

In the Matter Of:
STATE OF MISSISSIPPI vs
STATE OF TENNESSEE, ET AL
143, Original

PROCEEDINGS
May 20, 2019



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Proceedings - May 20, 2019

1 IN THE SUPREME COURT OF THE
2 UNITED STATES

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3 STATE OF MISSISSIPPI,

4 Plaintiff,

5 v.

No. 143, Original

6 STATE OF TENNESSEE, CITY OF
7 MEMPHIS, TENNESSEE, AND
8 MEMPHIS LIGHT, GAS & WATER
9 DIVISION,

Defendants.

-----x

11 May 20, 2019

12 9:03 a.m.

14 ON BILL OF COMPLAINT

15 Before:

16 HON. EUGENE SILER,

17 Special Master.

18 APPEARANCES

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23 LARRY D. MOFFETT

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A P P E A R A N C E S (continued)

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EXAMINATION

RICHARD SPRUILL

Direct By Mr. Ellingburg37

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1 (In open court)

2 (Case called)

3 THE COURT: Okay. I'm glad to see all these experts
4 with us and everything else, but anyway, we're finally to it.
5 And what we'll try to do, my goal is to find the facts,
6 determine the law, and send it to the Supreme Court and not
7 bring it back. So we don't want any remand in this case, and
8 so I'm going to be very liberal in allowing evidence to come
9 in. I might strike it later, but our goal is to provide
10 something for the Supreme Court to make its ruling. And so
11 they found somebody who would try it, and that's me.

12 And we can be very informal in this matter. We want
13 to follow the rules of evidence, obviously. If we have to, we
14 can move witnesses around and move the lawyers around. And the
15 biggest problem we will have, of course, is the stamina of all
16 of us in trying this case. So as we go along, you can remind
17 me of any kind of rulings we may have made in the past, and go
18 from there.

19 And I will try my best to be fair to all of the
20 parties. I have tried cases as a Court on the District level
21 on several occasions, and so I'm familiar with how you do these
22 things. And I have dealt with water rights. I have dealt with
23 ownership of property and property fines in Kentucky and places
24 like that.

25 So with that, I guess we need to let the counsel

1 identify themselves for the record, so that you -- so I'll
2 do -- I may forget who everybody is sometimes, but let's go
3 from there, and then we will start with our opening statements,
4 unless there are other matters that need to be brought to the
5 attention of the Court.

6 Okay. For the plaintiff?

7 MR. ELLINGBURG: Good morning, your Honor. My name is
8 Mike Ellingburg; I am lead counsel for the State of
9 Mississippi. My actual name is C. Michael Ellingburg, but I go
10 by "Mike."

11 THE COURT: Okay.

12 MR. ELLINGBURG: Would you like me to introduce the
13 other counsel?

14 THE COURT: Sure.

15 MR. BARRETT: Your Honor, I'm Charles Barrett from the
16 Neal & Harwell firm here in Nashville for Mississippi.

17 MS. RAY: Jacqueline Ray for the Mississippi Attorney
18 General's office.

19 THE COURT: All right. Is that it?

20 MR. MOFFETT: Larry Moffett on behalf of the State of
21 Mississippi.

22 MR. McMULLAN: Good morning, your Honor. David
23 McMullan for the State of Mississippi.

24 MR. FREDERICK: For Tennessee, your Honor, David
25 Frederick.

1 MR. BRANSON: Good morning, your Honor. Josh Branson,
2 also for the State of Tennessee.

3 MR. HILL: Your Honor, Dietrich Hill for the State of
4 Tennessee.

5 MS. KNOFCZYNSKI: Grace Knofczynski, also for the
6 State of Tennessee.

7 MR. L. BEARMAN: Good morning, your Honor. I'm Leo
8 Bearman, representing, along with my cohorts, the City of
9 Memphis and the Memphis Light, Gas & Water Division.

10 MR. D. BEARMAN: Good morning, your Honor. David
11 Bearman, representing the City of Memphis and Memphis Light,
12 Gas & Water Division.

13 THE COURT: All right.

14 MS. ROBERTS: Good morning, your Honor. I'm Kristine
15 Roberts, also representing the City of Memphis and Memphis
16 Light, Gas & Water Division.

17 THE COURT: Is there anything in housekeeping or other
18 problems that you need to bring up to the Court before we get
19 started? Is the United States on telephone now, does anybody
20 know?

21 MR. FREDERICK: Your Honor, David Frederick for
22 Tennessee. United States has indicated it's okay not being on
23 the phone. They'll review the transcripts as they become
24 available.

25 THE COURT: So that's resolved?

1 MR. FREDERICK: Yes.

2 THE COURT: Thank you.

3 MR. BARRETT: Your Honor, we have a few slides to use
4 in opening. Could we turn on the system?

5 THE COURT: You sure may.

6 All right. Are we ready? Have we set a limit of time
7 on the opening statements?

8 MR. ELLINGBURG: Yes, your Honor. 15 minutes each.

9 THE COURT: We've got a lot to cover in this case.

10 All right. You may proceed for the great State of
11 Mississippi.

12 MR. ELLINGBURG: Thank you, your Honor.

13 I'd like to open up by stating that the law to us is
14 clear. Mississippi has declared as its public policy,
15 consistent with its contained sovereignty under the
16 Constitution, that all water, whether occurring on the surface
17 of the ground or underneath the surface of the ground, declared
18 to be among the spaces publicly for the state. And the state
19 holds them in public trust.

20 This idea is not unique to Mississippi. Tennessee has
21 done what is the equivalent; somewhat different language in its
22 statute, but it has declared the public policy of Tennessee to
23 be part of the waters and of the State. And so both states
24 claim all the water in their boundaries.

25 Now, you're going to hear a lot of testimony about

1 hydrology, hydrogeology, and the earth and formation and all
2 those things which are really relevant to this case. But in
3 the end, this case is about groundwater that was naturally
4 occurring in the state of Mississippi, within the area of its
5 boundaries for thousands of years before it was actually formed
6 as a state. And groundwater that could be -- that was in a
7 volume essentially equivalent that didn't change under the
8 conditions of nature. And groundwater that would have remained
9 in Mississippi but for the pumping of the defendants in this
10 case.

11 It's important to understand at the outset that
12 groundwater flow can't really be compared to surface water
13 flow. I've put a slide up which is one of the exhibits in the
14 case, and what the slide shows is the travel time, if you will,
15 between the time that surface water enters a groundwater system
16 and the time that it is discharged from that system.

17 And I don't know if your Honor can see this clearly,
18 but the slide shows -- and this is something that is in
19 groundwater hydrology courses and teaching -- but it shows that
20 you have an unconfined water surface at the top. That's what
21 we call the water table, which you have confined aquifers below
22 it.

23 This case is about the confined aquifer in northwest
24 Mississippi. And so, as it shows on the slide, it takes either
25 years in some cases -- and it depends on the specific geology,

1 which you'll hear a lot about -- or it takes decades, or in
2 some cases it takes centuries for groundwater, from the time it
3 enters the ground until the time that it is discharged from
4 confined aquifer.

5 Now, if you want to compare that to what the Supreme
6 Court's previously dealt with, if you dropped your water ski --
7 although I don't know if anybody skis on the Mississippi River,
8 but if you dropped it in the channel on the Mississippi River,
9 a day later you'd find you're about 50 miles away. So when you
10 think about water in a river flowing, you can think about that
11 ski moving 50 miles in a day.

12 Well, there's really nothing on this chart that would
13 indicate you would expect confined groundwater, from the time
14 it enters the confined formation until the time it naturally
15 discharges, to take less than decades. So that's an important
16 distinction.

17 Now, the City of Memphis has been pumping water for a
18 long time. I forget the exact day; I think they say 1886. But
19 the United States Geological Survey has been paying attention.
20 They've done their job, and there is -- I found a report in
21 1906 when they're talking about Memphis pumping. And they
22 became active over the years, and they reported on numerous
23 occasions what the status was, because the amount of water
24 being pumped in the Memphis-Shelby County area was increasing
25 as the 20th century moved forward.

1 And in 1958 there was significant increases in the
2 amount pumped. So -- in the 1950s. So in about '58, '59, USGS
3 started a study of the impacts on the groundwater system within
4 Tennessee.

5 Now, I think it's important to note at this point that
6 before this, we've seen nothing that would indicate that the
7 pumping that was taking place in Shelby County was having any
8 material impact on any groundwater available in Mississippi.
9 So they started these studies as a result of significantly
10 increased pumping, and those studies are ultimately reported in
11 Joint Exhibit J22, J58, and I'm going to show you a few of the
12 things that it says in those studies.

13 The first one is in J22. And these are two clips.
14 And this is in 1964, after they've conducted this study of what
15 the conditions -- and the information they collected, I
16 believe, in 1960. And it makes it very clear that they are
17 drawing water out of areas within Tennessee.

18 If you go to that second paragraph, it says that
19 the -- "The present 1960 rate of withdrawal is about 150
20 million gallons a day."

21 Now, this is 135, of which is pumped from -- what they
22 call the 500-Foot Sand here, but it will consistently be
23 referred to as the Memphis Sand.

24 And that was all pumping in Shelby County. It wasn't
25 just the Mississippi line, okay? I mean, Memphis, Light, Gas &

1 Water.

2 But it says, of the inflow that was coming into these
3 wells, that about 45 percent was from the east, so that would
4 be in Tennessee. About 20 percent from the south; that would
5 have been out of Mississippi. And then about 15 percent from
6 the north, also in Tennessee. And about 10 percent or less
7 from the west.

8 Now, there was another study that was done -- now,
9 this study we just looked at, J22, was done in cooperation with
10 Memphis Light, Gas & Water. There was another study done that
11 was in cooperation with the State of Tennessee, and that is
12 Exhibit J58.

13 Chuck, put that up. Thank you.

14 Now, this one is -- it goes through the same types of
15 analysis. And here they're talking about Memphis. The area --
16 what they call the Memphis area, which is essentially Shelby
17 County; some north, some east, and a little down in Mississippi
18 a few miles.

19 And I think this particular quote is important in
20 context. It says that "Future development should be undertaken
21 with the full knowledge that the net increase in pumping will
22 be offset by an increase in inflow of groundwater from other
23 states." So at a decrease in the base flow of streams. But
24 they are acknowledging here that they will be taking more water
25 out of Mississippi if they increase the pumping.

