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UNITED STATES DISTRICT COURT
WESTERN DISTRICT OF NEW YORK

VOL 3-A

UNITED STATES OF AMERICA, et al, Plaintiffs,	
-against-	CIV79-988
HOOKER CHEMICALS AND PLASTICS CORP., et al., Defendants.	

PROCEEDINGS: Hearing.

BEFORE: HON. JOHN T. CURTIN, USDJ.

LOCATION: U.S. DISTRICT COURT, Buffalo, N. Y.

DATE: May 2, 1984.

REPORTER: EUGENE R. BECKSTEIN

APPEARANCES:

MICHAEL ELDER, ESQ.,
WILLIAM WALSH, ESQ.,
BRUCE BERGER, ESQ.,
Appearing for the Government.

MARCIA CLEVELAND, ESQ.,
BERYL KUDER, ESQ.,
Appearing for the State of New York.

WALD, HARKRADER & ROSS, ESQS.,
By: THOMAS H. TRUITT, ESQ.,
KEITH WATSON, ESQ.
Appearing for Occidental.

JOEL E. SCHWEITZER, ESQ.,
EARL W. BRYDGES, JR., ESQ.,
Appearing for Niagara Falls.

TERRIS & SUNDERLAND, ESQS.,
By: PHILIP G. SUNDERLAND, ESQ.,
Appearing for Ontario.

PHILLIPS, NIZER, BENJAMIN, KRIM
& BALLON, ESQS.
By: MARTIN B. WASSER, ESQ.,
Appearing for Occidental.

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THE COURT: Mr. Elder.

MR. ELDER: Good morning, Judge. Judge, a housekeeping matter, when Dr. Harris testified, I forgot to put in an exhibit, Exhibit Number 86, which is a -- the March 1984 water quality insurance data from the City of Niagara Falls. This exhibit illustrates Dr. Harris' testimony regarding the present levels of S-Area chemicals found for the indicators. I have spoken with Mr. Sunderland, and he has no objection if I tender it to the Court out of turn.

THE COURT: All right. Hand it up, please.

MR. ELDER: Judge Curtain, we have a brief redirect of Dr. Kimble.

THE COURT: Dr. Kimble, please. Mr. Elder, when you're ready.

BRENDA KIMBLE, having been previously sworn, was examined and testified as follows:

REDIRECT EXAMINATION BY MR. ELDER:

Q Thank you, Judge. Dr. Kimble, do you recall yesterday during Mr. Sunderland's cross-examination some questions regarding whether 245 trichlorophenol had been analyzed for in and around the S-Area landfill?

A I do.

Q Last night, did you review the available date regarding whether those samples actually had been done?

A Yes. As far as it was possible, I went through all of the documents that I have been given relating to S-Area. I have --

MR. WATSON: Excuse me, counsel. The microphone is not on. In any case, I can't hear.

THE COURT: It's on now. Okay. Yry again.

THE WITNESS: Yesterday evening, I want through all of the documents that I have been asked to evaluate with respect to S-Area. I have pulled out these reports. I can't guarantee that is all of the analyses related 245 trichlorophenol, but I suspect it is majority. In most cases, these analyses have been done by a variety of labs on a variety of samples. The reason that I was not able to recall the exact data results yesterday is because most cases in

these analyses, 245 trichlorophenol was
not detected in the samples, although
it was analyzed for. This, in fact,
was consistant with my recollection of
all of the data. The compound 245
trichlorophenol did not really stand
out in my mind, because it's not a
chemical that I found to be of great
significance with respect to S-Area.

Q Thank you, Doctor. Dr., yesterday Mr. Sunderland
also asked you some questions regarding 2378
TCDD. Dr. Kimble, can you tell the Court
something about the relative water solubility of
2378 TCDD as compared to some of the more water
soluble chemicals on the specific parameter list?

A Yes. The chemicals on the specific chemical
indicator list that are the most water soluble
are the monochlorobenzoic acids and
monochlorobenzenes. The solubility of 2378 TCDD
with repect to these chemicals is very much less.
In fact, 2377 TCDD is well known to be a very
water insoluble compound.

Q Doctor, in a plumb of groundwater contamination
from S-Area, I ask you to assume that 2378 TCDD
would be in that groundwater plumb. In that

event, would the 2378 TCDD be proceeded in the plum~~b~~le by the more water soluble chemicals that you just mentioned?

A Certainly it would be, yes.

Q Thank you. Now, Doctor, if the 2378 TCDD -- or let me ask it this way, if it were present in the landfill and migrating off-site, could it ~~desolve~~ dissolve in the non-aqueous phase liquid?

A Yes. In fact, that is where I would expect it to be rather than dissolved in the groundwater.

Q And are any of the chemicals on the specific parameter list designed to detect non-aqueous phase liquids?

A In fact, most of the chemicals on the list would be represented -- are representatives of chemicals in non-aqueous phase liquids.

Q Doctor --

A They are also, I might add, they are also present in non-aqueous phase liquids at very high levels. In fact, to date, there have been no detectable levels of 2378 TCDD in non-aqueous phase liquids.

THE COURT: Excuse me, what do you mean by non-aqueous phase liquids?

THE WITNESS: These are the organic liquids that --

THE COURT: Yes, but what are they; are they phenols or --

THE WITNESS: They are mixtures of organic chemicals that are derived from -- the organic chemicals that were disposed of in the landfill.

THE COURT: All right.

BY MR. ELDER:

Q And is it your testimony that if the 2378 TCDD were to dissolve in the non-aqueous phase liquids, that the analysis or the specific parameters with respect to those that are the NAPL constituents would allow you to identify any areas so contaminated?

A That is correct. They would be much better indicator chemicals than 2378 TCDD.

MR. ELDER: Thank you, Dr. Kimble.

MR. SUNDERLAND: Question your Honor, please.

THE COURT: Yes.

RECROSS-EXAMINATION BY MR. SUNDERLAND:

Q Dr. Kimble, to your knowledge, in the analyses that you reviewed last night or any indeed in any other analyses, has any of the non-aqueous phase samples, materials, that have been analyzed, have they been analyzed for 2378 TCDD?

A There have been several analyses of non-aqueous phase liquids, where, in fact, the analysis was designed in such a way that they -- all of the components that could be identified would have been identified and 2378 TCDD was not found in any of the samples.

did she answer the Q?

Q Now, in Dr. Samuel Fogel's affidavit in table 4, I realize that there is a breakdown of the NAPL constituants, breaking it down, as you indicated yesterday, into approximately fifteen component chemicals; isn't that correct?

A My recollection is that is correct.

Q And isn't it also correct that that affidavit is only able to attribute or to sum up approximately ninety-nine percent of the NAPL makeup?

A Could you be more specific?

Q Yes. Isn't it correct to say that there is approximately a percent of the NAPL makeup that has not been identified to date?

A The samples of non-aqueous phase liquids that have been identified were looked for in total of the components down to less than point -- less than one percent of the components. This is on an individual sample basis.

Q That is right. So we have been -- excuse me. Go ahead.

A So all of the chemicals have been accounted for down to a level of -- it's a little less than one percent.

Q So, we don't know a little less than one percent of the NAPL makeup; isn't that correct?

A The way the data interpretation is done is the components are looked for down to one percent of the major components. So, in fact, you're accounting for much more than ninety-nine percent.

Q Well, but the fact remains, does it not, you correct me if I am wrong, that there still is one or a little less than one percent, at least according to the Fogel affidavit, one percent of the NAPL, that we are not sure what constitutes it?

note how an experienced witness avoides counsel

A The individual analyses -- there is some small percentage which is less than one percent which is -- which has not been identified. That is correct.

Q Now, I was a little unclear of your prior answer. Let me ask you the question again. Has any of the NAPL samples -- have any of the NAPL samples been specifically tested for 2378 TCDD?

