:43.120,0:26:49.120
permeability relationship is nonlinear.
And in turn, that's related to saturations,

0:26:49.120,0:26:55.760
and in turn that's related to capillarity. So
there's a lot of interrelationships for how

0:26:55.760,0:27:02.160
even in the simplest steady state form
of an equation LNAPL might behave. The

0:27:02.160,0:27:07.200
continuity equation below here takes Darcy's
Law and says what happens over time and space.

0:27:09.200,0:27:13.120
It's quite a problem to deal with, in
it from a modeling standpoint, right?

0:27:13.920,0:27:17.600
The equation is quite easy, conceptually,
though. It just says on the left-hand side,

0:27:18.480,0:27:24.320
if there's a change in mass, it has to be
equaled by a change in movement of the fluids.

0:27:25.840,0:27:29.680
And then LNAPL transmissivity
has become quite popular lately.

0:27:29.680,0:27:35.520
This is the equation of LNAPL transmissivity.
So when you hear folks give you a number,

0:27:35.520,0:27:41.520
or say a transmissivity means this or that with
respect to LNAPL, it really needs to be put in

0:27:41.520,0:27:48.560
context of each of the individual parameters,
because it's an integral over the area or

0:27:48.560,0:27:55.200

vertical integral of where LNAPL is in the
formation. So that's kind of a sidebar, it really

0:27:55.200,0:28:00.240
doesn't apply too much to Red Hill. But it does
apply to other sites in Hawaiʻi and elsewhere.

0:28:00.240,0:28:05.360
And folks should really keep in mind that
it is not a simple parameter by any means.

0:28:09.040,0:28:13.760
Some of you who have had physics classes may
have done this experiment. If you put glass

0:28:13.760,0:28:22.000
tubes in a water bath, that's what's a cartoon is
shown here. The smaller the diameter of the tube,

0:28:22.000,0:28:28.240
the higher the capillary rise of water in
the presence of a non-aqueous phase fluid.

0:28:28.240,0:28:31.040
In this case, it could be
air or it could be NAPL.

0:28:32.160,0:28:38.960
Water will rise to an equilibrium in a glass tube,
in the presence of a non-aqueous phase liquid.

0:28:40.160,0:28:46.000
So the head here, at the high level, is equal
to the head here, there is no gradient, this is

0:28:46.000,0:28:53.200
steady state. So, and that's because of the
affinity for the pore wall, the glass, and water—

0:28:53.920,0:28:58.880
the polarity of water, and some other things
that we won't get into. But the bottom line,

0:28:58.880,0:29:05.200
is the smaller the aperture size, the harder it
is for NAPL to get into it and displace water.

0:29:09.520,0:29:15.360
The wettability of the fluids is also really
important. On the left-hand side is sort of a

0:29:15.360,0:29:21.280
schematic of a pore space. If it's water wet, in
this case, it's a dense NAPL but it doesn't

0:29:21.280,0:29:26.640
really make a difference, it's an oil. The
NAPL will reside in the largest fractions

0:29:26.640,0:29:33.440
of the pore space, the largest pore diameters.
But of oil is the wedding phase, it reverses

0:29:33.440,0:29:41.520
and it becomes present in the smaller portions of
either the pore space or in fractures. If it—when oil

0:29:41.520,0:29:47.680
becomes wetting, it's much harder to get at if you
will, from a remediation standpoint and so forth.

0:29:52.880,0:29:59.280
These—this is a bit busy so all I'm going to
have you take away is that the x-axis on each

0:29:59.280,0:30:06.800
of these four charts, is log scale. So
if we look at the upper left, what this is

0:30:07.840,0:30:13.200
equivalent to the pressure of oil as compared to
water, the capillary pressure, if you will. And

0:30:13.200,0:30:20.880
these are the effective permeabilities, towards
LNAPL in different soil types. And what you see

0:30:20.880,0:30:28.160
is it covers more than 10 orders of magnitude.
That's really the takeaway, that where waterflow

0:30:28.800,0:30:33.920
covers several orders of magnitude, because of the
multiphase processes we looked at a minute ago,

0:30:34.880,0:30:41.920
LNAPL spans many orders of magnitude, at least
in theory. And lastly, if we look at the lower

0:30:41.920,0:30:49.440
right sketch, again plotted against the equivalent
elevation or pressure of LNAPL, relative to water,

0:30:49.440,0:30:55.440
you can see that the LNAPL transmissivity, will
be a function both of that pressure, between oil

0:30:55.440,0:31:00.400
and water, and the, in this case, the
interfacial tensions of the fluids.