1 Now, with that information in hand, MLGW planned a new
2 wellfield. And that wellfield, they did a study before it
3 actually started, but they had already planned it, I believe.
4 But being this period between 1959, 1965, reported. So that
5 study, they wanted to look at how far they would be pulling
6 water from not just -- well, from the length of the entire
7 circular area of that wellfield, and that is J59.

8 And if you would put that up.

9 This is a study of the Lichterman field, that's not
10 yet started pumping, or is about to start pumping. And they're
11 talking about something you will hear about a lot, which is
12 cone of depression which is the area from which a well can
13 actually capture water. And they estimate about 20 miles.

14 Now, the reason that's significant is where they put
15 these wellfields. Now, before Lichterman was put in, when they
16 had these studies from both the USGS, both the Tennessee --
17 with Tennessee and with the City of Memphis and Memphis Light,
18 Gas & Water, if you'll look at the slide, these are the
19 wellfields they had pumping. And so the Lichterman field isn't
20 on here.

21 If you would pull the next slide.

22 So with the information that they had at that point in
23 time, they decided they would build a wellfield -- they were
24 already pulling water out of Mississippi; they decided they'd
25 build a wellfield closer to Mississippi, so they built the

1 Lichterman field. But they didn't stop there.

2 If you go to the next slide.

3 That Lichterman was in '65. In 1970, they're still
4 increasing their pumping, and so they build the Davis field,
5 which is even closer to Mississippi. And they've also now
6 added one to the northeast. And then finally in 1971 they
7 built the Palmer field, which is even -- it's small, but it's
8 even closer to Mississippi.

9 So what we have is a situation where, because the
10 Memphis area was studied so thoroughly, Memphis Light, Gas &
11 Water in Tennessee, they knew exactly what they were doing.
12 And it was not something that had to be done. The fact is that
13 a -- as the proof will show, wells, wellfields, at the time all
14 this was done, were -- could be planned; the area from which
15 they withdrew water could be estimated, and the ability to
16 avoid taking water from someone else was always available.

17 Now, the last thing that kind of fits into this is
18 that north of Memphis -- and you're going to see the geology,
19 and you're going to see the testimony, but south in
20 Mississippi, the water quality, the level of water
21 availability, all decreases.

22 North of Tennessee, they have an abundance of water.
23 I mean, in all of west Tennessee. So North Memphis, they have
24 an abundance of water. So had these wells been placed after
25 they'd gotten the information they received further to the

1 north, and there had been a systematic effort made in -- by the
2 City of Memphis and Shelby County, there wouldn't be any
3 significant water being moved out of Mississippi. But you'll
4 see the scientific testimony. And it's clear.

5 The water -- the groundwater in Mississippi, as
6 groundwater in Tennessee, was predominantly moving at the
7 rate -- at a rate measured in decades and centuries and
8 thousands of years across each state from the outcrop area,
9 which is to the east. And that water was entering the surface,
10 and it was meandering and finding its way down as shown on the
11 prior slide, and it was staying within the respective states in
12 terms of the amount of water. There was some little bit here
13 and some little bit there, but until pumping the amount of
14 water available in Mississippi, in Tennessee and Shelby County,
15 the amount of water residing in Mississippi was not -- the
16 available water.

17 Now, that doesn't say the water doesn't move; it does
18 move, ever so slowly. And so we'll put on some evidence about
19 that. The reality is this is -- case is about water that was
20 available in Mississippi under natural conditions, was not
21 shared with anybody, and had been appropriated or taken by
22 pumping. And they didn't need it. They didn't have to do it.
23 It was avoidable. They had alternative sources to the north,
24 and surface water.

25 Thank you, your Honor.

1 THE COURT: May I ask a quick question. I know it's
2 an opening statement, but what sort of remedy are you asking
3 for?

4 MR. ELLINGBURG: Well, in this particular case, the
5 Court has bifurcated the proceedings, so that there was a --
6 this hearing is about the question of whether there was a right
7 to take the water. Mississippi's position is that the -- that
8 the water within its earth, which is what this is, is its --
9 under its right to regulate, control, or preserve for its
10 citizens. As is the water that naturally resides in Tennessee,
11 and that neither State has a right to appropriate the other
12 State's water. And that's really the question.

13 THE COURT: Okay. So we'll do this in a bifurcated
14 style to determine whether they're liable, and then we go into
15 some sort of a remedy hearing, or what?

16 MR. ELLINGBURG: Yes, your Honor, that's what I
17 understand, was that your order set this hearing up for the
18 purpose of determining the right to the water, if you would.

19 THE COURT: Okay.

20 MR. ELLINGBURG: Thank you.

21 THE COURT: Are you all going to have separate opening
22 statements?

23 MR. FREDERICK: Yes, your Honor, we will. This is
24 David Frederick. I'll open for Tennessee. And Mr. Bearman for
25 Memphis and MLGW.

1 Your Honor, this hearing is focused on the sole and
2 what we believe to be the dispositive question of whether the
3 aquifer is an interstate water resource. As the Special Master
4 has already recognized, equitable apportionment is the only
5 litigation remedy for an interstate water resource that is not
6 governed by an interstate compact.

7 The evidence will show that the aquifer is an
8 interstate resource, and that the Special Master was correct,
9 that Mississippi has pleaded its way out of court by
10 disclaiming and claimed for equitable apportionment. And
11 equitable apportionment applies equally to groundwater,
12 especially when, as the evidence will show here, that
13 groundwater is connected to interstate surface water.

14 Mississippi and Tennessee do not have an interstate
15 compact concerning the aquifer; nor do any of the other eight
16 states under which the aquifer flows. So we're in an area
17 where, if you determine that the aquifer is an interstate
18 aquifer, the case is over, because Mississippi has disclaimed a
19 right to interstate water through the legal means that the
20 Supreme Court of the United States has recognized.

21 That is an equitable apportionment. Their complaint
22 says they are not seeking an equitable apportionment, and your
23 preliminary decisions, your Honor, have ruled that if the
24 resource is an interstate resource, then the case should be
25 over.

1 So we view your fact-finding in this phase of the
2 hearing to be directed to the sole question: Is this aquifer
3 an interstate resource? And if you find that it is, the
4 evidence overwhelmingly shows that -- and in fact Mississippi's
5 counsel has just conceded in his opening that this is
6 interstate water -- the case should be over. And we would ask
7 for you to make a recommendation to the Justices that the
8 complaint be dismissed with prejudice.

9 Mississippi argues that State law claims are
10 overriding their disclaimer of equitable apportionment, but
11 what is important is that they made a conscious decision to
12 avoid an equitable apportionment.

13 Why? Why did they do that? Because they are not able
14 to prove the key elements of an equitable apportionment:
15 Substantial injury by clear and convincing evidence;
16 justification for an equitable decree that would preclude its
17 demand for hundreds of millions of dollars in money damages; an
18 evaluation of the broader regional water system that would
19 include not just Mississippi and Tennessee's pumping, but also
20 the substantial pumping in other states that are on top of this
21 aquifer throughout the Mississippi Embayment.

22 Nor can they address the reliance interests of
23 Tennessee and Memphis in protecting its historical water
24 supply, which originates with the very first well, in the
25 1880s. In fact, an equitable apportionment, if done fully the

1 way the Supreme Court has done equitable apportionments, very
2 likely would be leading to bigger and much more complicated
3 litigation, and the result could mean that Mississippi would be
4 worse off.

5 So instead, what they're trying to do is to use
6 Mississippi tort law to ask Tennessee to pay it hundreds of
7 millions of dollars, because it cannot meet the requisites of
8 an equitable apportionment for the proper and fair sharing of
9 an interstate water resource.

10 We're going to ask you, your Honor, to keep the focus
11 on the threshold question of whether the aquifer is an
12 interstate aquifer. All of the maps of the aquifer will show
13 it to be a large multi-state resource. Mississippi spent half
14 of its time in its opening talking about Memphis's intent, but
15 the intent is irrelevant. The question before you is whether
16 this water resource is an interstate water resource, and we
17 believe the evidence will show overwhelmingly that it is.

18 If we were having an equitable apportionment, we would
19 have plenty to say about all the evidence that they want to
20 introduce that's irrelevant to the question you have said is
21 the sole dispositive question for this hearing. But we
22 directed our discovery at the question that you said we should
23 be focusing on, which is whether or not this is an interstate
24 resource. And we would ask you to confine what we're doing in
25 this hearing to the limited topic that you set out in your 2016

1 decision, because that's what we relied on in determining the
2 scope of the discovery in this case.

3 Now, counsel says the US Geological Survey has, quote,
4 done their job; but all of the USGS maps of this aquifer show
5 it to be an interstate aquifer going underneath eight different
6 states. Our trial presentation will demonstrate that
7 Mississippi cannot meet its burden because the Middle Claiborne
8 Aquifer, including the groundwater, is interstate.

9 In your decision on summary judgment, Judge Siler, you
10 identified four reasons why the aquifer is an interstate water
11 resource: The aquifer theory, the pumping effects theory, the
12 natural flow theory, and the surface connection theory. The
13 evidence is going to show through expert testimony, maps, and
14 other documents, that Tennessee will establish that all four of
15 those theories for why this is an interstate aquifer are
16 correct and provable.

17 Let's start with the first one, the aquifer theory.
18 Tennessee's expert, Steve Larson, will testify that from a
19 hydrogeological perspective, an interstate aquifer is a single
20 continuous hydrogeological unit extending beneath multiple
21 states, in which an action in one state can affect water in
22 another state. The aquifer in question here is called the
23 Middle Claiborne.

24 Now, to be sure, it's given local names in different
25 parts of the country where it underrides, but the US Geological

1 Survey identifies it as a single aquifer. And it lies
2 underneath eight different states, six of whom are not
3 defendants in this lawsuit. Those states are Illinois,
4 Missouri, Kentucky, Arkansas, Louisiana, and Alabama, in
5 addition to Tennessee and Mississippi.

6 Now, every relevant study is going to show that the
7 Middle Claiborne extends beneath those eight states. There is
8 no barrier restricting the lateral flow of water at the
9 Mississippi/Tennessee border, and this image here shows you the
10 different levels of sand at different elevations within the
11 groundwater system of the Middle Claiborne Aquifer.

12 And what this shows is that the sand levels do not
13 change at state boundaries; they cross state boundaries. And
14 the water that is encapsulated within this -- these geological
15 structures do not have a change either. And so what's
16 important to understand is that it is a single resource. It is
17 water in its geological formation, and they are in sands from
18 which the water can be pumped. But it is a single resource.