A To my recollection, they have not been analyzed specifically for that chemical. Perhaps if I can explain my previous answer a little better, we saw yesterday in the chromatogram, we have peaks of varying heights. In fact, it is the area under the peak that relates to the quantity of that chemical. The way the data is interpreted is we have a series of peaks representing the chemicals analyzed in the non-aqueous phase liquid. Compounds that were present to less than -- just less than one percent of the major component have been identified. This is different from saying it is one percent of all of the chemicals that have been identified. That puts the limits of detection, so to speck, somewhat lower than I think what you were referring to. does it? what if 50% of the junk is made up of mtls that are

Q The samples that you looked at last night, the analyses in terms of the 245 trichlorophenol, can you tell me how frequently 245 was sampled for?

A Well, I don't have any numbers. All of these reports contain analyses for 245 trichlorophenol. I can go through them, if you --

Q Well, can you do this for me; can you give me a proportion of all of the water samples that have

individually less than 1% of the total. She's bullshitting.

been taken over the years at or around the S-Area; can you tell me what proportion of those samples, approximately, involved an analyses for 245 TCP?

A I can't give you that number. I went through my seven thesis documents last night, and I pulled out the reports. I have not had time to go through.

THE COURT: When you went through, did you find any numbers -- I mean, can you give us the range, the high mark?

THE WITNESS: Of the number of samples?

THE COURT: The samples were taken from different locations, I take it?

THE WITNESS: That is correct.

THE COURT: Is there any one place where there seems to --

THE WITNESS: Where 245 --

THE COURT: What is the highest finding you got?

THE WITNESS: I don't recall that number either. I haven't had the chance to go through those documents in detail.

BY MR. SUNDERLAND:

Q If someone were to ask you to take a NAPL sample and to the best that science allows us today to

analyze for 2378 TCDD, is it possible, is there a analytical method that would enable you to do that?
A Yes.
Q Is it the GCMS analytical method that you defined for us yesterday?
A It would use GCMS analytical instrumentation, but it would not be the method that we talked about yesterday.
Q Is there a term or title to that method that you can give to me, so I can identify it?
A We could define one.
Q Let's call it X; can we do that?
A Certainly.
Q Has, to your knowledge, X been utilized in analyzing any NAPL sample to date that has derived from the S-Area environment?
A To my knowledge, it has not, no.
MR. SUNDERLAND: That is all I have, your Honor. Thank you.
MR. ELDER: May I confer?

RE-REDIRECT EXAMINATION BY MR. ELDER:
Q Dr. Kimble, just a couple brief questions. Is the non-aqueous phase liquid matrix the kind of

matrix that would enable one to easily analyze for 2378 TCDD?

A No. It is not. In fact, the more complex the sample is in terms of the amount of organic material that is present in the sample, the harder the NAPL analysis, particularly if the chemicals present are chlorinated organic molecules.

Q Doctor, aren't there a variety of reasons that the very tiny percentage that you said were not accounted for, aren't there a variety of reasons that this could be the case, that you couldn't find that last less than one percent?

A There are all sorts of reasons, mostly relating to detection limits that we talked about yesterday. I should also add that --

THE COURT: Can you wait just a minute?

THE WITNESS: Excuse me.

BY MR. ELDER:

Q Doctor, let me direct -- why don't you continue your answer?

A I just wanted to point out that in fact when I looked at the details of the data for the analysis of non-aqueous phase liquids, I was incredibly surprised, in fact, at how many of the components of non-aqueous phase liquids were in fact identified. My experience with complex environmental samples, this is not normally the case. Normally, we can account for very much less of the components.

Q Doctor Kimble, directing your attention to Government's Exhibit 77, had 2378 TCDD been present above the detection level, would it have appeared on that chromatogram?

but does the detection level have anything to do with the level of hazard? (with this test)

A Yes. It would.

MR. ELDER: I have nothing further, Judge.

THE COURT: Anything else? No. Thank you.

MR. ELDER: Judge, the Government now calls Doctor George Pinder.

GEORGE F. PINDER, 343 Prospect Avenue, Princeton, New Jersey, called as a witness, having been duly sworn, was examined and testified as follows:

DIRECT EXAMINATION BY MR. ELDER:

Q Could everybody hear Dr. Pinder?

MR. TRUITT: I am having difficulty.

BY MR. ELDER:

Q Dr. Pinder, could you keep your voice up?

THE COURT: Yes, keep your voice up.

BY MR, ELDER:

Q If the Court please, Dr, Pinder is a hydrogeologist and is Chairman of the Civil Engineering Department at Princeton University. Dr. Pinder holds a Doctor of Philosophy and Geology which he received from the University of Illinois in 1968. He also holds a Bachelor of Science Degree in Geology with honors from the University of Western Ontario. In addition to being Chairman of the Department at Priceton, he is the RCA Professor of Energy Resources. Dr. Pinder is a member of the Society of Sigma Psi, Phi Kappa Phi, which are honorary societies in his field, the American Society of Civil Enginerrs, the Society of Petroleum Engineers, and the American Geophysical Union. Dr. Pinder has received the Horton Award which was presented by the American Geophysical Union for outstanding papers on hydrology. He also is the recipient of the O. E. Meinzer Award which was presented by the Geological Society of America for outstanding contribution in the field of hydrogeology. Dr. Pinder, I want to ask you to identify this document and tell me if it is your resume?

A Yes, this is a copy of my resume.
Q And can you examine the list of publications to see if those are your publications?
A Because this resume is a little out of date, there are several additional professional papers and three scholarly books which don't appear on this resume.
Q And can you tell us something about those scholarly books?
A The scholarly books were involved in the description of the techniques for mathematically modeling problems such as we are encountering in today's testimony.
Q These are text book type publications?
A That is correct.
Q Dr. Pinder, do you serve on the editorial board of any scientific journals or publications?
A Yes, I do.
Q Can you tell the Court what those journals or publications are?
A I am editor of a magazine called Advantages and Water Resources. I am also on the editorial board of several journals involved in a mathematical simulation, one of them being Applied Mathematical Modeling.

Q Dr. Pinder, can you indicate to the Court about how many articles and publications you have authored in the field of hydrogeology and computer simulation?
A The last time that I tallied them, there were approximately a hundred.
Q Now, Doctor, in addition to your teaching duties at Princeton University, do you provide consulting services?
A Yes.
Q And can you name or provide information regarding the types of clients to whom you provide consulting services?
A I provide services to both Governmental and industrial clients. Examples would be the State of New York, the Justice Department, EPA and private industry. IBM Corporation, I consulted for four or five different sites that they are involved in. McGraw, Edison Corporation.
Q And, Doctor, what kind of services do you provide for those private clients?
A Normally, I am asked to evaluate the difficulties they are having with ground water contamination and to recommend remedial measures to try and correct situations that currently exist.

Q Now, Doctor, I note on your resume that you have provided consulting services in the past to the Hooker Chemical Corporation. Was that in connection with the present litigation or any of the Niagara sites?
A No, sir.
Q And can you tell the Court, just for the sake of clarification, the nature of the consulting services that you provided?
A Several years ago, I was asked by the Hooker Corporation to teach one of their staff members the mathematical technology behind contaminant transport modeling. At that time, one of their staff members came to Princeton University and discussed this concept with me. We worked together over a period of several months to bring her up to a level where she would be able to do transport modeling on her own.
Q Thank you, Doctor. Prior to the time that you joined the faculty of Princeton University, were you employed by the United States Geological Survey?
A Yes.
Q And can you tell the Court what your professional activities were in that capacity?