0:31:01.280,0:31:07.200
So the takeaway from all this is, you can do these
kinds of calculations at home if you feel like it.

0:31:07.200,0:31:14.800
But there's a lot of variability in behaviors
because of these contrasts in LNAPL properties

0:31:14.800,0:31:19.840
is a function of capillary permeability,
relative permeability, and fluid factors.

0:31:23.600,0:31:28.240
A lot of folks think about residual saturation,
that fraction of oil that gets trapped in the

0:31:28.240,0:31:34.320
pore space as being a constant. In other words,
hey, the residual saturation, that sand is 5%.

0:31:35.920,0:31:44.320
It isn't, because of hysteresis, and other things
like that, the residual saturation of oils is a

0:31:44.320,0:31:50.800
function of either the initial saturation of those
oils plotted on the y-axis versus the, I'm sorry,

0:31:50.800,0:31:59.840
the initial is on the x-axis versus the final on
the y-axis. Or similarly, a function of pressure.

0:32:00.400,0:32:06.640
Set in another way more much more simply, if you
inject oil at a high pressure into a material,

0:32:06.640,0:32:13.200
it will have a higher residual than if you put oil
in at a low pressure. And from a release context,

0:32:13.200,0:32:19.600
what that means is the style and character of
a release, and the pressures generated during

0:32:19.600,0:32:26.160
that release will dictate not only how much gets
into the fractions of the pore space that will see

0:32:26.160,0:32:34.480
oil, but also what the residual will be. So
it's not a constant, it's a variable in itself,

0:32:35.120,0:32:44.000
can't be measured in the laboratory as a single
number. This chart's a bit busy, but it's actually

0:32:44.000,0:32:49.520
quite easy when you divide it up. So on the
top is a sandy material and on the bottom is a

0:32:49.520,0:32:52.640
silty-sandy material. Obviously,
these are not basalts, these are

0:32:54.240,0:32:59.040
more simplified sedimentary lithologies. But
then we've got three different LNAPL types:

0:32:59.040,0:33:05.040
we got a gasoline, a diesel, and an oil. That's
the same for both of the soil types in a large,

0:33:05.040,0:33:10.800
medium, and small spill. So it's just kind of
broken up by that, in quite intuitively,

0:33:10.800,0:33:18.320
large spills go a lot farther than small
spills. And large spills of things like

0:33:18.320,0:33:25.840
oil will go much less distance laterally than the
same exact volume for something like gasoline.

0:33:27.360,0:33:34.160
However, because the oil is trying to equilibrate, and
cannot spread laterally to equilibrate

0:33:34.160,0:33:40.560
as quickly as say, gasoline, it penetrates much
deeper into the formation, all other things being

0:33:40.560,0:33:47.040
equal. The other thing, the reason zeros in the
middle is because for any release on almost any

0:33:47.040,0:33:53.120
groundwater gradient in normal senses, there
is both what you would think of as upgradient

0:33:53.120,0:33:58.960
and downgradient flow of the LNAPL. In other
words, the water gradient is not sufficient,

0:33:58.960,0:34:05.840
in most cases, to strongly influence most releases.
The exception being the very smallest releases.

0:34:07.200,0:34:13.680
So a phrase that we often hear, you know, LNAPL
is downgradient, if somebody means gradient with

0:34:13.680,0:34:19.840
respect to the water table, chances are they're
not thinking about it holistically enough.

0:34:19.840,0:34:21.600
This is an interesting

0:34:21.600,0:34:27.040
experiment done a long, long time ago by Rick
Johnson at Oregon Graduate Institute. It's been

0:34:27.040,0:34:34.080
repeated many times by others, but it's the issue
of homogeneous materials, and yet heterogeneous

0:34:34.080,0:34:41.680
behavior of NAPL. So here are the measurements
downward of NAPL spilt into a uniform sand tank.

0:34:42.400,0:34:48.880
So at eight centimeters, the circle is sort

of like what you would see in a core sampler.