19 The second theory that we are going to present is
20 called the pumping effects theory. The opening conceded that
21 20 percent, according to one very rough estimate made 50 years
22 ago, of water came from Mississippi. That concession ends the
23 case, because that demonstrates that through the natural
24 effects of physics, pumping in one state will affect the
25 groundwater movement in another state.

1 Now, what they're going to talk about, and you're
2 going to hear a lot of testimony about cones of depression.
3 And this diagram shows you where some of the most significant
4 cones of depression are in the region that is within the Middle
5 Claiborne Aquifer.

6 And if you look at this diagram, your Honor, you're
7 going to see that the cones of depression are actually larger
8 in Arkansas, and in Arkansas, the boundary with Louisiana, and
9 even in south central Mississippi, than they are up in Memphis.

10 Think about that. They're pumping out, and the cones
11 of depression are larger in adjoining states than what they're
12 accusing Tennessee of in this case. And those cones of
13 depression cross state boundaries and affect the flow of water
14 between Louisiana and Mississippi and between Arkansas and
15 Mississippi.

16 So when you look at the very right cone of depression,
17 up in the Memphis area, and you compare the sand level and
18 density, you will see that the cones of depression in these
19 other states is much more significant. That's from pumping.
20 And the evidence is going to show that it is the pumping
21 effects theory that is causing these cross-boundary flows of
22 water.

23 Now, the third theory that we will explore with you is
24 called the natural flow theory. And Steve Larson will testify
25 that no water, including the water that Mississippi claims is,

1 quote, intrastate, will remain under Mississippi permanently.

2 As your 2018 opinion at page 19 has already
3 recognized, Mississippi's experts have adopted a predevelopment
4 flow map showing all the water leaving Mississippi. This is
5 from the plaintiffs, this exhibit. And all those arrows show
6 that water was leaving Tennessee and Mississippi and flowing
7 toward the Mississippi River and under the Mississippi River
8 into Arkansas, or in some instances -- and you noted that it
9 was being -- it was going from Mississippi into Tennessee
10 itself; that's the famous yellow triangle in which
11 Mississippi's conceded that under predevelopment conditions,
12 water was already flowing to the north out of Mississippi and
13 into Tennessee.

14 The fourth theory that we're going to present evidence
15 on is the surface connection theory. Mr. Larson also will
16 testify about the interconnection of the aquifer to interstate
17 surface water. Now, it's undisputed that the Middle Claiborne
18 is part of the larger Mississippi Embayment Regional Aquifer
19 System. It contains multiple interstate aquifers that are
20 separated by confining layers.

21 You're going to hear a lot about layers in the
22 testimony this week, your Honor, but it's also undisputed that
23 the aquifer is connected to interstate surface streams. And
24 this diagram here shows you the boundaries of the Middle
25 Claiborne Aquifer. And then the blue are all the rivers, the

1 surface streams that flow into the Mississippi River, but in
2 various forms create recharge for the Middle Claiborne Aquifer.

3 And that recharge source is very important from the
4 interstate river network. And because of that, what the
5 Supreme Court's cases have said is that if there is a dispute
6 between one state and another that deals with the surface water
7 and groundwater, it should be addressed through an equitable
8 apportionment, not through the use of one State's tort law to
9 claim that another State owes it hundreds of millions of
10 dollars.

11 Now, we don't think you're going to need to get into
12 the predevelopment, but you're going to hear a lot about it
13 anyway, and let me just give you some sense of what you're
14 going to hear in terms of testimony: That even if no water
15 flowed across Mississippi into Tennessee under natural
16 conditions, the aquifer would still be an interstate resource,
17 for all the reasons I've discussed and that we're going to
18 prove.

19 You're not going to need to go back into the 1880s,
20 your Honor, and try to reconstruct through historic maps and
21 age information what the state of predevelopment pumping was.
22 That's not necessary to the question that you have before you
23 which is: Is this aquifer an interstate resource?

24 However, if you decide you want to look at that, we
25 have probably the world's foremost expert on this aquifer,

1 Brian Waldron, who spent more -- thousands and thousands of
2 hours studying the Middle Claiborne Aquifer. And he's going to
3 testify to you, and he's going to show you, based on the most
4 precise data possible, which way the water was flowing in the
5 predevelopment state.

6 And this diagram, which we'll have him walk through
7 when he testifies, is going to show that water was leaving in
8 significant amounts, northward into Tennessee and then
9 thereafter into Arkansas.

10 As I say, I don't think you're going to have to decide
11 that in order to resolve the case. But we're going to present
12 that evidence to you, because you've indicated you want to have
13 a full evidentiary record.

14 Both Mr. Larson and Dr. Waldron will testify that all
15 of the maps and models of the predevelopment potentiometric
16 surface will indicate natural interstate flow in the Middle
17 Claiborne Aquifer. And why is that? Water is not static.
18 Water is constantly moving. When it rains, the water seeps
19 through to the ground. When it seeps into the ground, it seeps
20 into places where it moves, but it is always moving. There is
21 no such thing as static water.

22 Now, you've already indicated at the pleading stage
23 that the yellow triangle from Mississippi's expert does not
24 help their case, because it shows that even in predevelopment
25 conditions, there was some water that was moving across State

1 boundaries. And of course the effect of the pumping has
2 altered that, the evidence is going to show that less water is
3 moving now, after development, than before development.

4 Think about that. They brought this tort suit on the
5 theory that Tennessee is doing something wrong by having water
6 go across the boundaries. The evidence is going to show, in
7 fact, that Mississippi's pumping has slowed down that
8 intra-aquifer flow across the state lines.

9 Now, Mississippi's evidence is not going to
10 demonstrate that the water in the aquifer is intrastate.
11 They've got a couple of theories that they're going to trot
12 out, based on what they have done in their pleadings.

13 One of them is that there are in fact two aquifers,
14 not one. As simply a new characterization of a long
15 established hydrogeological fact, where there's no physical
16 barrier to prevent the flow of water. You'll hear something
17 about a facies change. This is a geological formation that is
18 south of the border between Tennessee and Mississippi. But
19 there is an uninterrupted layer of primarily sand that
20 saturated with water, and that is the Middle Claiborne Aquifer.

21 We're going to ask you to reject their repeated
22 attempts to characterize this aquifer as an intrastate water
23 resource. They'll probably give you hours of testimony about
24 the velocity and movement and residence time of the aquifer
25 water. All of that is irrelevant. It's irrelevant because

1 water constantly moves. They cannot prove that any water would
2 stay in Mississippi forever, and that Tennessee has somehow
3 gotten water that would have stayed in Mississippi forever.

4 Similarly, they're going to talk a lot about Memphis's
5 groundwater and pumping management practices. Those might be
6 relevant if we were having an equitable apportionment. But
7 they already disclaimed we're not doing an equitable
8 apportionment. So when we listen to their testimony, it will
9 all be geared toward an irrelevancy to what you are charged
10 with deciding after this hearing.

11 And that is: Is the aquifer an interstate water
12 resource? It is a single, continuous, hydrogeologic unit
13 extending beneath multiple states, in which pumping in one
14 state can, through the natural laws of physics and hydrology,
15 affect water in another state. And the predevelopment flows
16 are unnecessary to that conclusion, but they nonetheless
17 further support the claim that the aquifer is an interstate
18 water resource.

19 Thank you, your Honor.

20 THE COURT: Thank you.

21 You may proceed on behalf of the City of Memphis and
22 Memphis Light, Gas & Water.

23 MR. L. BEARMAN: Thank you, your Honor.

24 MR. ELLINGBURG: Excuse me, your Honor. Before we
25 proceed, I wanted to make one request.

1 THE COURT: Sure.

2 MR. ELLINGBURG: I know it's unusual, but we agreed to
3 15 minutes, and I pretty much pushed myself through 15 minutes.
4 And Mr. Frederick just took about 19. And so when Mr. Bearman
5 finishes, I'd like just a few minutes. I won't necessarily
6 even take four minutes.

7 THE COURT: Okay. If you can stick to the limits.
8 I'm not keeping track of your time. I hope you are keeping
9 track of your own time.

10 All right, Mr. Bearman.

11 MR. L. BEARMAN: Good morning, your Honor. If you
12 will allow me, I'd like to introduce my cohorts and people that
13 are working with me.

14 First, my son, David Bearman, partner; secondly,
15 Kristine Roberts, partner; third, our paralegal, Kathy Hughes,
16 who is back there; and fourth, what they now call a litigation
17 support specialist, your Honor, which, I take it means he can
18 work a computer. His name is Cole Taylor.

19 Also, if your Honor will allow me to introduce
20 Ms. Cheryl Patterson, who is vice president and general counsel
21 of the Memphis Light, Gas & Water Division back there. And
22 Ms. Charlotte Knight Griffin, who is manager of the legal
23 services at the Memphis Light, Gas & Water Division. And
24 finally, Mr. Bruce McMullen, who is City Attorney of the City
25 of Memphis.

1 Thank you, your Honor. I appreciate that.

2 THE COURT: Glad to have them along.

3 MR. L. BEARMAN: Your Honor, we adopt of course what
4 points have been made by Mr. Frederick.

5 I was going to start, but he's made the point before,
6 and it's significant that Mississippi ignores what your Honor
7 has designated as what we're doing here today; namely, on
8 page 36 of your Honor's opinion, an evidentiary hearing on the
9 limited issue of whether the aquifer and the water constitutes
10 an interstate resource is appropriate.

11 Okay. That's what we've -- I assume are going to do,
12 and it's significant, as I say, that Mississippi has ignored
13 that and began talking about intentional actions. We're not
14 anywhere near that, as Mr. Frederick points out.

15 Now, your Honor is going to need, I suggest --
16 although your Honor may already be aware of some of the
17 geography that's going to be alluded to in this case -- can
18 your Honor see that poster board over there?

19 THE COURT: Yes, I can.

20 MR. L. BEARMAN: Good. I apologize for not putting it
21 up on all kinds of screens here, but I've won a lot of cases on
22 poster board, your Honor, so I'll keep trying it this way.

23 Your Honor, the key area in this -- obviously
24 Arkansas, Tennessee, and Mississippi; but the key area of focus
25 here is Shelby County, Tennessee, right in the southwest corner

1 of Tennessee. And Memphis, Tennessee, is of course located in
2 Shelby County, and your Honor can see that part. And just
3 south of Shelby County, in Mississippi, is DeSoto County.