A I was responsible for doing research into ground water flow and contamination transport. This was usually directed toward developing mathematical models for describing these phenomena.
Q And did you have any connection with the USGS modeling instruction courses that are presently held in Denver, Colorado?
A Yes, John Bredehoeft and I were responsible for initiating these schools where the employees of the United States Geological Survey would come to learn mathematical modeling techniques.
Q Doctor, prior to the time that you worked for USGS, did you have occasion to be employed by the Nova Scotia Department of Mines?
A Yes, sir.
Q And what did you do in that capacity?
A In that capacity, I was responsible primarily for field investigation work and analysis. This normally involved well construction, pump test analysis, ground water sample collections and the interpretation of this material.
Q Doctor, did this experience enable you to acquire hands-on experience in field investigations of hydrogeologic systems?
A Yes.

Q Now, Doctor, you had indicated that some of your activities were in the area of the mathematical modeling; can you describe to the Court what is meant by mathematical modeling?

A Yes, sir, I would be happy to do that. May I use an exhibit?

Q Certainly.

A You prefer that I walk to the exhibit?

THE COURT: That is all right. Why don't you go over there, Doctor. The only thing, keep your voice up. Make sure everybody can hear what you say.

THE WITNESS: Your Honor, I have two exhibits, Numbers 87 and 88. I would like to use these exhibits to try and explain to you how mathematical modeling is used in ground water contamination problems and what a ground water model is.

THE COURT: Dr. Pinder, is this the concept that the man from Hooker came and spent several months with you to learn?

THE WITNESS: This is a very simplified version of it, your Honor. If you want details, I would recommend an excellent book by Peter Reakohrn and myself.

THE COURT: Nothing is simple. What is the name of the book?

THE WITNESS: It is called Simulation Methods and Sub-Surface Flow.

THE COURT: All right.

THE WITNESS: It is not selling very well. On this particular chart, I tried to outline the whole procedure from the time that someone recognizes they have a ground water problem to the point where they are actually putting some monitoring scheme in place. This is rather typical of the things that I have encountered as a consultant when I am asked to come in and investigate a site. The client, for one reason or another, recognizes he has a problem, usually by accident. Someone, for one reason or another, reports a problem and then he investigates and finds indeed it exists.

THE COURT: Excuse me, Doctor. What do you mean when you say ground water?

THE WITNESS: What I mean by ground water, your Honor, if I may use the easel, let's assume we have a slice through the earth surface, down. In the case of S-Area, we would have a layer of material, say twenty feet, that consisted of materials deposited by the ice sheet during the last glaciation. Then there is a confining layer, not entirely complete, like so, and then you have a bedrock below that. If I take a small sample of this material and blow it up into a big picture like this, assume we are looking at it through a magnifying glass, this is my magnifying glass, we would see in here sand grains like so, and between these sand grains we would have what we call pore space. Water that is moving down from precipitation will tend to move in and occupy part of this pore space, like this. If the sample we take is fairly close to the surface of the ground -- in other words, we don't godown very deep -- we will find that there will be some air left in that pore space, some water and some air. It is like a sponge. A sponge holds water, but also has air. If we take a sample that is a little further down, say at this point, we may find that if we blow it up that entire pore would be full of water. As you are measuring down, the point at which this whole pore space is filled with water is normally called the water table and that is where the ground water is normally defined from that point down. One would say that water that appears in what we call the unsaturated zone where you have both air and water coexisting, some people call this ground water, also. But as a general classification, I think we could say it is water that occurs beneath the surface of the earth that is ground water. So we are talking about problems where contaminants have been recognized in this kind of water. At that point, the person who is somehow responsible for investigating this problem will contract, normally contract to have some field information collected. This normally consists of samples of ground water or soil or both. This information is subsequently analyzed. That is, someone lookes at this data and tries to comprehend what the problem is and its extent. This is the field information analysis step. You go from recognition to data acquisition to information analysis. From this, a competent hydrologist will try to determine what is going on at that particular site, try to understand the physical system. Unfortunately, he normally will come back and say, I am terribly sorry, but we need more data, I don't have enough information, and he will go back up and acquire more information and this, in the computer language, means you go through this series of events a number of times. Is the data adequate? No. You go back up and collect some more and go through it. If the data is adequate, then the hydrologist is saying, I understand this system. Let us try and define a remedial scheme that will decontaminate or contain this problem. At that point, he will develop what we call a model or sometimes we call it a simulator. The word model was not in vogue a few years ago. Many people began to call them simulators, so I called it a simulator. We are going to talk about this over here in more detail in just a moment. The "simulator," then, is a mathematical model, a tool that predicts what will happen in the future and, in some cases, is used to determine what has happened in the past. Let's assume that we are able to develop this mathematical model, which I will expand on in a moment. We use that model to design a remedial strategy. In other words, the hydrologist and the modeler sit down together and say, what can we do to correct this situation, and they take that strategy and they put it into the model to test it. It is like a model airplane in a wind tunnel. They design the airplane, they test it in the wind tunnel before they put it up in the air to see if it is going to fly. Here we are doing the same thing, but it is not easy to build the equivalent of a wind tunnel, so we do it mathematically instead, the same idea, a test chamber. So the strategy is designed and then it is tested with the mathematical model, and if it is deemed to be inadequate, then you go back up and you try another one. I have been involved in cases where I have done thirty-six trips around this loop, looked at thirty-six different schemes, before I found what I was really happy with. Then you assume that if the strategy is effective, you must implement it, and finally, because in anything involving natural materials there is a certain degree of uncertainty, you must put in place an effective monitoring system to assure the public, safety of public health.

note the uncertainty inherent in any abstraction

This is an overview of where the mathematical model fits in all this. It basically fits in from this point on on down. This is the steps that one normally goes through in expanding this development of the mathematical model. The first thing is to try and formulate the problem, in other words, what are the questions we are going to try to answer with this test chamber or this mathematical model, and within the context of what I said over here, normally what we are -- the questions we are asking is or are, how will various remedial strategies work? Now, the first step is conceptualize the physical system. In other words, we take the information from these boxes on Exhibit 87 and try and get a conceptual or develop a picture in our minds of what this physical system is. This leads naturally in the hands of the competent modeler to a mathematical formulation. In other words, we can translate that physical world into a mathematical world. This is the mathematical modeling step. This leads to a large number of equations, not unlike the ones that you learn to solve in elementary school, except there are many, many of them, like ten thousand of them. Each one, basically, is a description of balancing the amount of water that goes into an area and the amount of water that goes out, or the amount of contaminants moving in and the amount of contaminants moving out. We solve these equations with large computers, but we have to somehow generate some credibility for these calculations. How do we know the mathematical model we built reproduced the real world adequately. This leads to what we call calibration stage, and this is normally a step where one tries to match the results of the model to something that is known in the field, some type of information like how water levels change over time or how water levels change over distance, water levels in wells. This history-matching step normally goes through a loop just like the one I described over there. If the match is not very close, you must go up and perhaps change your conceptual modeling system, perhaps modify the mathematical way that you described that system. Eventually, one expects to get a satisfactory history match, so the answer to this question is yes, and now you use it to do something that you couldn't do before, namely, test hypotheses, and these hypotheses, in our case, are going to be remedial strategies, ideas on how to decontaminate or contain the system. These new conditions then are used in the forecasting mode and after we have forecasted the response of the system, we can evaluate the plan that we implemented when we chose these conditions. This is the key part of the model from a practical prospective, putting in remedial technology and observing how that technology will behave over some specified period of time.

BY MR. ELDER:

Q Dr. Pinder, you have given a description generally of what mathematical modeling is and what it can do. Can you tell the Court whether you have had any practical experience in modeling hazardous waste situations?

A I have had several cases where I have modeled hazardous waste situations.

Q Approximately how many sites have you modeled, either with respect to the ground water system of with respect to the contaminant flow?

A The last time that I tabulated them, there were ten.

Q Thank you. Doctor, can you describe how mathematical models are used to help you design remedial measures? I believe you gave some general testimony from that exhibit, but could you elaborate on that a little bit?