0:34:48.880,0:34:53.920
So you see a lot of NAPL in the core sampler,
you move over one to the right, you see at 10

0:34:53.920,0:35:00.880
centimeters, there's still lots of NAPL but your core
sampler's not seen very much of it. And by 15

0:35:00.880,0:35:05.600
centimeters, which is roughly I don't know, I
can't do the math in my head, six inches or so

0:35:06.400,0:35:14.640
you actually see no NAPL in the sampler. This
is in a sandbox. So I'll let people in the room

0:35:14.640,0:35:19.920
take their own guesses at what you think NAPL
distributions in a hard-rock setting that looks

0:35:19.920,0:35:26.160
like what Iris showed earlier, might actually
look like. And the challenge is, in describing that.

0:35:28.480,0:35:36.720
This is probably some of the best work ever done
in NAPL research. It's so old now that a lot of

0:35:36.720,0:35:41.680
folks have forgotten about it. But John
Wilson at New Mexico Tech and his colleagues

0:35:41.680,0:35:47.440
did a lot of experimentation, both with models
that were constructed, but also with sands

0:35:47.440,0:35:53.600
and other materials. So starting at the top,
this was oil injected into a water wet

0:35:54.560,0:35:58.160
pore network that is designed
based on a fractured network.

0:35:58.880,0:36:04.960
And then to the right of that is the residual oil
in that network after they drove water through and

0:36:04.960,0:36:10.960
drove as much oil out as they could. What you
see is a really highly heterogeneous distribution.

0:36:10.960,0:36:17.920
So you can put a number on this, whatever that is
2%, 3%, but it's not uniform in its distribution,

0:36:17.920,0:36:26.160
by any means. And this is an—again, simplified,
manmade model. These blobs below are just actual

0:36:26.160,0:36:33.200
blobs in a sandy porous medium. These are what
the residual oil looks like, in a sediment.

0:36:36.320,0:36:41.920
Others like Geller and his colleagues actually
built a model of a fracture, they did this

0:36:41.920,0:36:47.440
by injecting liquid metal into a fracture.
And then with geophysics and some imaging,

0:36:47.440,0:36:52.640
were able to make a model of the fracture. And
then they injected water and NAPL into the

0:36:52.640,0:36:58.000
fracture and looked at the distributions. And,
unfortunately, my recollection is that oil is

0:36:58.000,0:37:03.200
actually blue and water is red. But it really
doesn't make much difference in the sense that

0:37:04.160,0:37:10.880
even in a single fracture, it is virtually
impossible to describe the distributions of

0:37:10.880,0:37:17.200
oil and water. Meaning in a forward sense, how
would I predict where these things would be?

0:37:17.200,0:37:20.480
And where there's continuity,
what we call phase continuity,

0:37:20.480,0:37:26.720
oil connected to oil, there's mobility; where
there's phase discontinuity, there's immobility.

0:37:29.040,0:37:35.840
So, even in a single fracture, these are
the complications that you might expect.

0:37:37.520,0:37:41.520
There's a lot of different ways to look at
different geologic systems and model them, both

0:37:41.520,0:37:46.560
with respect to groundwater, contaminant transport,
NAPL transport. I'm not going to go through

0:37:46.560,0:37:53.360
all these, it can be simple on the upper left, it
can be highly complicated on the lower right. But

0:37:53.360,0:38:00.640
like I said earlier, stochastic methods tend to be
one of the norms. If you have enough information,

0:38:00.640,0:38:05.520
you could do things like discrete fracture
networks, and other types of things. You can also

0:38:05.520,0:38:10.080
do scaling parameters and other stuff that I'm
not going to get into. But the bottom line is you

0:38:10.080,0:38:14.800
have to have a way to wrap your arms around the
complexity of the system that you're dealing with.

0:38:16.400,0:38:21.440
This is just some incredible work that
Don Reeves and some others at DRI did.

0:38:22.880,0:38:30.000
These are all the fractures in a hard-rock setting
that they mapped out. The yellow plane is what

0:38:30.000,0:38:37.280
you're now looking at below. The left hand
figure is all the fractures in that plane.

0:38:38.560,0:38:42.000
The right hand is just the
fractures that are interconnected.

0:38:43.120,0:38:48.400
So what you see is there's a scaling. First,
the scaling is now you've gotten 2D, right.