4 Your Honor may hear other counties mentioned:
5 Marshall County and Benton in Mississippi, and perhaps Fayette
6 and Hardeman in Tennessee. But the focus your Honor is going
7 to find, and what I suggest is the appropriate proof, is Shelby
8 County and DeSoto County, and of course the Mississippi River
9 that runs down the side.

10 Now, your Honor also needs to be aware, I suggest, of
11 certain nomenclature, if your Honor will allow me. If the
12 aquifer that we're talking about is the light-blue shaded area,
13 your Honor's already seen that on the screens, but that is
14 known generally as the Middle Claiborne Aquifer. The Middle
15 Claiborne Aquifer.

16 Now, your Honor, also needs to know, because you'll
17 hear this, I suggest, as the testimony goes on, some people
18 have called the aquifer in Tennessee the Memphis Sand Aquifer.
19 Some people in Mississippi have called the aquifer the Sparta
20 Sand Aquifer. Some people have called it the MSSA, Memphis
21 Sand/Sparta Sands Aquifer.

22 The fact is that those words are interchangeable, and
23 they all stand for the Middle Claiborne Aquifer, which is what
24 we're talking about today; is that an interstate resource?
25 Your Honor is going to find that the answer is yes.

1 But here is some of the proof that I suggest your
2 Honor is going to want to mark, number one -- and this point
3 has been made well by Mr. Frederick, and I'm not going to
4 overdo it, but it's important, because these are crucial
5 issues.

6 The aquifer underlies eight states, and your Honor can
7 see that on the poster board, in the light blue area:
8 Missouri, Kentucky, Tennessee, Arkansas, Mississippi, Alabama,
9 and Louisiana. That is certainly one added factor that
10 indicates that the Middle Claiborne is in fact an interstate
11 resource and interstate aquifer.

12 Your Honor will also find -- and the reason I'm making
13 these points, let me say in advance, these points that I say
14 are proof are going to be undisputed, in my judgment,
15 undisputed, that it underlies eight states; that before
16 pumping, groundwater naturally flowed across state lines,
17 including flowing from Mississippi into Tennessee and also,
18 your Honor will find, as the proof goes on, from Tennessee into
19 Arkansas. And so that, your Honor will find, is also going to
20 be undisputed.

21 The third point is that pumping in one state impacts
22 the flow of groundwater in the same aquifer in other states.
23 And that of course is one of the reasons we're in this
24 courtroom today. And that is, it's -- it is quite undisputed
25 that pumping in Tennessee will affect groundwater in

1 Mississippi.

2 And let me add, your Honor, because it's important,
3 pumping in Mississippi will affect groundwater, the same
4 groundwater, in Tennessee. So that is one of the additional
5 factors.

6 And finally -- not finally. I'm sorry. The aquifer
7 is hydrologically connected with interstate rivers. That's
8 going to be undisputed as well. Your Honor has seen
9 designation of that on the screen earlier from Mr. Frederick.

10 One of the main rivers in this area that your Honor
11 will find is connected to is the Wolf River, which runs --
12 starts in Mississippi and runs in Tennessee and then into the
13 Mississippi River.

14 Now, there are two other points in addition to that
15 that I think your Honor will find important. There is no
16 physical barrier -- I'll repeat: No physical barrier along the
17 Mississippi Tennessee boundary -- that impedes groundwater from
18 crossing the State line.

19 In other words, there is no -- rephrase it -- there is
20 no physical barrier that impedes this groundwater moving
21 interstate from Mississippi to Tennessee, from Tennessee to
22 Mississippi. That will be undisputed.

23 And as also has been alluded to, the groundwater --
24 this is not -- your Honor, this is not a Mississippi bathtub.
25 This water is constantly moving. This water in the aquifer is

1 constantly moving in the Middle Claiborne, to some extent. And
2 it is recharging constantly. It is moving in and out of
3 Mississippi, and in and out of other states.

4 So I think your Honor will find that with these facts
5 that I have set out being undisputed in the record, I think
6 your Honor will conclude, undisputed in the record, the
7 plaintiff's position in this case is going to be not only
8 unworkable but illogical; and that the proper way, as indicated
9 by Mr. Frederick, and we concur, is if this is -- and we
10 certainly view it as an interstate resource, then equitable
11 apportionment is the solution.

12 The solution from Mississippi will be, if their
13 position is upheld, their position will involve dozens and
14 dozens of lawsuits around the country from areas where the
15 aquifer is underlying more than one state. It's untenable and
16 it's illogic, and so we ask your Honor to answer that question
17 that your Honor posed as yes. This is an interstate resource.
18 So is the aquifer water. So is the water. And we think the
19 proof will be clear and undisputed.

20 Our expert, Mr. David Langseth, will testify in the
21 case. Your Honor will find him to be highly competent, highly
22 learned, two degrees from the University of Minnesota, a
23 master's and doctorate from MIT, and he will support the
24 positions that we have reiterated to indicate that in fact this
25 is an inter -- interstate -- I'm sorry, interstate resource.

1 So that will be our proof, if the Court please. And
2 when it's concluded, your Honor will be strongly persuaded.

3 Thank you.

4 MR. ELLINGBURG: Excuse me. You said I could have
5 just a few minutes.

6 THE COURT: Okay. Makes no difference if you save it.
7 He got 19, so you get 4 minutes

8 MR. ELLINGBURG: Yes, sir. This won't take long.

9 What the proof's going to show is that the defendant's
10 case is based on undisputed generalizations, labels that
11 weren't necessarily included as part of the report, and if they
12 were, they were just titles and characterizations.

13 That's what their case is all about. Mississippi's
14 case is about the signs, and the reason it's been the signs is
15 very clear. This issue has never been addressed by the Supreme
16 Court. And groundwater is simply not surface water. And all
17 of these efforts to make it look the same are going to
18 disappear during the course of this case.

19 The reality is that groundwater is -- the availability
20 of it, the quality of it, is different in virtually every
21 location on the earth, including within the Mississippi
22 Embayment. There are some common characteristics; we don't
23 deny that. There are -- you know, certainly geology didn't
24 stop at the State line.

25 The case isn't really about the geology; it's about

1 the water. And this -- in this case, this is a mixed question
2 of law and fact. It's a question that has to be decided under
3 the United States Constitution. I mean, states' rights have
4 been eroded, but as recently as the last year, the Supreme
5 Court has reaffirmed the state sovereignty over the waters
6 within its borders.

7 And that's what this case is about. This case is
8 about Mississippi's right to protect, preserve, control the
9 taking, regulate groundwater within its borders. And it has
10 been denied that right by the attitude of its neighboring
11 state, which said, "We can pump it, and so it's ours."

12 And it didn't have to be pumped from there. So
13 they're -- this is an issue not about generalizations,
14 characterizations, high-level labels. It's about the
15 groundwater in this area, what its natural condition is, and
16 about the fact that it's being pumped by another state out of
17 Mississippi, and Mississippi has a constitutional right to
18 regulate and control it, before the Supreme Court.

19 Thank you.

20 THE COURT: Thank you.

21 Well, are we ready to put on any testimony?

22 MR. ELLINGBURG: Yes, your Honor.

23 THE COURT: Are you planning on putting on joint
24 purposes defense now, later on, or is Memphis and Tennessee
25 going to have separate witnesses?

1 MR. FREDERICK: We'll have separate witnesses, your
2 Honor.

3 THE COURT: All right.

4 Okay. Are you ready, Mississippi?

5 MR. D. BEARMAN: Your Honor, just as a housekeeping
6 matter, the Court -- this is my -- an issue with me personally
7 is my hearing is a little difficult. Would it -- if it's not
8 too much trouble, to ask your Honor to bring the microphone a
9 little bit closer --

10 THE COURT: Okay.

11 MR. D. BEARMAN: -- to you; and perhaps on the podium,
12 too, if your Honor would not mind.

13 THE COURT: Sure.

14 MR. D. BEARMAN: Thank you, your Honor.

15 THE COURT: Can you hear that? Is that better?

16 MR. D. BEARMAN: Absolutely.

17 THE COURT: Thank you for bringing it to my attention.
18 I have the same problem sometimes, if people don't get close to
19 the mics.

20 Okay. Yes.

21 MR. D. BEARMAN: May I move the microphones together,
22 or -- Mr. Ellingburg, if you wouldn't mind.

23 THE COURT: We want everybody to hear what we're
24 saying.

25 MR. D. BEARMAN: Thank you, your Honor. I appreciate

1 that.

2 THE COURT: Okay. You may call your first witness for
3 Mississippi.

4 MR. ELLINGBURG: Thank you, your Honor.

5 THE COURT: Are you all keeping track of your time now
6 that -- for the whole part of your case, as we talked about
7 before?

8 MR. ELLINGBURG: Yes, we'll keep the time -- track of
9 the testimonial time, and we have parties who will agree to
10 mediate at the end of the day.

11 The State of Mississippi would like to call as its
12 first witness Dr. Richard Spruill.

13 THE COURT: Do we have a clerk here to swear him in?
14 I guess I can do this now.

15 DR. RICHARD SPRUIL,
16 called as a witness by the Plaintiff,
17 having been duly sworn, testified as follows:

18 MR. ELLINGBURG: Your Honor, before we start, I would
19 like to ask if it would be acceptable -- certainly not the
20 whole time, but we're going to use a lot of illustrations to
21 show some issues. Could it be acceptable for Dr. Spruill at
22 times to step down and point at the screen?

23 THE COURT: Oh, yeah, sure. That would be fine.

24 MR. ELLINGBURG: Thank you, your Honor.

25 THE COURT: You're going to use the screen primarily

1 for your exhibits?

2 MR. ELLINGBURG: Yes, your Honor. You'll see them up
3 there also, and you should have a book of them.

4 THE COURT: Yes, I have.

5 MR. ELLINGBURG: Thank you. I have a propensity to
6 sometimes get a little too loud, so I try to keep it away from
7 me. But I'll try to keep that down.

8 THE COURT: It's okay. I never complain about
9 somebody speaking too loud.

10 MR. ELLINGBURG: Thank you, your Honor.

11 Before we start, I'd like to say that Dr. Spruill's
12 résumé or curriculum vitae has already been submitted to the
13 Court.

14 THE COURT: Sure.

15 MR. ELLINGBURG: It is Docket Number -- let's see.
16 It's Docket Number 73. We're not going to go through the
17 entire contents of it, but I am going to -- I'll try to get
18 some highlights on his background. I think it's important.