A Well, specific techniques that are normally used in problems of this kind involve the construction of walls to prevent movement, drains to collect large amounts of water, also to act as barriers, wells put in the ground to collect contaminated water. Occasionally, one reinjects clean water into the ground to push contaminated water in a direction that you want it to go. All of these technologies can be examined using mathematical simulators.

Q Thank you, Doctor. Doctor, respecting hazardous waste remediation technology, do you have any practical experience in that area?

A Would you repeat the question?

Q Yes. Have you had occasion to become familiar with the technology that is available for remediating hazardous waste sites?

A Yes.

Q And how have you acquired that information?

A I acquired that information through the literature, through personal experience, through discussions with my colleagues in the area.

Q And --

A Those are the primary --

Q I am sorry. Can you tell the Court approximately how many sites that you have worked on where you have had participation in evaluating remedial technology?

A Perhaps fifteen.

Q Can you name some of those sites?

A   Price landfill in New Jersey, Kinbuck in New Jersey. I was involved in Love Canal project. A number of private clients, such as the IBM Corporation.

Q   Doctor, can you tell the Court whether the types of information that you have acquired, practical experience, participation in seminars, consultations with colleagues, are those the types of information that a hydrologist and a modeler would normally rely upon in making judgments about ground water systems and contaminant transport?

A   Yes.

Q   Thank you. Doctor, -- excuse me. Judge, at this time we would offer Dr. Pinder as an expert in the areas of hydrology and ground water and contaminant transport modeling.

THE COURT: Fine. Why don't you continue.

MR. ELDER: You want to resume the stand, Dr. Pinder?

BY MR. ELDER:

Q   Dr. Pinder, can you tell the Court the areas in which you provided advice to the Federal Government in connection with the S-Area litigation?

A My major participation in the case has been to provide a conceptualization of the problem and to evaluate the applicability of certain mathematical models to the valuation of remedial measures to be provided at this site.
Q And, Doctor, did your services include evaluation and advice in the area of multi-phase flow?
A Yes, sir.
Q Can you tell the Court what is meant by multi-phase flow?
A I was afraid you would ask me that after I left my easel.
Q Would it be of assistance to go back to the easel?
A Yes, it would.
Q Please do.
THE COURT: We expect to be here for a month or so, anyway.
THE WITNESS: Your Honor, I indicated to you that we have zones where we have water and air that co-exists. Let me take a sample out of that zone or that location where we would expect only water would exist, under normal circumstances. Let me blow that up so

that we can see clearly what is going on at the very small level of the pore. Once again, I draw my grains. Under normal circumstances, in the absence of any separate phase liquids, such as NAPL, we would define this pore as being totally occupied by water, remember below the water table. In the case of the movement of NPAL through the ground surface via spill or leakage of tanks or whatever reason, that NAPL will move in and it will occupy part of the pore space, so you will have NAPL, that is indicated by dots, and around that you will have liquid water, which we will indicate without any pattern; Then you also have the grains co-existing. In certain circumstances, this NAPL will occupy almost all of the pore. Only under the most extraordinary circumstances will it entirely occupy the pore. As long as you have two liquids that are separated by some type of interface -- in other words, imagine a bubble in water, the air is separated from the water -- as long as an interface exists, then we call that multi-phase.

MR. ELDER: I think that was the question. And multi-phase flow relates to how the two separate phases would move in relationship to each other, or move separately?

THE WITNESS: That is correct. When one has two different phases, trying to move through this pore, to me it is counter-intuitive, but it is in fact true, that the existence of the water in this pore will impede the flow of the NAPL through that pore. In a contrary way, if air occupied this pore and the water was trying to move into it, the air would tend to impede the flow of the water. Whenever you have two phases present, one will always affect the other, tend to block the movement of the other.

BY MR. ELDER:

Q Doctor, for the sake of the record, could you mark that exhibit two-phase, just put the words two-phase on the top, and for the record, that is Exhibit 92. I think you can resume the stand, Dr. Pinder. You did say you needed some exercise today. I thought I would provide you with the opportunity. Dr. Pinder, in the course of the services that you provided to the Federal Government in this matter, did you attend technical meetings in which computer modeling, upward grading technology and monitoring were discussed?

A Yes, sir.

Q And did these meetings include the technical experts of the other parties?

A Yes, sir.

Q Including the representatives of Hooker?

A Yes, sir.

Q And the representatives of the State of New York?

A Yes, sir.

Q Dr. Pinder, were these meetings with the technical representatives of the other parties useful in assisting you in understanding the remedial proposals that were put forward and in assisting the Federal Government in developing counter-proposals?

A I think they were effective. I think they were particularly effective because you had two groups of technical people who were trying to filter out a large number of ideas, and in those circumstances, only the best ideas tend to survive.

Q Thank you, Dr. Pinder. Did you find these discussions rigorous?

A Yes.

Q Now, let me direct your attention to some of the requirements of the settlement agreement. Are you familiar with the three requirements set forth in the settlement to define a confining layer?

A Yes, sir.

Q And do these three requirements relate to a maximum hydraulic conductivity of no greater than 10 to the minus 7th; is that one of them?

1

A Yes, that is one.

Q And is another one a continuous strata three-foot thick?

2

A Yes, that is another.

Q And is the final one no presence of non-aqueous phase liquids?

3

A That is correct.

Q Now, Doctor, do you have an opinion whether downward NAPL migration will be prevented in an area where there exists a clay till layer meeting these three requirements?

A I believe that will indeed be the case.

Q And what is the basis for your opinion in that regard?

A The basic physics that underlies describing multi-phase flow, such as I tried to outline on my diagram, rules that a phase will not enter another material of finer grain size or smaller pores, except under a specified additional pressure; in other words, the small pores tend to try to hold out the separate phase when it is a non-wedding phase such as NAPL, and therefore I feel it is unlikely that the NAPL phase will enter a confining layer under normal circumstances.

Q Can you tell the Court what role the concept of capillarity would play in this phenomenon?

A Capillarity is what holds water in a sponge; it also happens to be what is going to hold the NAPL out of the clay area.

Q And is there a term, are you familiar with the term, wedability?

A Yes.

Q And can you tell the Court how that would apply to the clay till layer in relation to non-aqueous phase liquids?
A When you have two liquids, such as NAPL and water, one liquid will have more affinity for the grains than the other; it will tend to want to hold the other liquid out. That is true for any pair of phases, whether air and water, or gas and oil, or in this case, water and NAPL, and the liquid that tends to want to hold the grains most tenaciously is called the wedding phase.
Q Thank you, Doctor. Now, in areas where all three of the requirements that we have discussed are not met, is that area within the landfill referred to as a confining layer discontinuity?
A Yes.
Q And by that, in layman's terms, we mean a hole in the clay layer; correct?
A Yes.
Q Was a mathematical model used to develop a remedy to contain and collect non-aqueous phase liquids in the area of confining layer discontinuities?
A Yes.
Q And can you describe for the Court the remedy that was formulated?

A The remedy that was proposed was that a vertical upward flow of the water phase be generated that was sufficiently strong that it would either hold NAPL in place or move it vertically upward and I think that this is a hard concept to grasp. no kidding! An analogy that you can draw on is the exhibit that you may have seen in one of the department stores where they hold a ball in place with a vacuum cleaner billing on it. That air rushing past the ball or balloon or what have you holds that balloon suspended much as the aqueous phase moving past the NAPL will tend to suspend that NAPL. If you increase the air flow, it is like increasing the water flow, you move that ball vertically in an upward direction.

Q Doctor, in the settlement agreement, are these conditions referred to as a confining layer equvalent?

A Yes.

Q Thank you. Was a mathematical model used to evaluate the feasibility of this concept?

A Yes.

Q And let me show you what has been marked Exhibit Number 84, and ask you whether this is the model that was so used?