0:38:48.960,0:38:54.320
And now you have all these fractures and just
that single 2D plane, but only this much smaller

0:38:54.320,0:39:02.160
fraction of those fractures are at play in a
hydraulic continuity setting. If that makes sense.

0:39:05.280,0:39:06.480
A little more math,

0:39:06.480,0:39:12.640
but I'm not going to go into it at high length.
But if fractures don't behave like porous media,

0:39:13.280,0:39:17.360
they can be approximated sometimes
but that's really not what the theory

0:39:17.360,0:39:22.320
or experience supports. And
so if we look at bulk flow Q,

0:39:23.200,0:39:27.760
this is the permeability term, the effective
hydraulic conductivity term that we looked

0:39:27.760,0:39:35.280
at earlier. In this case with simple fractures,
it's a function of the cube, cube of the aperture

0:39:36.240,0:39:43.680
with. For more real fracture settings, Climzak
and others suggest that it's to the fifth power.

0:39:45.200,0:39:52.160
So, complex Darcy flow like we looked at before
is even not complex enough, if that makes sense.

0:39:52.160,0:39:57.760
Plus, even beyond this, this is again just
experimentation and other work that says

0:39:57.760,0:40:04.080
through apertures and fractures NAPL and other
fluids can move very quickly. If the fracture

0:40:04.080,0:40:10.560
aperture is big enough, you can also get film
flow, think about how oil spills propagate

0:40:11.280,0:40:15.440
in the open ocean, open water, film
flow is a real thing for NAPLs.

0:40:17.520,0:40:19.920
Switching over to sort of
more Hawaiʻi specific, then,

0:40:20.960,0:40:28.480
you know, the experiences that we've all seen, and
I think I saw Bob Whittier logged on here. Bob,

0:40:29.280,0:40:34.880
and some others have lots and lots of experience
with this. Typically move quickly, and in complex

0:40:34.880,0:40:41.440
pathways, fast track and other geologic features
exists. Iris did a good job covering those,

0:40:42.240,0:40:47.440
they may have a sparse distribution, but that
doesn't mean they don't have a very large effect.

0:40:49.680,0:40:53.760
The weathering of the rock is complex too.
So even though I may have a clinker zone,

0:40:54.320,0:40:58.160
as Iris pointed out, that clinker
zone may be completely different

0:40:59.280,0:41:04.160
50 feet away from another location, even though
they're both clinker beds, one may be weathered,

0:41:04.160,0:41:09.920
with clays and pore space that's occluded and
the other may be open and quite permeable.

0:41:12.320,0:41:16.320
So you know, our questions for Red Hill
and other places like it in the state is,

0:41:16.320,0:41:21.360
how has that architecture arranged? How
will the fuel behave within that effects of,

0:41:22.320,0:41:27.200
of those things on capture and remediation of
fuels. And of course, all those relate them to

0:41:27.200,0:41:35.600
groundwater protection, goals, and so forth. These
are some core photos that were done at the Red

0:41:35.600,0:41:42.000
Hill facility, this is from the redacted Navy CSM,
these are really beautiful quality core photos.

0:41:42.960,0:41:46.480
But the thing I will point out is, there's a
lot that can be learned from them. Don't

0:41:46.480,0:41:53.600
get me wrong, but this is testing the rock body,
if that makes sense, not the transport pathways.

0:41:53.600,0:41:59.040
The transport pathways are things like the
fractures or the open pore space or other features

0:41:59.040,0:42:05.040
like Iris was talking about. But you can learn a
lot from these cores. And they were beautifully

0:42:05.040,0:42:12.160
done, they really were. One of the things that
we noticed, and this is often true not

0:42:12.160,0:42:18.560
just at Red Hill or in Hawaiʻi, but everywhere
that we look, they're field and lab scale

0:42:18.560,0:42:25.200
issues. And this though, is a calculation set
that's done specifically for the Red Hill area

0:42:25.200,0:42:31.280
where the blue and the red permeabilities and
Darcy's are based on field-scale measurements,

0:42:31.280,0:42:35.120
you can see that no matter whether you
look at the geometric mean, or the average,

0:42:35.120,0:42:40.880
the median, or the max, they're all around the
same order of magnitude. But when you look at

0:42:40.880,0:42:47.760
the permeability from the petr—petrographic
lab, they span a lot more orders of magnitude.