19 THE COURT: All right. I don't think there's any
20 objection on the other side.

21 MR. FREDERICK: No objection, your Honor.

22 THE COURT: Okay. All right. Go ahead. You may hit
23 some high points.

24 MR. ELLINGBURG: Thank you.

25

1 DIRECT EXAMINATION

2 BY MR. ELLINGBURG:

3 Q. Would you state your name.

4 A. My name is Richard Kent Spruill.

5 Q. And what is your residence address?

6 A. I reside at 4100 Timberlake Drive, in Grimesland, North
7 Carolina.

8 Q. And what is your profession?

9 A. I'm a geologist and hydrogeologist.

10 Q. Is there -- is there a difference between geology and
11 hydrogeology?

12 A. I think that geology is a more general term. There are
13 many different types of geologists: Mineralogist, petrologist,
14 and so forth. And I have trained as a geologist first, and
15 then added additional training that I think qualifies me to
16 specialize in the study of water.

17 So I think that's the difference between the two. I'm
18 a specialist as a geologist who understands something about
19 groundwater and surface water.

20 Q. Do you -- would you -- briefly, what is your educational
21 background?

22 A. I studied geology at -- master's -- undergraduate at
23 master's level down at East Carolina University and the south
24 coastal plains of North Carolina, and I then enrolled in the
25 PhD program at the University of North Carolina at Chapel Hill,

1 where I studied geology and isotope geochemistry.

2 Q. And did you have any further studies that related
3 specifically to groundwater hydrology?

4 A. Well, throughout my three-degree program, I was fortunate
5 to take some courses in hydrogeology at both the undergraduate
6 and graduate level. But I didn't find the subject at that time
7 to be something that I wanted to adopt, because I was
8 fascinated by isotope geochemistry.

9 And so I started teaching at East Carolina University
10 in 1979, and mainly taught courses in mineralogy and petrology
11 and isotope chemistry. But at that time the university offered
12 me the opportunity to go back to North Carolina State
13 University, in addition to everything else I was doing at the
14 university, and take courses with a renowned hydrogeologist
15 named Ralph Heath, who was a retired US Geological Survey
16 hydrogeologist. So I trained extensively with him.

17 Q. Just for a moment, before we go there, can you hear me,
18 Dr. Spruill?

19 A. Yeah. It just shakes me up. The sound all of a sudden
20 comes here, and I think it's the judge. Sorry.

21 Q. What I was going to ask is, what made Ralph Heath somebody
22 you went to study under?

23 A. Well, Ralph Heath, in my opinion, is one of the preeminent
24 hydrogeologists who ever worked for the US Geological Survey.
25 In addition to being a North Carolinian and graduate of

1 University of North Carolina Chapel Hill, he worked throughout
2 his career as a high-level district chief at the US Geological
3 Survey.

4 But what was more important to me is that he wrote a
5 couple of books that I think serve as the foundation for modern
6 applied hydrogeology, and these are water supply papers. And
7 so I had been fortunate to read those papers and was fascinated
8 by his approach to evaluating groundwater hydrology,
9 especially.

10 Q. Yes, I believe one of those has been marked as a joint
11 exhibit. I'm not sure of the number at this moment, but it's
12 Basic Groundwater Hydrogeology, right?

13 A. Basic Groundwater Hydrology.

14 Q. Hydrology. And so what -- would you describe briefly your
15 studies with -- under Dr. Heath -- I mean, under Mr. Heath?

16 A. Mr. Heath.

17 So I had an opportunity to go to NC State and attend
18 his class in the school of engineering, where he taught after
19 his retirement, and as a return to the great Tar Heel state.
20 And that first course was an advanced course in applied
21 hydrogeology. And so I studied that semester with him and
22 became fascinated with the subject because of his approach.

23 Following that first semester, I feel that I
24 established a bond with Ralph Heath, and we worked together to
25 begin to evaluate some issues that he thought were critical

1 issues that he could perhaps pass along to me as a budding
2 hydrogeologist in North Carolina.

3 Q. Did you work with him on any specific projects in North
4 Carolina?

5 A. That first year we wrote a research proposal to I think the
6 Water Resources Research Institute to evaluate how water moves
7 in certain parts of the bedrock aquifer system in the Piedmont
8 of North Carolina. And we were successful in getting funding,
9 and we installed wells. And he mentored me throughout that
10 first early project.

11 Q. How much of this was fieldwork and how much of it was
12 classwork?

13 A. About half and half.

14 Q. Okay. And what is the value of the fieldwork?

15 A. Well, I've always been a field-oriented person, and so the
16 value of the fieldwork to me was to learn a lot of the
17 techniques. And I was never exposed to that as more of an
18 academic-style geologist, and that is dealing with well --
19 learning how to design and construct wells, and learning how to
20 take measurements in wells, and doing the kinds of things that
21 I call applied hydrogeology.

22 Q. So what did -- what effect --

23 THE COURT: You're taking your coat off?

24 THE WITNESS: Yes. It's warm in here.

25

1 BY MR. ELLINGBURG::

2 Q. Richard, would you like some water?

3 A. I'd love some -- I have some right here.

4 Q. You ready?

5 A. Yes.

6 Q. Before I move on, I'd like to step back just a little bit.

7 Is there anything about your CV that needs to be
8 changed?

9 A. Yes.

10 Q. And what is that?

11 A. After 39 years, which equates to almost 80 semesters, I
12 retired last year from East Carolina University. I don't think
13 that's indicated on this; I didn't update it on this résumé.
14 So I'm officially retired from ECU, after almost 40 years,
15 effective September 1st of 2018.

16 Q. Is that the only change you need to make?

17 A. As far as I know.

18 Q. Okay. Now, after you worked with Ralph Heath, did you take
19 any actions that were motivated by that work with him?

20 A. It's a funny question.

21 Q. Did you shift your focus? You said earlier you --

22 A. I shifted my focus both at the university and both outside
23 the university to really getting involved in to the groundwater
24 issues that are significant in the coastal provinces of the
25 Carolinas and all the way down to Florida.

1 And one of the most important things that I started to
2 do early on was Ralph had made me aware of the very large cone
3 of depression that was generated by pumping from the major
4 coastal plain cities of North Carolina and the impacts it was
5 having on the groundwater system. And so he and I developed a
6 series of presentations that I gave over a multi-year period to
7 try to convince the State to take some action with respect to
8 the impacts that our use of groundwater from certain aquifers
9 on the coastal plain was having.

10 Q. What was your concern about those cones of depression?

11 A. Well, the cone of depression and what we call the
12 Cretaceous aquifer -- that's a geological time period for
13 materials that are deposited during the time of the dinosaurs,
14 100 or more million years ago -- was that the larger cities of
15 the coastal plain, Greenville, Kingston, Jacksonville, were
16 taking large quantities of water from the groundwater system.
17 And then that result was that a large cone of depression was
18 generated. Water levels were declining, and perhaps more
19 significance, there was evidence that groundwater flow patterns
20 were altered, and saltwater intrusion was occurring in response
21 to those large-scale withdrawals.

22 Q. And so what action did the State take, if any?

23 A. The State didn't take any action for a long period of time.
24 But after giving more than 100 presentations and working with
25 lots of different groups, the State of North Carolina finally

1 passed the Central Coastal Plain Capacity Use Area, which
2 governed the withdrawal of water in a roughly 15-county area --
3 slightly larger than that, actually -- and forced the reduction
4 by 75 percent, with respect to the volume of water that the
5 water -- major water purveyors were removing from the
6 groundwater system.

7 Q. Was that to protect the sustainability of the system?

8 A. Absolutely.

9 Q. Okay. Now, after -- I got a little off course, but after
10 you studied with Ralph Heath, did you start your own business?

11 A. I started my business a year or -- a year or so later.

12 Q. And what is that business?

13 A. My business is called Groundwater Management Associates,
14 Incorporated.

15 Q. Is that where you are now?

16 A. Yes.

17 Q. Okay. So you started it in 1986?

18 A. About 1986.

19 Q. And could you describe what the resources you currently
20 have are at Groundwater Management and Associates.

21 A. Groundwater Management Associates is a small company. I
22 have two offices. I have an office in Apex, North Carolina,
23 which is a suburb of Raleigh, and I have an office there in
24 Greenville. The office in Apex is housed by my partner, who is
25 a world-class engineer. And he has geologists and other staff

1 members in that office. And I keep all of the geologists and
2 most of the CAD operators and so forth in the Greenville
3 office, because I am a geologist; and our company, we separate
4 the geological and the engineering services.

5 Q. Are you a licensed geologic -- geologist?

6 A. Yeah, I'm a real proud licensed geologist, professional
7 geologist in North Carolina, Number 942.

8 Q. Have you done any work with any national associations
9 relating to testing and groundwater hydrology?

10 A. I'm not sure what you're asking, but early on in my career
11 at ECU, I became fascinated with the concept of professional
12 licensure, mainly because professional licensure at its core is
13 protective of the health, welfare, and safety of the public.
14 And so I became involved in professional licensure by being
15 appointed by the Governor to the North Carolina Board for
16 Licensing of Geologists. And I was on that board for six
17 years, and shared the board for the last three years of my
18 tenure on the North Carolina Licensing Board.

19 Q. Is there a national board?

20 A. There isn't a national board, but through my experiences on
21 the North Carolina Board for Licensing of Geologists, I really
22 got interested in how we can impact the profession through the
23 development of the national examinations that every geologist
24 has to pass in order to become licensed.

25 So I got involved in what's called ASBOG. It's a

1 terrible acronym, but the acronym is A-S-B-O-G, and it stands
2 for the National Association of State Boards of Geology. And
3 what it does is design, build, administer, score, and report
4 the national examinations that every geologist has to suffer
5 through if they want to be licensed in the United States. And
6 we also administered this exam in Canada.

7 And this whole thing fascinated me so much that I
8 contributed about 17 years of my career to it, involving moving
9 up through the executive committee to become the president of
10 ASBOG in the year 2010, 2011.

11 Q. Did they -- does ASBOG identify subject matter specialists
12 or experts?

13 A. Yes. So the structure of ASBOG is in which one subject
14 matter experts in specific disciplines are designated by the
15 organization, and the organization brings those subject matter
16 experts together to craft the exam and to evaluate the results
17 of scoring of the exam.