A Yes. This is the description of the model that was used for that purpose.

Q And can you describe for the Court the type of model that is?

A This is a mathematical description of the two-phase phenomenon that I described on the easel. The equations involved are rather complicated, but the concepts are really no more difficult than what I just showed you.

Q Indicating for the record some of the equations contained in Government Exhibit 84, for the record, your Honor, this model is entitled S-Area Two-phase Flow Model, prepared by Arthur D. Little. Doctor, what role did you play in the development of that model?

A I was responsible for describing the original porous flow physics that went into this model and for evaluating the method was used to solve the equations that came out of that physical description.

Q And can you tell the Court how you satisfied yourself regarding the adequacy of that model?

A The initial modeling effort was proposed by myself in conjunction with Arthur D. Little Company, and the model was prepared by Arthur D.

Little. The person who prepared it came to visit me at Princeton and described the progress he was making. We discussed how perhaps it could be enhanced. He adopted those suggestions and eventually returned to me a report which I reviewed and found satisfactory.

Q Doctor, just for the purposes of clarification, is it the purpose of this model to simulate two-phase flow in the vertical dimension in the vicinity of the confining layer discontinuities?

A Yes, sir.

Q And the two phases under consideration are the water phase and the non-aqueous phase liquid phase?

A That is correct.

Q Now, Doctor, I believe prior testimony in the model itself indicates that the model examines conditions in the one dimension, the vertical dimension. Can you explain to the Court why that is adequate for the purposes of the problem at hand?

A Well, there are two reasons why I feel this model is adequate in looking at just one dimension, namely vertically upward, one is the problem at hand is basically a one dimensional problem, in other words, flow is essentially straight up and down in the area of discontinuity, therefore, satisfies the necessary conditions for one dimensional simulation. The second is that a separate model was built that was indeed two dimensional in nature and the results of that two dimensional model were - confirmed the applicability of this one dimensional model.

Q Doctor, is two-phase flow modeling a new technique?

A Not at all.

Q And can you tell us something about other applications of two-phase flow modeling?

A There are two areas where it is very commonly used, one is in the area of soil physics, where air and water co-exist in the root zone, and the other is oil reservoir simulation, where we have oil, water and sometimes gas co-existing and they want to describe this behavior so they can determine the optimum exploitation strategy for the resource.

Q And by exploitation strategy, you mean the strategy designed to have the oil phase come to the top and be removed for commercial use?

A Yes.

Q Thank you, Doctor. Now, Doctor, has actual field experience demonstrated the applicability of mathematical models to forecast the behavior of such two-phase flow systems?

A Yes. They have, and this methodology has been known since at least 1937 when a definitive volume was prepared by Muskat on this topic.

Q Now, Doctor, could you explain for the Court how the physical system at S-Area might be a comparable to the oil reservoir situation?

A The systems are quite similar in the sense that both involve organic liquid, in one case oil, in the other case NAPL, and they both involve water, so I think that the appropriate phases are present in both case.

Q Thank you. Do you have personal experience in simulating with mathematical models two-phase systems of the type encountered at S-Area?

A Yes, I have done that kind of research at the University and I am very much involved in it.

Q And can you describe for the Court something about that research?

A The most relevant research is that done by myself and a graduate student who has just now received her Doctrate where we modeled the movement of

NAPL-like substances, water and air simultaneously in the soil, and we even had the additional feature of allowing the NAPL to dissolve slightly in the water phase.

Q Doctor, have the results of that research been published?

A Yes. That material appears in the Students' Thesis and also in several abstracts to presentations that we made around the country regarding this work. We also have several manuscripts currently prepared and in review in various journals.

Q Thank you, Doctor. Dr. Pinder, as a result of your personal experience and the independent EPA modeling that you mentioned, do you have a professional opinion concerning whether the A. D. Little model is adequate to predict the response of non-aqueous phase liquids to upward ground water flow in discontinuity areas?

who is giving this testimony?

A I think this model is adequate for this purpose.

Q Thank you. Now, Doctor, is it true that the purpose of the A. D. Little model will be to establish the upward gradiant requirement in the area of discontinuities?

A Yes, sir.

Q What evidence do you have that these upward gradiant requirements can in fact be achieved?
A There is another model that has been built to forecast how the water level in S-Area will respond to the installation of drain and walls. This model provides four casts of water level changes in S-Area that lead me to conclude that we will be able to achieve an adequate upward movement of water to contain the NAPL in the area of discontinuity.
Q Doctor, is it these changes in water levels within the overburden that provide the upward force to retain and collect the non-aqueous phase liquids?
A That is correct, sir.
Q Now, to your understanding, under the settlement agreement, will Hooker be required to submit plans, specifications and protocols to demonstrate this upward gradiant, in fact, can be achieved?
A Yes, they will.
Q Now, Dr. Pinder, based on the work that has been done to date, do you have an opinion concerning whether the site containment system set forth in the settlement for S-Area will both contain and

remove non-aqueous phase liquids?
A I believe it will contain and remove at least some of the non-aqueous phase liquids.
Q And can you describe for the Court how this will happen?
A Well, when you put in place a mechanism to stop the downward migration of the NAPL, it is very unlikely that you are going to just stop downward migration. You are going to tend to overdesign so that the NAPL will actually move upward, and if it moves upward, it will make its way eventually to the drain and be collected.
Q Doctor, in the area at S-Area above the suspected discontinuity, is the slope of the clay till layer toward the discontinuity?
A The information that I have seen has indicated that this is the case.
Q And will it be the case that the non-aqueous phase liquids might tend to migrate down towards the discontinuity?
A I would suspect that that would be what would happen, provided there is not any local depression that tends to hold it.
Q And when these non-aqueous phase liquids reach the area where the upward gradiant force is being

created, will they also be retained or move upward as you have described?

A Yes.

Q Now, Dr. Pinder, can you tell the Court how the actual field performance of the confining layer equivalent will be verified under the settlement?

A The concept here is to generate vertical movement of the liquids upwards. This can be established by measuring the energy level in the water at two different locations, and this is reflected in terms of water levels in wells. The water levels in the wells will be measured and the difference between the water levels at two vertical locations will have to be sufficiently great to assure via the math model that the organic solvents are moving up or the NAPL is moving up.

Q And will these measurements of water levels involve the use of Piezometers?

A Yes.

Q Dr. Pinder, do you have an opinion regarding whether the use of Piezometers as you have described will be adequate for the purpose of ensuring that the required upward gradiant is, in fact, being achieved?

A This is the standard way of measuring this. I

feel it will be satisfactory.
Q Fine. Thank you, Doctor. Doctor, you indicated that there was another model used to predict decreases in water level. Has this model been referred to as the Gannett-Flemming model?
A Yes.
Q And are you aware of the source of the mathematical fomulae that were used in this model?
A Yes, sir.
Q And can you tell the Court where those mathematical formulae were derived from?
A Ultimately, from my PhD thesis.
Q Did you have occasion to apply that work in a model developed for the USGS?
A Yes, sir.
Q And what is the name of that model?
A Well, it goes under various names. I believe the version that was used here is the Trescott, Arson and Pinder model, and the names in some permutation thereof.
Q Doctor, in your review of the Gannett-Flemming model, was that review for the purpose of examining these mathematical formulae?
A Yes, sir.

Q And based on that review, did you make a determination regarding whether the Gannett-Flemming model was an appropriate model for the purpose of simulating the effects of the remedial measures on water level decreases in the overburden?
A Yes, sir.
Q And what conclusion did you reach regarding its adequacy for that purpose?
A I feel that the model is adequate for the purposes for which it was designed.
Q Do you have an opinion concerning whether that model is consistent with current engineering practice in the geohydrologic field?
A It is my opinion that this is indeed consistent with current engineering practice.
Q And are you satisfied as with respect to the level of sophistication found in that model?
A Yes, sir.
Q Now, Doctor, I believe that you earlier testified that in your opinion non-aqueous phase liquids will, in fact, be collected by the tile drain systems. Do you know of any way that we can tell at this point in time how much non-aqueous phase liquids will, in fact, be collected?