0:42:47.760,0:42:53.360
But the one thing that they all have in common is
they're quite a way, several orders of magnitude

0:42:53.360,0:42:58.640
away from the field-scale permeabilities.
And since we're interested in the features

0:42:58.640,0:43:05.200
that transmit fluids, water, oil, air, those
are the things that we need to understand.

0:43:07.680,0:43:13.440
Another figure from the Navy's work in the
conceptual model is sort of, some three dimensional

0:43:13.440,0:43:18.640
renderings of the barrel logs. These are the
logs that were taken when the Red Hill tanks

0:43:18.640,0:43:26.160
were put in. Stearns and others sort of directed
the work, and it's great work. It's one of the few

0:43:26.160,0:43:32.880
places probably in the world, because Red Hill
itself is such a unique engineering marvel,

0:43:33.440,0:43:41.680
where each of these 20 tanks, some person was able
to look around 360 degrees, and geologically log

0:43:41.680,0:43:47.520
these really enormous holes. So you can see that,
you know, they're things like loose rock and lava

0:43:47.520,0:43:52.720
tubes were recognized and clinker zones and all
these other features. And, you know, if you talk

0:43:52.720,0:43:59.040
about the lava tubes in red, even though they're
not very many of them, they are certainly present.

0:43:59.040,0:44:04.720
And this is a cross-section from the same work.

0:44:05.520,0:44:09.520
And all I'm really pointing out here is that
even when you simplify the cross-sections,

0:44:09.520,0:44:13.520
which all of us necessarily have to do
as geologists that's nothing unusual,

0:44:13.520,0:44:20.080
but the things that are important are the way

these bridging zones and other features where lava

0:44:20.080,0:44:28.480
flows stop or other types of behaviors during
the volcanic flows, how these are interconnected

0:44:28.480,0:44:33.680
vertically because in a very simple way we
know that rainfall percolates and recharges our

0:44:33.680,0:44:39.840
aquifers in Hawaiʻi. That's a good thing,
that's why our water is so good here. And so

0:44:39.840,0:44:45.120
there are ways for fluids to get down and where
those features are is really quite important.

0:44:48.720,0:44:53.680
Dr. Roland at UH, some of you may know but
you know really did some very nice work.

0:44:54.560,0:45:00.000
Before I get into his work on the upper right
is sort of a schematic of the kinds of features

0:45:00.000,0:45:02.720
in hard rock systems that we're
interested in knowing about,

0:45:03.440,0:45:09.600
and what Dr. Roland did is he went out to an
outcrop but near the Red Hill area, and mapped out

0:45:10.400,0:45:16.640
the different types of lithologies that are there.
And then mapped out sort of how the pore features

0:45:17.360,0:45:22.720
in those lithologies distribute themselves.
So on the lower right, is that schematic,

0:45:24.160,0:45:30.240
it's that, and that, you know, that's just one
face in two dimensions, right. So this captures

0:45:30.240,0:45:37.520
a sense for the complexities of how fluid behavior
might be influenced, in particular NAPL behavior

0:45:37.520,0:45:42.080
might be influenced by the characteristics
of these features, how often they occur,

0:45:42.880,0:45:47.840
where they are, the uneven nature of
the lower surfaces of these features,

0:45:47.840,0:45:52.160
all of those things will have an effect
on how both water and fuels behave.

0:45:54.400,0:45:59.760
So there's a couple of ways of, well, there's more
than a couple, but there are many ways of looking

0:45:59.760,0:46:06.560
at different aspects of the fuel behaviors.
In the CSM, the Navy had a fuel holding model,

0:46:06.560,0:46:11.840
and this is based on some of the older
work because it's simple to view,

0:46:11.840,0:46:17.440
not that it doesn't update the reflect, the
modifications and other things. But essentially

0:46:17.440,0:46:21.760
a holding model just says fuels can be
retained at some residual based on the

0:46:21.760,0:46:27.200
type of lithology that they pass through. And
so the holding model was built out of a number

0:46:27.200,0:46:32.320
of lithologic layers with different residual
capacities. And out of those came numbers, and

0:46:33.600,0:46:37.280
there was a, in some public domain
documentation, there were some

0:46:37.280,0:46:42.080
estimates of what's safe release volumes
might be based on a holding model approach.