18 Q. Okay. Could you run -- were you a subject matter expert?

19 A. I was a subject matter expert for 17 years.

20 Q. In what area?

21 A. In the areas of mineralogy, petrology, geochemistry, and
22 groundwater hydrology. The surface water hydrology.

23 Q. Okay. Back to, I guess, the timeline a little bit here.

24 After you formed -- well, GMA, how many licensed
25 professionals do you have at GMA now?

1 A. Oh, boy. So one -- one professional engineer. One
2 professional engineer who's also licensed as a geologist. And
3 approximately 13 licensed professional geologists.

4 Q. Okay. And what is your role at GMA, or Groundwater
5 Management Associates, with regard to the work that's being
6 done there in the area of groundwater and groundwater and
7 hydrology and groundwater development?

8 A. So my company has two divisions. It has an environmental
9 division; it has a water resources division. And I have
10 well-trained hydrogeologists heading up both those divisions.
11 Then we have the engineering division. What I do is I oversee
12 the work in both of those divisions that is hydrogeological in
13 nature but not engineering part of it, the company.

14 So I serve as sort of an oversight person, reading all
15 the reports, etc. But since my retirement from the university,
16 at night, I only had one job instead of two. I've become
17 fascinated again with getting back out into the field, doing
18 the things that really applied to other geologists actually do.

19 Q. So what kind of projects does Groundwater Management
20 Associates handle with regard to groundwater and its
21 development and use?

22 A. So that would be the water resources division of the
23 company. We're involved in the -- the evaluation and
24 management of groundwater resources through the -- throughout
25 just about any place that you can manage. And we are real

1 specialists in how to design wells and wellfields and managed
2 groundwater resources in an effective way.

3 Q. What part does sustainability of the groundwater resource
4 and availability play in the work you do in the groundwater
5 area?

6 A. I don't think you can have a company like Groundwater
7 Management Associates without a heavy emphasis on
8 sustainability. Sustainability is the one issue that Ralph
9 Heath preached throughout my wonderful time with him before he
10 passed away. So it's a real serious issue for us, is dealing
11 with the issue of sustainability.

12 Q. And from the management standpoint, what are you looking at
13 on your projects oftentimes?

14 A. From the management perspective, what we're doing is
15 actually designing wellfields and testing and developing
16 wellfields, which end up in municipal water supplies for small
17 towns, big towns. But we also do a tremendous amount of work
18 in support of the groundwater resource issues associated with
19 large-scale withdrawals from mining operations.

20 Q. Okay. I'm going to move forward. You in the courtroom --
21 and I made this comment that groundwater wasn't like surface
22 water. Could you tell me, what is groundwater?

23 A. Groundwater is that water which occurs in the core spaces
24 or fractures in naturally occurring material below the land
25 surface.

1 Q. Okay. Does it flow underground, like a river?

2 A. Rivers flow on the land surface in channels of their own
3 creation, in my opinion. Rivers don't find channels and flow
4 in them. Rivers generate the channels after water accumulates
5 on the land surface following precipitation.

6 Groundwater is different, in that water falling on the
7 land surface percolates through portions of the groundwater
8 system, where the groundwater system then becomes saturated;
9 then groundwater then flows at pretty low flow rates through
10 and around, mostly around, individual particles in the
11 subsurface.

12 Q. Okay. Let me show you something. I'm going to put a slide
13 up and ask if this helps you explain by looking at groundwater.

14 This slide is a slide, proud to say, from Ralph
15 Heath's water supply paper 220, that's designed at sort of the
16 introductory level to make the point that groundwater occurs in
17 the pore spaces around rings of naturally occurring material.
18 And this particular diagram, which Ralph referred to as primary
19 openings, those are the pores around sediment after it forms.

20 The whole idea was these would be sand-sized
21 particles, and sand-sized particles are illustrated or defined
22 by definition in the upper left-hand corner of the left-hand
23 figure with the simple scale one millimeter. Millimeter is
24 about, as you know, the thickness of your little fingernail.
25 About the thickness of your little fingernail.

1 And so this is a blowup, so that sand-sized particles
2 can be easily observed. And the blue-green color on this
3 diagram is simply designed to get across the point that water
4 fills these pore spaces as part of groundwater, and that water
5 flows through and around -- around these particles in response
6 to certain physical forces.

7 Q. Okay. So those -- those sand particles shown in that case
8 would generally be about the size, in terms of thickness, of
9 your fingernail, or smaller?

10 A. About the thickness of your little fingernail. Not the
11 length of your little --

12 Q. That little bitty part.

13 A. Mm-hmm.

14 Q. Okay. Let's -- let's go to the next -- now let me ask you,
15 is this -- is this an -- what kind of material, geologically is
16 this? Sand, you said; what is that?

17 A. Sand. Sand is a geological term that is a size term, not a
18 composition term. People confuse all the time sand. Sand can
19 be composed of any naturally occurring material, as long as the
20 grain size is between a 16th of a millimeter and 2 millimeters.

21 Q. Okay. I'm going to put up another slide here, and that
22 we'll be referring to on occasion.

23 What does the slide show?

24 A. So I want to know, how this can work? Can I walk down to
25 the slide? I'm capable of speaking pretty loud.

1 THE COURT: Sure.

2 THE WITNESS: So this is the 1922 Wentworth scale
3 that --

4 Q. Speak up some more.

5 A. This is the 1922 Wentworth scale used by geologists from
6 the Journal of Geology quite some years ago, and it is the --
7 sort of the fundamental scale that geologists use to talk about
8 the gradational sizes of naturally occurring materials.

9 Now, just hit a couple highlights. Materials that are
10 less than 1/256th of a millimeter are referred to by geologists
11 as clay. 1/256th of the thickness of your fingernail is
12 really, really tiny, and that material is called clay.

13 We actually use the word "mud" as a scientific term.
14 I know it sounds like a child's term, but we actually use "mud"
15 to describe these particles of both silt and clay. Any
16 particle that's between 1/256th of a millimeter and a 16th of a
17 millimeter, this size range is referred to as silt. So silt is
18 bigger than clay.

19 Q. But it's still 1/16th the size, thickness of your
20 fingernail?

21 A. Yeah. It's less than 1/16th the size of your little
22 fingernail.

23 So clay, really, really tiny; silt, also tiny.
24 Geologists are fond of actually saying you can -- if you were
25 to chew on a piece of clay, you wouldn't be able -- it wouldn't

1 be pretty, but silt would be slightly gritty. You can hardly
2 even see these particles with some analytic magnification.
3 Anything bigger than a 16th of a millimeter but smaller than 2
4 millimeters -- that's two times the thickness of your little
5 fingernail -- is called "sand," regardless of its composition.
6 It could be gold sand; it could be quartz sand. "Sand" is a
7 size term.

8 I think it's important to note that we also subdivide
9 sand to the different types of particles; for example, very
10 fine sand, fine sand, medium sand, coarse sand, etc.

11 Any particle bigger than two millimeters, regardless
12 of its composition, is called gravel. And there are
13 subdivisions of gravel: Granule, pebble, cobble, and boulder.
14 These terms -- clay, mud, silt, sand, and gravel -- are used
15 exclusively by geologists to indicate that the particles aren't
16 stuck together. They're unconsolidated materials.

17 If you stick the particles together, you form a rock,
18 so we will say it's lithified. For example, if you take some
19 gravel which is bigger than 2 millimeters, and you in the
20 natural environment cement the grains together, maybe by
21 groundwater percolating through it, the resulting rock would be
22 called "conglomerate." If you stick the sand grains together
23 by natural processes, it would be called a sandstone. It would
24 be called a sedimentary rock. If you -- and etc. Silt stone,
25 and a clay stone or a mud stone would be the lithified

1 equivalent of these unconsolidated materials indicated on this
2 chart.

3 Q. Okay. And this is a -- this is the chart -- it says at the
4 bottom, but it's hard to read; it's a scale of grade or class
5 terms for clastic sediments?

6 A. Sediments.

7 Q. So what is a clastic sediment?

8 A. Clastic sediments are those that are derived from the
9 weathering breakdown of pre-existing materials into discrete
10 particles without being dissolved first. So these are -- these
11 are fragments of other minerals, in many cases.

12 Q. So how does this relate to the earth under northwest
13 Mississippi, west Tennessee and throughout the Mississippi
14 Embayment?

15 A. Well, materials that make up the Mississippi Embayment are
16 not lithified, and so they would be composed of varying
17 compositions of clay, silt, sand, and some gravel in some
18 locations.

19 Q. Okay. So this is the earth basically on the Mississippi
20 Embayment?

21 A. It is.

22 Q. And the earlier slide showing the big blowup of the sand,
23 the groundwater we're talking about is water that is in the
24 spaces between those -- these particles in the ground?

25 A. That's correct.

1 Q. Thank you.

2 Now, the term "aquifer" is thrown around a lot. In
3 fact, the representation has been made that the entire
4 Mississippi Embayment is one totally hydraulically related
5 aquifer. So what is an aquifer?

6 A. I use the Heath's definition of an aquifer that I've used
7 in the past 20-some years. An aquifer is a rock or sediment
8 layer capable of transmitting usable quantities of water.

9 Q. And if -- is there -- are there different kinds of
10 aquifers?

11 A. We classify aquifers differently --

12 Q. Okay.

13 A. -- based on lots of different hydraulic properties.

14 Q. Are there any fundamental large classifications?

15 A. Yes. Yes.

16 Q. What are they?

17 A. Those classifications, in my mind, would be a simple one:
18 Unconfined aquifers and confined aquifers would be the two
19 fundamental types.

20 Q. Okay. Do you -- I'd like to put a slide up and ask you if
21 you could explain what the differences in the ground --

22 THE COURT: We'll take a short recess at this time.

23 MR. ELLINGBURG: Thank you.

24 THE COURT: We'll take a ten-minute recess.

25 (Recess)

1 THE COURT: You may continue with your witness.

2 MR. ELLINGBURG: Thank you, your Honor.

3 BY MR. ELLINGBURG:

4 Q. Backing up just a little bit, earlier I asked you if there
5 were different types of aquifers in terms of their -- and I
6 meant to ask you in terms of their geological materials. And
7 I'm sorry I wasn't clear about that; but could you explain what
8 the different groupings of aquifers are in terms of geological
9 materials.

10 A. So we had evolved, I thought, to a discussion of the types
11 of aquifers and unconsolidated materials. And I had described
12 those as confined and unconfined.