A I don't think we know how much there is in the ground. Until that information is available, I don't think there is any way to forecast how much is going to be collected.

Q Doctor, you indicated that that calculation would depend on the quantity of NAPL in the landfill. Do you believe that there is any way to accurately estimate the quantity of non-aqueous phase liquids in the landfill?

A I don't believe so.

THE COURT: Well, there was some estimate made here, from records of Hooker; I believe that there was some sixty-three thousand tons of material. Is there any way that some percentage can be applied to that to determine that?

THE WITNESS: My experience in cases of this kind is that it is very difficult to know how much of that is still, in fact, contained in drums that have not undergone disintegration, and others, other cases clearly the drums have been destroyed for a long time. I have seen no indication in the materials that I have looked at of the amount of liquids that were put in the site that, in fact, become free liquids in the soil. In other words, I don't know how much is still resident in drums, and therefore not available to flow, and how much has somehow then be made available to flow.

MR. TRUITT: Counsel, your Honor, we will offer some brief testimony on this very point.

THE COURT: Thank you.

BY MR. ELDER:

Q Doctor, I would like to ask you one more line of questions, but I need to consult with Mr. Sunderland before I do that. Doctor, excuse me, Doctor. For the record, Judge, I have conferred with Mr. Sunderland regarding a report entitled Calculation regarding Possible NAPL Migration from S-Area and Bedrock under Niaraga River by G. E. Grisak, dated April 1984, and Mr. Sunderland has indicated that, in fact, this is the report that will be submitted to the Court. We would like to mark this set of calculations as Government Exhibit 93. Now, Dr. Pinder, I show you Government Exhibit 93 and ask you whether you [redacted] the [redacted]?

A Yes, I had an opportunity to look at this.

Q Now, Dr. Pinder, have you had sufficient opportunity to reach an opinion regarding the accuracy of the calculations made by Mr. Grisak?

A Yes, sir.

Q And do these calculations relate to NAPL migration under the Niagara River?

A Yes.

Q And can you give the Court your opinion of the accuracy of those calculations?

A Well, your Honor, the equations that were used in this particular calculation are not the ones that we have described here today and the ones that were used in the ADL model. [redacted]

Q Doctor, are there any conditions existing in the bedrock under the river relating to ground water flow that you don't feel are adequately addressed in that document?

A The main physical phenomena that has not been addressed here is the fact that when you have two co-existing phases, one phase tends to impede the movement of the other. This particular document assumes that only one phase, in fact, is present, namely, the NAPL. seems highly probable?

Q Doctor, in your opinion as a hydrogeologist, with experience in the design of remedial measures, do you have an opinion regarding whether those calculations could reasonably be used to justify the installation of remedies in the bedrock under the river?

A The calculations that Mr. Grisak has presented, you mean?

Q Those calculations, Doctor.

A I don't feel these calculations have any particular practical use.

MR. ELDER: Thank you, Doctor. Your witness, Mr. Sunderland.

CROSS-EXAMINARION BY MR. SUNDERLAND:

Q Thank you, Mr. Elder. Dr. Pinder, as I understand your testimony the last couple of minutes, you indicated that in order to determine how much of the NAPL will over time be

collectedby the drain collection system, you would have to know how much is in there today?
A Yes, sir.
Q And then you indicated that you have no idea how much is in there today?
A Yes, sir.
Q Am I correct in concluding, therefore, that we well never know how much in a relative sense, that is what proportion of the existing NAPL that is in the landfill today we will know?
A Would you --
MR. TRUITT: Excuse me, Counsel. I think that what we know may be different from what the witness knows.
MR. SUNDERLAND: You present your testimony, Counsel; that is fine. Let me ask you if going on your assumption that you do not know how much is in the landfill today and going on your statement that in order to know how much is collected, we have to know how much is in there today, it seems reasonable to me that even though the system collects NAPL over time, we will never know whether it has collected all of the NAPL that is in

there today or a big or small
proportion of it?
THE WITNESS: Let me clarify part of your question
in my mind.
BY MR. SUNDERLAND:
Q Fine.
A When I addressed the comment of the Judge, what I was saying was that even if we know how much is in the landfill, I assume that estimates can be obtained of that, I don't know how much occurs as a free liquid flowing in the soil and how much is still retained in the original canisters in which it resided at the time of burial. This uncertainty is what I am talking about when I say that I don't know how much is in the landfill. I don't know how much is a free fluid in the landfill.
Q Do you have any opinion as to the -- let me strike that. If we start by assuming that all of the NAPL as of today has exited from the drums, then do you have an opinion as to the proportion of the original NAPL that was deposited at the landfill --
MR. ELDER: Objection, your Honor. I would object to the question unless counsel

can offer proof that in fact his assumption is correct.

THE COURT: Well, I think the witness can either tell us that he can answer the question or he can't. That is the best way to leave it.

BY MR. SUNDERLAND:

Q Well, let me back up one step, your Honor, if I can do that. Do you have any opinion as to the likelihood that NAPL is still retained in any of the drums in the landfill?

A I have no knowledge whatsoever how they were buried or what containers were used.

Q All right. Then let me ask you to make the assumption that all of the NAPL that was placed in the landfill in drums form originally has now exited from the drums. Having made that assumption, do you have an opinion as to the proportion of the NAPL which may over time have migrated from the landfill?

A If I can paraphrase your question, I think you're asking me if all of the liquids that were originally drummed waste are somehow in the soil, and recall that volume, V, what percentage of V has left the site?

Q That is correct.
A Is that the question you're asking me?
Q Or what proportion of V remains in the site?
A The answer to either one is the same, I have no idea.
Q Do you have an opinion as to the roots of possible migration of that free flowing volume, V?
A I can describe to you the various mechanisms that are at work in such a situation, if that is what you are getting at.
Q What I am getting at is at the S-Area landfill when you originally drew your diagram of the landfill, you indicated that there was a discontinuity in the clay.
A Yes.
Q Does exposing what we have been calling the overburden directly to the - or the sand and the fill directly to the bedrock?
A Yes.
Q And my question then to you is simply whether that discontinuity is a potential root of migration for any free flowing NAPL in the landfill?
A Without the remedial measures in place, I would

anticipate that would be such a vehicle.

Q Okay. Now, you anticipate that that would be such a vehicle, let me ask you, would you anticipate that it has been such a vehicle in the past?

A I would say that it is probably more probable than not that some NAPL has entered that discontinuity. I think the evidence we currently have about the site would suggest that.

Q But do you have an opinion as to the amount of NAPL which may have?

A I simply have no idea.

Q Fine. All right. Doctor Pinder, in your original charts there that is entitled Ground Water Contaminant Containment and Renovation Strategy, there is a box there midway down which is entitled Remedial Strategy Tested, and that follows the box that is entitled Remedial Strategy Design. Now, I understand from your testimony that the remedial strategy designation was made in this case on the basis of the computer modeling that you had helped out in. Can you tell me where in the S-Area matter that we are discussing today that the remedial strategy tested box was taken care of?

A Oh, what this refers to when I say remedial design here, I am saying that we conceive of a potential design to renovate the system, then the next box which says Remedial Design Tested, we take that strategy --
Q Excuse me, it says remedial strategy tested.
A Remedial strategy, the strategy constitutes the design.
Q Okay.
A So, in the Remedial Strategy Tested box, we are taking this conceptual idea of what can be done and we are putting in the mathematical model, seeing if it will work, and that is what I mean by remedial strategy tested.
Q And so the --
THE COURT: Excuse me, the question is that now that has been accomplished?
THE WITNESS: That has been accomplished.
THE COURT: The mathematical testing has been done?
THE WITNESS: Yes, sir.
THE COURT: Thank you.
BY MR. SUNDERLAND:
Q And the testing that has been done is, from the point of view of your testimony today, has to do

with obtaining the NAPL upward gradient; is that correct?