0:46:43.360,0:46:48.320
What we've been interested in from a technical
basis is more of the dynamics. And so what

0:46:48.320,0:46:53.040
you're gonna see here is something we've shown at
several workgroups before, but we'll show again.

0:46:53.040,0:46:59.440
These are actually dynamic models of LNAPL
movement, through time or at 50 minutes so far,

0:46:59.440,0:47:04.800
don't worry, it won't, won't last several years,
as it seems to be implying and get done pretty

0:47:04.800,0:47:12.400
quickly. But the middle one is probably closest
to what happened in November, around the **Adit 3**

0:47:12.400,0:47:19.920
tunnel, and so forth, a sudden release
of LNAPL into the ground, the colors represent

0:47:19.920,0:47:24.880
different lithologic characteristics. Obviously,
a sudden release builds up higher pressures,

0:47:25.520,0:47:29.040
causes things to behave differently
than chronic releases on the right,

0:47:29.040,0:47:33.760
or small releases on the, on the left.
And as things move forward in time,

0:47:33.760,0:47:39.840
you saw that I stopped it there that a
dynamic model suggests that on the order of days,

0:47:39.840,0:47:45.600
I think it was 7 or 10, or whatever, LNAPL,
on a sudden release had the potential to

0:47:45.600,0:47:50.800
reach the water table. You'll notice as time
goes on, that the LNAPL continues to drain from

0:47:50.800,0:47:54.800
the formation at some rate based on all those
different properties that we looked at earlier.

0:47:54.800,0:47:58.880
So, you know, the moral of the story is,

0:47:58.880,0:48:04.160
is even this modeling, which, by the way,
is not based on site-specific parameters,

0:48:04.160,0:48:10.080
because we don't have those for the multi-phase
environment. Even so, scenario building

0:48:10.960,0:48:14.640
suggests that, you know, these are the kinds of
behaviors that we should be on the lookout for,

0:48:15.520,0:48:22.080
in the case of fuel releases. So, you know,
all of that, hopefully, for especially for a

0:48:22.960,0:48:27.120
broad-based science group, like I think most
of the people are here, although I don't know

0:48:27.120,0:48:31.600
everybody and I don't have a list in front of
me. But I think maybe the takeaways are fairly

0:48:32.880,0:48:37.600
straightforward. The fuel mechanics,
the wave fuels move is complex,

0:48:38.240,0:48:42.880
got not only the physical aspects, you have
the chemical aspects, biologic aspects that

0:48:44.000,0:48:49.200
Iris was talking about. The other interesting
thing that we're not going to talk about, is when

0:48:49.200,0:48:55.040
you make polar hydrocarbons through degradation,
you also create a surfactant effect that typically

0:48:55.040,0:49:00.320
lowers the interfacial tension between oil
and water, and changes the way oil behaves.

0:49:01.120,0:49:06.960
So you know, fuel transport itself in hard-rock
settings, and this setting is no different,

0:49:07.680,0:49:10.080
itself can be a primary
risk driver. In other words,

0:49:10.800,0:49:18.320
secondary transport in water is usually more
limited, and between dispersion degradation

0:49:18.320,0:49:24.400
other factors. So often, LNAPL is the source
for the impacts that we're concerned about,

0:49:24.400,0:49:29.840
again, LNAPL is the same as fuel to folks
like me that work in this end of the field.

0:49:30.720,0:49:36.800
The parameterization of hard-rock systems is
incredibly difficult. Nobody, nobody would even

0:49:37.360,0:49:42.320
begin to say it's easy. But the starting point is
not really in the lab, at least in my experience,

0:49:42.320,0:49:47.760
it's old fashioned geology, starting with
mapping like Dr. Roland showed in that example

0:49:47.760,0:49:53.360
earlier. And due to all those uncertainties,
modeling itself is non deterministic,

0:49:53.360,0:49:59.600
but that doesn't mean that key processes and
accounting for key features, geologic and otherwise,

0:50:00.560,0:50:07.920
can't be looked at, investigated. So that useful
modeling can be, can be created to explain whatever

0:50:07.920,0:50:13.840
observations you're interested in looking at.
So I think that's, that's if I'm not mistaken.