13 Q. Right.

14 A. But on a broader scale, there are rocks and there are
15 sediments. I've described sediments -- clay, silt, sand,
16 gravel -- and there are aquifers in those. But rocks can also
17 be aquifers. There are three rock types: Igneous rocks,
18 I-G-N-E-O-U-S, metamorphic, and sedimentary rocks. I actually
19 gave an example of sedimentary rocks in the previous example,
20 where I pointed out that sand can become sandstone. And
21 sandstone is a sedimentary rock.

22 Igneous, metamorphic, and sedimentary rocks can be
23 considered aquifers. Many times igneous and metamorphic rocks
24 have water in fractures and cracks rather than in the pore
25 spaces between grains. But you can have pore spaces that have

1 water in them, and sedimentary rocks, like sandstones and silt
2 stones.

3 And so that's a general discussion of the three
4 different types of rocks, in fact, that they can be aquifers,
5 and are important aquifers in many places around the country
6 and the world where we don't have sediment or sedimentary
7 aquifers.

8 Q. So in the fractured rock aquifers, do you -- do those
9 sometimes, I guess, does the water over millions of years erode
10 some of the fractures away?

11 A. Groundwater velocity is so low, in my opinion, in these
12 kinds of rocks, that there's no erosion. But mineral
13 precipitation in response to changes and conditions in the
14 fractures can be a problem.

15 Q. Okay. Well, that was kind of an aside. What kind of
16 aquifer system do you have in the area of North Mississippi and
17 West Tennessee?

18 A. Those aquifers that we seem to be talking about here today
19 are composed of unconsolidated sedimentary materials. They're
20 composed of kinds of particles I've described: Silt, clay,
21 sand, etc.

22 Q. And when we look at some of these early slides, we'll see
23 an area, and it will say "sand," okay? And within the geology
24 of Northwest Mississippi and West Tennessee, when it says
25 "sand," is that like the sand I get at the Home Depot? Comes

1 in a bag, it's all nice, regular, and sorted, and same size and
2 everything?

3 A. It can be. But most geologists, I think, agree that
4 naturally occurring materials tend to be less than perfect.
5 They tend to be a little messy. They tend to have some
6 variation in grain size. For example, a sand can have -- can
7 be characterized as poorly sorted, which means that it could
8 have fine sand mixed in with the coarser sand. It could be a
9 silty sand.

10 So as a general rule, when you see the words on a map,
11 "sand," most geologists would take that to mean that there's a
12 preponderance of sand-sized particles; but there could be other
13 things in it and still classify it as a sand.

14 Q. Okay. So the maps are the generalization?

15 A. They are.

16 Q. Okay. Now, in terms of the recovery of groundwater, or in
17 terms of the presence of groundwater, where it's found, you put
18 a slide up that says "Aquifers and confining beds." Could you
19 explain to us what that shows.

20 A. Yes.

21 I'm going to move down again. I don't have a lot of
22 experience with this. Is that too loud?

23 THE COURT: That's fine.

24 THE WITNESS: Is it okay without it?

25 THE COURT: It's better if you have it.

1 THE WITNESS: Okay. So this figure is also from Ralph
2 Heath; probably no surprise. Probably no surprise. Thank you.
3 Is from his Basic Groundwater Hydrology textbook.

4 And what it shows is the difference between aquifers
5 and confining beds. And so just to give you some understanding
6 of what's going on here, this is a geological cross-section of
7 the earth. So the land surface would be here.

8 And just to get things going, we'll subdivide the
9 groundwater system into two zones: The unsaturated zone and
10 the saturated zone. And in the unsaturated zone, there is
11 water, but the pore spaces aren't completely filled with water.
12 It's not saturated. The unsaturated zone overlies the
13 saturated zone, and by definition, the saturated did -- in the
14 saturated zone, all the pore spaces are filled with water,
15 hence they're saturated.

16 In this illustration I try to distinguish between two
17 types of unconsolidated aquifers, the unconfined aquifer and
18 the confined aquifer, but I throw in the issue of a confining
19 bed. Confining beds are materials that have -- can have a lot
20 of water in them, but they don't transmit the water very
21 readily. So while clay actually has more water in it, and more
22 pore space, the pore spaces aren't as interconnected, and it's
23 hard to get water to flow through clay. So we say clay can be
24 confining; that is, it can be the boundaries between the
25 different types of the groundwater system.

1 Above a confining layer, the first confining layer
2 that we find below the land surface, we usually find an
3 unconfined aquifer system. It's not confined above, but it's
4 confined below.

5 Below it, we define confined aquifers. And confined
6 aquifers are usually confined above and below, even though
7 there's no confinement shown on this particular diagram.

8 So there's an important distinction between unconfined
9 aquifers and confined aquifers, that are really the result of
10 the presence of this confining bed. When water falls on the
11 land surface as precipitation, some of it runs off and becomes
12 the water that will breach the rivers; but a lot of the
13 water -- some proportion of the water seeps underground and
14 goes down and saturates the pore spaces. And so while it's not
15 completely obvious in this diagram, every pore space between
16 this -- below this line, between the pore spaces in the clay
17 and pore spaces in the sand, are completely saturated with
18 water. Every pore space below that line, every pore space in
19 all these different units, is completely saturated with water.

20 If you were to go out into the unconfined aquifer and
21 put in a well, and put some pipes in the ground to keep it from
22 collapsing, and put some slots there that we call screens, that
23 will allow the water to come in but not let the sand in this
24 case come in, the water would rise to the height of the
25 saturated zone -- unsaturated zone, more or less.

1 And I say "more or less" because of the presence of
2 this thing called a capillary fringe. And the capillary fringe
3 is perhaps one of the most complicated parts of the groundwater
4 system, because there the water is under tension caused by the
5 attraction of water molecules for each other and the water
6 molecules for grades of sand.

7 And so the water actually in this capillary fringe is
8 at less than atmospheric pressure, and it can't come into the
9 well. So we say, for all practical purposes, the water table
10 is the boundary between the saturated zone and the unsaturated
11 zone at the base of the capillary fringe.

12 If you put a well into the unconfined aquifer and ask
13 yourself the question, "Well, where is the top of the aquifer?"
14 Well, it's there.

15 And so the water table, the water table in an
16 unconfined aquifer does not rise above the top of the aquifer
17 at the well. The top of the aquifer at this well is there.
18 The water is going to be here. This is the kind of well you'd
19 see out in Mom and Pop's farm, with an old pumphouse and a hand
20 crank and a bucket to get the water out of the ground.

21 When we developed the ability to drill deeper holes,
22 we realized we can drill into the deeper aquifers and get water
23 which is often not always a higher quality.

24 So I'll move on, then, to some discussion about the
25 confined aquifer, in which case I'm showing it as a sand. And

1 I show it uniform in composition, but it could be variable.

2 And so in this case, if we put in a steel pipe with
3 slots in it, so that the water can come into the well but the
4 sand can't, we would find a situation, in real simple, terms
5 like this: The water level in this well will rise above the
6 top of this aquifer. At this well.

7 In other words, the water level could rise all the way
8 to here, in this generic example. So when the water level in
9 that well rises above the top of the aquifer in that well, we
10 call it a confined aquifer well. And the general terminology
11 is "Artesian well."

12 Sometimes particularly the water surface in this well,
13 the standing water level in this well is above the land
14 surface, and it will flow freely, and it's called a
15 free-flowing Artesian well. I'll show you one later.

16 Many times, however, the water level in a well
17 attached to this aquifer is above the top of the aquifer but
18 below the land surface.

19 An important point about confined aquifers is that the
20 water in the pore spaces is under pressure. And you tap this
21 aquifer, the water will rise to a certain height, that can be
22 related to sea level.

23 So sea level is down here. We would say, "Oh, it's
24 up -- a hundred feet up to this surface," or to this height in
25 this well, and so that is the potential that this water has to

1 rise to that height. So we call it, in general terms, the
2 potentiometric surface.

3 Q. And those wells -- in that case there's no pumping; this is
4 just a hole in the ground. Right?

5 A. These are holes in the ground, in which we would install
6 things to keep them from collapsing. And so, yes, these are
7 wells that do not have pumps, and that I would call a
8 monitoring well.

9 Q. Okay. All right.

10 A. I'm monitoring things in the groundwater system, like
11 heights of the water table, or height to which water would rise
12 in this aquifer, called the potentiometric surface.

13 Q. Okay. So the water in the water table is essentially -- so
14 the water in the water table is at a level that is confined by
15 atmospheric pressure?

16 A. The water in the water table is actually at greater than
17 atmospheric pressure, because atmospheric pressure exists in
18 this well. So if the water here is at greater than atmospheric
19 pressure, it can come into the well. The water in the
20 capillary fringe is at less than atmospheric pressure, so it
21 can't overcome atmospheric pressure, so it remains in the
22 groundwater system.

23 Q. But everything in the confined aquifer is residing under
24 pressure?

25 A. Yes. Yes.

1 Q. And that pressure is higher than atmospheric pressure, on
2 average?

3 A. Yes.

4 Q. And that's what shows an Artesian well?

5 A. By definition -- my definition of an Artesian well is one
6 in which the water in the well rises above the top of the
7 aquifer at the well.

8 Q. Thank you. Let's move to the next slide.

9 And I'm going to ask you, we have those clay layers in
10 that last slide; and what does this show? That shows one --

11 A. Can we go back one slide?

12 Q. What --

13 A. Are you talking about this clay layer?

14 Q. Yes, that one. Let's go to the next slide.

15 A. Okay.

16 Q. And so what does it show?

17 A. This slide shows a more realistic depiction of a
18 groundwater system. A groundwater system usually is not just
19 one unconfined aquifer overlaying a confined aquifer. It's
20 probably more common to find a series of confined aquifers
21 stacked one on top of the other, with intervening clay layers,
22 that we would call confining beds; or it could be silt layers
23 that we call confining beds.

24 Q. So in this particular depiction, you have these dotted
25 lines. What are they showing?

1 A. This particular figure, from -- also from Ralph Heath, is
2 designed to educate people about the functions of the
3 groundwater system, which are to store water, to transport
4 water, and to treat water. Those are the three functions of
5 the groundwater system.

6 And so the predominant thing that you get from these
7 arrows is that well water stored underground, with a molecule
8 of water at this location, can, given existing conditions
9 within these aquifers, follow this line, moving across
10 confining layers at a really slow rate, and then moving through
11 the groundwater system before ultimately discharging to some
12 area that we call the discharge area, which could be a creek, a
13 river, or even the ocean.