A The NAPL upward movement.

Q All right. Or alternatively stated, the upward gradient necessary to retain or contain the NAPL?

A I know this is a subtle point, but so we don't get mixed up somewhere along the way, we are talking about the upward gradient of the aqueous phase, which by virtue of its movement passed the non-aqueous phase or NAPL phase, will hold the NAPL in place or move it upward.

Q All right. But your testimmony is that with respect to the remedy or the Remedial Strategy Tested box, that that has been a mathematical form of testing?

A Yes, sir.

Q All right. There has not been any on-site or physical testing of the necessary upward gradient to hold in place the NAPL liquids?

A Not to my - there has been no testing that directly involved the NAPL migration, to my knowledge.

Q Has there been any other, either laboratory or field testing, of the mathematical simulation that you have undertaken?

A There has been mathematical - there has been experimental verification of the mathematical models that were used in this case, but the exact mathematical model that was used in the verification at Princeton under my supervision is similar to, but not in every sense identical to the one that ADL used. There was some subtle mathematical differences that I don't think are relevant.
Q But in the context of the S-Area matter --
A Yes.
Q And in the context of achieving this necessary upward gradient to contain the NAPL --
A Yes.
Q Is it your testimony that there has been no either laboratory or field testing to verify the mathematical simulation?
A I think that that is a fair statement.
Q So, again as to the Remedial Strategy Tested box, we have a mathematical or a remedial form of testing only?
A For the specific concept that we are talking about, the answer to that I believe is, yes. I tend to hedge because there are many ways to test various pieces of the model and over the last

fifty years, it has been tested in as many ways as people can conceive of. When you narrow it down to the point when you talk about a specific location and a specific model, then I have to tend to hedge.

Q I would like to develop with you just a little bit the notion of where NAPL is. You have the diagram, the exhibit over there entitled Two-phase. Your testimony, as I understand, was that the NAPL is not a liquid which occupies space or a volume in and of itself in the landfill, in other words it occupies space in the pores or within the pores of sand and the fill and other overburden material?

A Once the NAPL has escaped from whatever container it might have been in, then it occupies pore space.

Q Now, you earlier indicated that in certain situations, the NAPL will reside or will reside in a large proportion of the pore space, in other situations you indicated that the NAPL will reside in a small proportion of the pore space. Can you explain what those situations are and what determines whether the NAPL assumes a large proportion or a small proportion of the pore space?

A That is very difficult to answer that in a brief way. I think the easiest way to think about it is imagine that you have a pail of sand that is occupied by air and you add water to that sand, and you visualize movement of the water into that sand. Those situations that arose where you have more water than air would be similar to the situations at S-Area where you have more NAPL than water.

Q Well, what I am trying to get at is just a picture of the landfill where - or what portion of what part of the landfill would the NAPL be occupying the greatest proportion of the pore space?

A I would suspect that there are two obvious situations where NAPL would tend to be occupying more pore space than other locations, one is very close to the source in a sense that if the drum breaks, right around the drum you are going to expect to have primarily NAPL. I think that is self-evident. The other is if the NAPL comes in contact with a relatively impermeable layer, such as the clay. Then the NAPL will tend to pool on that clay layer and move along the clay layer

much as water moving along the stream bed toward the lowest elevation.
Q Seeking the lowest point?
A Yes.
Q All right. Now, let's go to that first concept, the NAPL that is located near the broken drum, it will concentrate heavily in the pore space around the bottom of the drum; correct?
A Initially, I would think that would be the case.
Q Now, how, if at all, does the NAPL in that location move anywhere else in the landfill?
A Well, there are two fundamental forces at work. One is gravity, the other is the forces that are associated with the movement of any liquid, be it aqueous or non-aqueous liquids, in other words, pressure forces, the same forces that are involved when you push the back of your car and your car moves.
Q Well, would I be correct in saying that the NAPL that initially occupies a lot of the pore space around a broken drum will eventually move from that location in the landfill?
A It will move some distance. The actual distance that it moves depends on the amount that is present, because as it moves, there is always a

certain amount of NAPL that is left behind physically, and so it can't move indefinitely. It is going to move a certain distance when it becomes exhausted and no longer will move.
Q So if we have drums here and a drum here and a drum here, eventually the NAPL from those drums will start flowing in other areas, but in a sense leaving behind a trail of NAPL?
A That is correct.
Q And is that trail of NAPL characterized or caused residual NAPL?
A Yes.
Q So, in other words, in each pore space that the trail passes through, there will be trapped, in a residual sense, a certain amount of NAPL?
A It will be trapped there until it eventually dissolves in aqueous phase.
Q And am I correct in saying --
A Let me also add, if the NAPL is turned around and moves back up again, it would, you know, move back through that residual zone.
Q Is that conceivable in light of NAPL being more dense than water?
A Absolutely. The whole concept here is based on that.

Q Well, that is true down at the point of discontinuity; if I take you up, take you over fifteen feet from the discontinuity, move you up ten feet, is it possible at that point for the NAPL actually to move vertically upward?
A Oh, yes, indeed.
Q How is that?
A Well, we are going to have vertical gradiant not just over the discontinuity, but throughout the site in those areas where the gradiant is sufficiently strong in an upward direction.
Q I see. The NAPL could be going back over the trail that it had left a few days or weeks or years ago?
A Yes.
Q I see. All right. Well, from all of these questions and answers, would I be correct in saying that throughout the landfill there is going to be trapped in a residual sense a certain amount of NAPL?
A Yes, until such NAPL is eventually dissolved by the aqueous phase.
Q And that that trapped NAPL will only leave the landfill through dissolution in water?
A The residual NAPL, I would say that is a correct

statement.

Q Okay. Now, do we know, does science know what this residual factor is; in other words, how much NAPL will continue to reside over time in the pore space?

A It knows within reasonable bounds. It actually depends very much on the individual phase that you are talking about, but as a rule of thumb, I would say we are talking about something in the order of ten percent.

Q Ten percent of what?

A Of the total saturation.

Q Ten percent of the volume of the pore?

A If the pore was originally occupied by a volume V of NAPL, then a reasonable estimate would be that upon removal of the NAPL to its residual level, we have probably got ten percent residing, ten percent of V residing in that pore.

Q I see. So, essentially, ninety percent of the NAPL will move on, but ten percent will stay behind?

A A rough estimate, yes.

Q Okay. Now, you also indicated that NAPL, when it -- to the extent that it moves on -- gets down to the clay layer in the landfill, will not move into the clay because of wedding and other properties that you indicated in your direct testimony. You indicated in response to an earlier question that the NAPL will start moving along the clay seeking the lowest point, simply seeking the lowest point?

A Yes, that is correct.

Q Now, are there, however, or is there a possibility that within that clay layer at the landfill there are certain pockets or dishes or simply configurations that the NAPL would become trapped in?

A I believe the answer to your question involves whether this would tend to pool in depressions, should they exist in the clay?

Q That is correct.

A I would say that should such depressions exist, they tend to trap the NAPL.

Q Do you have any opinion as to whether such depressions do exist at the S-Area site?

A I really can't say. I have no evidence to indicate one way or another.

Q Based on your experience in the area of hydrogeology, can you say whether it is typical or perhaps not typical for a clay stratum like the one at S-Area to have potential pockets or dishes or dips?

A Well, it is always possible to have potential pockets and dips. I think the question is does this particular site have pockets and dips, and I again say to you, I don't have any information with which to base that. evasive?