0:50:21.840,0:50:27.200
[Keri Kodama:]
All right. Thank you very much for both of you. Really great talks, a lot of valuable information. I

0:50:27.200,0:50:32.960
think a lot of people are really interested in hearing about that. We've already got

0:50:32.960,0:50:38.080
a couple of questions in the chat. But the audience is welcome to continue adding a few more.

0:50:39.680,0:50:46.880
So let's get started with the questions then. So the first one we got was from Erik Meade

0:50:48.000,0:50:53.920
to say, "Do we have the details on how all this great information is being or not being used

0:50:53.920,0:50:58.560
in the various modeling that is being done? Specifically the modeling the Navy is using?

0:51:02.720,0:51:05.440
[Gary Beckett:]
That's a question you unfortunately have

0:51:05.440,0:51:09.600
to ask the Navy, I don't know, in full what they've been done. Certainly, these

0:51:10.480,0:51:22.000
processes, areas of interest and concern have been discussed in, over several years, in fact.

0:51:22.000,0:51:23.440
[Keri Kodama:]
Next question from

0:51:23.440,0:51:29.200
Lily Bui, "Is there anyone here working with MODFLOW to look at Red Hill scenarios?

0:51:29.200,0:51:34.320
[Gary Beckett:]
I'm sorry, I'll pick it up just because

0:51:34.960,0:51:41.760
Iris has stepped out of the Red Hill work and so maybe I'm a little more current with it. But

0:51:42.640,0:51:49.840
yeah, MODFLOW is the platform that the Navy and its contractors are using for the Red Hill

0:51:50.400,0:51:58.480
aquifer system, that portion of it. And they're currently in the phase of doing

0:51:58.480,0:52:03.840
some modifications with it. There's been a number of iterations using the MODFLOW platform.

0:52:09.360,0:52:12.560
[Keri Kodama:]
And then there's a question from Aurora

0:52:12.560,0:52:20.240
Kagawa-Viviani. This is for Iris, "What is known about contaminant discharge to surface waters

0:52:20.240,0:52:22.880
in the area around Red Hill, given many springs?"

0:52:22.880,0:52:27.680
[Iris van der Zander:]
All I know is at this point,

0:52:27.680,0:52:34.400
we don't have any indication that there is any contamination in that scenario,

0:52:35.120,0:52:42.160
especially when you look at at Hālawa Stream, there is no indication. And actually,

0:52:42.880,0:52:48.320
the stream is situated above the water table, so there is no real

0:52:50.080,0:52:52.960
hydraulic connection to get the contamination in there.

0:52:57.920,0:53:05.840
[Gary Beckett:]
I'll add just a touch to that. And we've noted in the data themselves, things like dilution

0:53:05.840,0:53:11.760
and buffering and, and so forth. So it is a complicated system, but there do seem to be some,

0:53:12.320,0:53:17.200
you know, inherent buffering features, like for instance, you know, quite a bit, kind of

0:53:17.200,0:53:22.880
surprising, but the Red Hills Shaft still has small amounts of free product fuel

0:53:23.440,0:53:31.440
in it, and yet pumping at a laminar flow as has been going on since January, I believe, you know,

0:53:31.440,0:53:41.840
the influent detections in the water itself are, are quite low to non-detect. So, that's good news.

0:53:43.920,0:53:47.680
[Keri Kodama:]
One more question from Ali El-Kadi, "Are

0:53:47.680,0:53:55.840
you about stochastic transport
processes or geological features, or both?"

0:53:56.960,0:54:01.440
[Gary Beckett:]
Well, so the stochastic processes, Aly,

0:54:01.440,0:54:07.360
we're talking about ways of embedding
the geologic features into modeling.

0:54:08.400,0:54:14.000
That's one way of doing it, for sure. But
the way I'm modeling can be done a number of

0:54:14.000,0:54:19.680
different ways, as I showed in that one slide,
and certainly you of all folks know that so,

0:54:19.680,0:54:25.680
you know, for instance, it can be done with
scaling parameters. So if one had a good basis,

0:54:25.680,0:54:31.280
statistical or otherwise, to if you remember the
fracture models that I showed from Dan Reeves,

0:54:32.720,0:54:37.200
you know, you could say okay, only 10% of
the pore space is interconnected here. So,

0:54:37.200,0:54:42.800
despite having an effect of a field-based
porosity of say, whatever it is 15% or 10%,

0:54:43.920,0:54:50.400
the effective flow pathways are, in fact, 2%.
And all of my flow and other parameters need to

0:54:50.400,0:54:55.040
be scaled accordingly. That's just one example,
but there's a number of different approaches.

0:55:01.760,0:55:10.800
[Keri Kodama:]
Okay, I don't see any more questions. Oh, Aurora
slipping in with one more. For Gary, "Does this

0:55:10.800,0:55:18.640
suggest macropore/preferential flow are
dominant processes? Regarding Red Hill

0:55:18.640,0:55:24.320
field scale versus lab scale? And in this context,
what is the right scale to assess a monitor at?"

0:55:27.440,0:55:32.480
[Gary Beckett:]
Yeah, that's, that's a great question. I
mean, these kinds of systems are typically

0:55:32.480,0:55:41.120
dominated by macropores. Now for the basaltic
system, you know, that kind of behavior is

0:55:41.120,0:55:45.360
different for each of the various zones. So
for instance, if you're in the clinker zone,

0:55:46.400,0:55:51.680
you know, whether or not there's
weathering, and occlusion of the pore space,

0:55:51.680,0:55:58.320
and so forth. That's one type of macropore
system, so not—so if the average porosity of the

0:55:58.320,0:56:05.440
clinker zone is 35%, or whatever it is, not all
of that 35% is engaged across even a given single

0:56:06.000,0:56:12.400
lithologic unit, at least most likely. But
then that's different than the way the ʻaʻā core

0:56:12.400,0:56:16.560
would behave, whereas Iris mentioned their cooling
fractures, and if I remember, right, you know,

0:56:16.560,0:56:24.720
it's roughly five or so percent, plus or minus,
the initial volume of the material is what the

0:56:24.720,0:56:30.160
cooling fractures typically are. But the point
being is that if you have a very slow cooling ʻaʻā

0:56:31.120,0:56:35.520
core, that's going to have a different
set of fractures than if it's a thin,

0:56:35.520,0:56:45.280
fast cooling ʻaʻā core. And so not all of the
fractures within a given bed, even a single bed

0:56:45.280,0:56:50.960
will behave in the same way. So for a small spill,
the big fractures are going to transmit, for a

0:56:50.960,0:56:55.600
large spill where there's enough pressure built up
more than the big fractures would become involved.

0:56:57.360,0:57:00.400
That's a long answer, and probably doesn't
even start to answer your question.

0:57:05.760,0:57:08.160
[Keri Kodama:]
Followed up with, "Any

0:57:08.160,0:57:12.560
thoughts on how to sample/monitor
strategically to really capture

0:57:12.560,0:57:15.040
the effects of what 'might' be
happening in the subsurface?"

0:57:18.720,0:57:26.800
[Gary Beckett:]
Yeah, so, there are some ways I mean,
everything is a bit difficult, but we have been

0:57:27.760,0:57:30.640
talking with the Navy. The Navy
has been responsive looking at

0:57:31.600,0:57:35.200
what are called in-well tracer tests and
some other characterization techniques,

0:57:35.920,0:57:39.840
you can take those kinds of techniques
to a larger scale more of a field scale.

0:57:40.720,0:57:44.640
There are some downhole geophysical techniques
and others that can help us as well.

0:57:45.680,0:57:52.000
There are vapor tracers that can be used that have
partitioning characteristics that some have an

0:57:52.000,0:57:59.760
affinity more for water say than they do for
NAPL. And so I at least my own thought is that

0:57:59.760,0:58:07.840
it needs to be a multi-pronged investigation to
get a holistic understanding of system behaviors.

0:58:10.320,0:58:12.720
And Iris, you may have quite a bit to add on that.

0:58:12.720,0:58:16.800
[Iris Van Der Zander:]
No, I was just gonna say if you listen to Bob

0:58:18.000,0:58:25.280
Whittier's presentation last time, they
were talking about actually about looking at

0:58:25.280,0:58:35.840
these tracer tests. So I think that, that is
a perfect way to to start tackling the issue

0:58:39.920,0:58:43.920
[Keri Kodama:]
Okay, I think we can wrap it up here.
So just want to extend a big thank you

0:58:43.920,0:58:49.520
to both of our speakers for joining us in
this series. I'm really glad to have you.