Q I know that. I know that you don't, but I am moving to another question which is generally speaking, based on your experience and your expertise in the area of hydrogeology, whether you have come across in that experience clay stratum that have pockets, dishes and similar configurations?

A I would say that it is quite likely that such things do exist in nature, that I have, although I can't remember specifically observing one, I have no reason to believe they wouldn't occur.

Q And if such pockets or dishes existed at the S-Area site, those pockets or dishes could serve as a trapping mechanism for the NAPL that is sliding down the clay stratum?

A Yes, sir.

Q Mr. Elder asked you about the three prongs of the confining layer equivalent definition. Could you, in your own -- putting aside those three prongs -- could you tell us what is behind the notion of confining layer equivalent -- I'm sorry -- can I strike that? I was getting confined layer equivalent mixed up with confining layer. Mr. Elder asked you the three pronged definition of confining layer. Then we went on to confining layer equivalent. As defined in the agreement, what is the idea behind the confining layer equivalent concept?

A Well, I think that the idea behind the confining layer equivalent --

Q Equivalent.

A Equivalent concent?

Q Yes

A Is that there is no technically reasonable way that I am aware of to retrieve this NAPL, except by some hydrodynamic mechanism, and the design that we have put in place here is the only hydrodynamic mechanism that I can envision that would be an appropriate operation.

Q Now, the confining layer equivalent notion applies only in the situation where we have a confining layer discontinuity; am I correct?

A Yes, sir.

Q In other words, under the settlement agreement, if a discontinuity is found, certain remedial actions have to be taken, and I will ask you those in a minute, unless the definition of confining layer equivalent is met?
A Well, confining layer equivalent has inherent in it, as I understand it, certain operational characteristics. It is not a placid phenomenon.
Q That is what I wanted to ask. Tell me what the operational characteristics are.
A My understanding of the consent order, recognizing I am not a legal counsel and this verbiage is not easy for me to comprehend sometimes, it is my understanding that in the area where a confining layer equivalent is deemed as necessary, that there will be put in place a requirement that as certain vertical movement of aqueous phase or water will be required and that that vertical movement will be adequate to suspend in place or move upward, the latter of which is much more probable, the NAPL phase. In other words, we will assure that the NAPL phase will not move down under gravitational effects through the use of a very strong vertical upward aqueous movement.

Q So what I am trying to get at very simply is whether the confining layer equivalent notion is based on the principle of retaining the NAPL in the landfill or retaining and collecting the NAPL in the landfill?

A I think my recollection is that the primary objective was to contain. The consequences of the containment design, in my opinion, will be decontamination to a large extent.

Q I am going to come back and ask you a little more about that, but how, if you can tell me, will the potential that the confining layer equivalent has for collecting NAPL, how will that potential affect the residual NAPL that is located perhaps in wide areas around the landfill, that being the residual NAPL we just talked about a few minutes ago --

A Yes.

Q And how will the confining layer equivalent upward gradiant notion, how will that enable there to be collection of any NAPL that is caught in dishes and pores?

MR. ELDER: Object to the compound question.

THE COURT: Well, I don't know. Maybe the Doctor can answer. Can you?

THE WITNESS: I think I understand what he wants.
We must separate residual NAPL from
NAPL that occurs in dishes and
depressions. They are quite different.
BY MR. SUNDERLAND:
Q Correct.
A Residual NAPL is a mobile. NAPL that may exist in a dish can respond to hydrodynamic gradiant and be moved, so I believe that there will be certain areas, perhaps large areas at the site, where NAPL that would otherwise be immobile because of the location and depressions will respond to these hydrodynamic gradiants and move toward the drains. I think you will find in this report simulations that suggest this, this to be the case.
Q All right. That deals with the pockets or the trapped pores --
A Yes.
Q -- in dishes?
A You must be careful. There are NAPL that is residual in pores --
Q I stated that wrong. I am sorry.
A That is not going to go anywhere except by dissolution in the aqueous phase. Then you have

NAPL that is trapped hydromatically, just like oil is trapped in an oil reservoir, and that can respond to hydrodynamic gradiant and eventually be removed.

Q Now, as I understand the agreement, if by chance the hydraulic gradiant necessary to hold up the NAPL is not able to be achieved, then there has to be grouting at any discontinuity that is found at the bottom of the landfill?

A That is my understanding.

Q Do you have any opinion, if that is the case, if there is grouting, do you have any opinion as to the ability of the site containment system at that point to collect the non-aqueous phase liquids?

A As I understood it, the grouting basically that is going to be put in place is a cement mixture where otherwise what would be located is water or NAPL. Under those circumstances, there would be no NAPL present to move, so I find your question difficult to answer.

Q Well, I guess maybe you and I have a different understanding. My understanding -- if we have a discontinuity and it has to be grouted, a cement or a grout bottom will be placed at the discontinuity, correct, in order to plug up the discontinuity?

A In the sense that cement will be forced into the pore locations wherein it should become a solid, then I am saying that where there is cement, there is no NAPL.

Q But won't there be NAPL still inside the landfill?

A Above it.

Q Above it?

A I would expect that to be the case.

Q Now, my question is, assuming that we have gone the grouting route --

A Yes.

Q What, in your opinion, is the potential of the proposed site containment system to collect the NAPL?

A Better than it was before, because now you have still got the upward gradiant that you wanted before and now you are going to have less NAPL to move toward the drain.

Q Why is there going to be less NAPL?

A Because you have displaced the NAPL that originally was in the pores with the cement; moreover, if there is any NAPL that for one

reason or another is below that discontinuity, it will not be part of the trapping mechanism.
Q But we are talking about the, as I understand, a considerable potentially amount of NAPL in the landfill. Now, if we grout the bottom --
A Yes.
Q -- and we still have a drain collection system --
A Yes.
Q -- running around and down the middle, as I understand the site --
A Yes.
Q -- I don't understand --
THE COURT: I think the question is, how can you have the upward gradiant if you don't have the discontinuity; is that the question?
MR. SUNDERLAND: Well, your Honor --
THE WITNESS: I would be happy to show you on the board.
THE COURT: Well, I think --
MR. SUNDERLAND: Can I ask him this, maybe get right to your point. Will you have an upward gradiant at the point of the grout, at the point of the discontinuity that has been grouted?

THE WITNESS: Yes.

BY MR. SUNDERLAND:

Q It will not, however, be the same or the same degree of upward gradiant that you might have had or you might have had to have had if you were going to achieve the confining layer equivalent?

A That is very difficult to say. I would have to turn to my mathematical model to answer that question. Intuitively, I would think the gradiants would be similar.

Q So if we grout, underneath the grout you are saying we are still going to have a head pressure that will exert an upward force on the bottom of the grouted material?

A It will actually be a downward force, I think, because if you are really, truly going to isolate the overburden from the bedrock, keep in mind that the natural gradiant is downward. If you seal that off, then below that concrete I would expect that natural gradiant to continue down, above the concrete, because you are drawing liquid up into the drain, and that liquid has to go from a point of high head to lower head, and we agreed that the water is going to move up, I believe, to the drain. Do we have that common

base of agreement?
Q I think we will come back to that. Let's make the assumption --
THE COURT: Mr. Sunderland, I think -- well, I don't think right now the questioning is very helpful, because you want to put a lot of -- I think it would be a lot easier and we would understand it better if Doctor would go to the board and simply explain to us what he believes will happen if the discontinuities were plugged. That is where we started at the beginning.
MR. SUNDERLAND: That is fine.
THE COURT: Well, let's do this. We will take a recess break, about ten minutes, and then return.
(Whereupon, a short recess was taken.)

I hereby certify that the foregoing pages is a true and accurate record of my stenographic notes.

EUGENE R. BECKSTEIN

Official Reporter

U.S.D.C., W.D.N.Y.