14 Q. Okay. So when you talk about groundwater coming in, say,
15 in this case, it doesn't show one other layer; but when it
16 comes into the confined aquifer system, it will then follow a
17 path. Now, you've got some -- or Mr. Heath put some -- put
18 some time scales that are pretty generic on there?

19 A. Yeah.

20 Q. But could you explain why those time scales are there, what
21 they show?

22 A. So what Ralph has always emphasized is that the residence
23 time of water in different aquifers is different. And as a
24 general rule, groundwater flows from recharge areas, indicated
25 by this, to discharge areas in both the shallow aquifers and

1 the deeper aquifers.

2 But the amount of time required for a molecule of
3 water to flow from recharge areas to discharge areas varies
4 pretty dramatically. In the unconfined portion of the
5 groundwater system, travel times -- that's the amount of time a
6 molecule of water stays in the groundwater systems -- could be
7 measured in days, or weeks, or even years. But for deeper
8 groundwater systems -- and I'm talking about systems where the
9 aquifers are thousands of feet, for example, below the land
10 surface -- water can require -- a molecule of water can require
11 centuries or even millennia to move from the recharge area,
12 where it ultimately could be discharged in the discharge areas.

13 So this is an indication of a really, really slow
14 velocity of water in the groundwater system.

15 Q. And those things, what's called the travelers time?

16 A. Travelers time or residence time.

17 Q. Or residence time. What determines -- just generally, at
18 this point, what determines those? Is it the makeup of the
19 material? What is it?

20 A. It's a wide variety of factors. The travel time, for
21 example, in this aquifer would be a function of the
22 permeability of all the materials through which it flows. It
23 has to flow through this material. It has to flow through this
24 clay and through this material. And each of these could have
25 different abilities to transmit water, which is what we call

1 permeability.

2 Q. Okay. So --

3 A. So that would be a factor.

4 The other factor could be the pressures that are
5 operating in the system, that are the driving force for water
6 through these systems.

7 Q. And these are all natural systems?

8 A. These are just generic -- it's a portrayal of kind of a
9 generic system that would be considered natural.

10 Q. Focus on concepts?

11 A. Pardon?

12 Q. To help us understand the concepts?

13 A. Absolutely.

14 Q. Okay. Now, let's move -- in the last two slides, these
15 aquifers were like flat; were like a cake, except for the top,
16 where somebody messed up the icing.

17 Let's move to the next one. Are there different-sized
18 aquifers than that?

19 A. Yeah. I think Ralph was a master of moving from the simple
20 to the complex, so in his text he always started out with
21 horizontal layers. But we recognize that many layers that we
22 call aquifers in confining beds can have an inclination, and so
23 the logical next step would be to show an aquifer here, called
24 the confined or Artesian aquifer, that actually has an
25 inclination relative -- relevant to showing in a flat

1 orientation a horizontal orientation.

2 So in this case I'm actually showing a confining layer
3 down here that's nonporous -- I don't know if that's spelled
4 correctly -- and an aquifer sitting on top of it with a
5 confining layer.

6 And the purpose of this slide, in my mind, is to
7 illustrate this concept that aquifers can become inclined when
8 it rains, and what we call the recharged area of the confined
9 aquifer. It's -- water can percolate down. And by the way, I
10 would perceive that that's an unconfined portion of the
11 groundwater system. And where the clay picks up, it becomes
12 confined, and water flows down the confined aquifer system,
13 because it's under pressure.

14 And the only way you can see that pressure is to put
15 in a margin well here, that lets the water come in here, the
16 pressure rises to there, you would say, relative to sea level,
17 there's its pressure; there's its potentiometric surface in
18 feet.

19 And if you were to come over here, somewhere else and
20 do it, what you would find is that at this location for this
21 diagram, the pressure would be lower; so groundwater moving in
22 the direction of decreasing pressure, down the axis of this
23 confined aquifer.

24 Q. Okay. Now, we're talking in this case about -- these are
25 some general concepts. Now we're talking about aquifers,

1 systems, and units within the Mississippi Embayment, right?

2 A. Mm-hmm.

3 Q. Talking about -- put the next slide up.

4 Now, what is that?

5 A. This is a -- this is a map by Clark, et al., 2011, you see,
6 and it shows the general location of the northern part of the
7 Mississippi Embayment, the part of the Mississippi Embayment in
8 Mississippi and Louisiana up into Tennessee, Arkansas, and so
9 forth.

10 Q. Okay. Now, as a geologist, could you give us some history
11 as to how the Mississippi Embayment was formed, and why that is
12 important in this case?

13 A. So the Mississippi Embayment is a rather large sedimentary
14 structure that is what I would describe as a synclinal form,
15 which means it's a downwarping. And this downwarped geological
16 feature, which is part of the Gulf Coastal Region, began
17 forming, in my opinion, about 100 or so million years ago,
18 during Cretaceous time.

19 Q. Let's go to the next slide.

20 Okay. So what are you showing here?

21 A. Okay. And so this is a --

22 Q. Tell us how many years we're talking about here.

23 A. Okay. I call this a paleogeographic map. It shows the
24 geography a long time ago, hence "paleo" to geographic. And so
25 75 million years, according to this artist's rendition, who was

1 also a geologist, the Gulf of Mexico and -- which is here, and
2 the Gulf states at the East Coast of the United States, and
3 indeed the central part of the United States, was inundated by
4 a great sea. And that's because sea level was a whole lot
5 higher than it is today.

6 And so this embayment, this low spot -- which has a
7 really interesting geological history, which I'm sure you don't
8 know about -- formed in response to some kind of tectonic
9 forces as a sedimentary basin, that it's a low spot. And in
10 this time, late Cretaceous, 75 million years ago, and before a
11 sea occupied this area.

12 And so you can imagine, 75 million years ago, a river
13 flowing down here -- oops.

14 Q. Got ahead of you.

15 A. It moved.

16 Q. I'm sorr.?

17 A. A river flowing down. And in this area, a complex land
18 surface with some beaches all along there, these would be late
19 Cretaceous beaches, and there would be dinosaurs walking around
20 there instead of people. And offshore, there would have been
21 other types of sediment deposited, and maybe some barrier
22 islands; I see a few barrier islands in there, for example.

23 And so in Cretaceous time, the Mississippi Embayment
24 was inundated by the ocean. And the net result would be some
25 layers today that geologists would say are Cretaceous in age,

1 because they formed in this area 75 million years ago.

2 In the last 75 million years, sea level has been
3 rising and falling pretty dramatically. It gives new meaning
4 to global climate change and global warming. Here the climate
5 was a lot different than it is today, and you can imagine that
6 all of Eastern North Carolina, for example, where I live, was
7 underwater, and most of Mississippi was underwater.

8 The point here is that during these times, sediment
9 layers were being deposited. And their complexity is enormous.
10 There were beach sands, deposits like estuarine deposits of
11 mud, silt and clay, all kinds of complexity in this geological
12 environment, just during this time.

13 And what I think it would show in the next slide would
14 be that as time progresses, to 65 million years ago, the ocean,
15 which covered pretty far up on the continent and now regressed
16 off the continent, and so those layers that could have been
17 deposited up into here now might eroded by rivers, and some of
18 it could be eroded away, and now new material is being
19 deposited down here that has a slightly different age. It
20 would be called Tertiary, or 65 million years ago, etc.

21 And then if we progress just a little bit more,
22 Paleocene time, which is 60 million years ago, the sea had
23 regressed pretty far off. So those sediments are still there
24 in large part; those Cretaceous sediments are still there. But
25 they could have been impacted by the fact the sea level has

1 fallen, and rivers are cutting down into the land surface and
2 changing those, the compositions of those materials.

3 But then, at about the end of this time period, about
4 56 million years ago -- and I think this was listed as 50, but
5 about 56 million years ago -- the climate of the earth changed
6 dramatically, and it launched what we geologists call the
7 Eocene time period, a word for 56 million years ago to about
8 33.9 million years ago. The climate of the earth changed
9 dramatically. And the glaciers melted. And there was no
10 Arctic and no Antarctic at the time, and all of that water went
11 into the ocean again, and it inundated the land surface, and
12 once again flooded the land surface all the way up to the
13 present-day position of Memphis and beyond.

14 And I think it's really important, if you want to
15 understand this stuff, to know that this is just a snapshot,
16 one time frame, within a 25-million-year period that we call
17 "Eocene." And during this time, sea level rose and fell
18 throughout all this time. The intermediate level age aquifers
19 or layers that make up the Mississippi Embayment today were
20 formed in this kind of a protrusion of the ocean up onto the
21 continent during that time. So you would say they are Eocene
22 formations, geological formations.

23 Q. And so are you saying that there was a beach up here
24 somewhere?

25 A. I think there was a delta up here, bringing sand down from

1 the Mississippi River, all of its tributaries, and depositing
2 it, the sand at this particular time in the Eocene there.

3 And I can imagine sand being deposited and
4 distributaries and all kinds of interesting bodies, and clay
5 being deposited over here. So tremendous complexity.

6 And then further offshore, right in this area, I
7 actually see barrier islands. So there could be beaches of
8 sand there, and sand dunes, and all kinds of material being
9 deposited behind it.

10 So the net result is that if you find a lot of
11 geological formations that are that age, Eocene, but they have
12 tremendous lateral and vertical grading.

13 Q. Now, when you say grading, what sediments were being
14 deposited?

15 A. Sand, silt, clay, and probably some gravel layers
16 associated with the primary channel of the major rivers flowing
17 down from the north.

18 Q. Okay. And is there some reason that they wouldn't be
19 uniform?

20 A. I think geologists look at an environment like this and see
21 ultimate complexity. If you were at this location up here,
22 you'd be in a delta not unlike the delta south of New Orleans
23 today. And if you came down the Mississippi River, you'd see
24 splays of the river going off in different directions. By the
25 time you get down to here, you'd see kind of an estuary out

1 there; you might be able to see Gulf Coast-type barrier islands
2 with big sand dunes on them. And then the beach, and then more
3 sand deposited here, silt and clay being deposited out here.

4 So my point in showing you this is, this is the
5 reality of the formation of geological materials. We don't get
6 the same geological material formed over really large areas
7 except under some different geological circumstances. And I'm
8 showing for this region at this time.

9 Q. Would this generally -- you're saying that the level of the
10 ocean would move up and move down, but would this generally
11 show where what's been called by many geologists the Southern
12 Mississippi Embayment was primarily being formed, of the South
13 Mississippi Embayment --

14 A. I think you would see sediments of the middle and upper
15 part of the Mississippi Embayment here, as well as a lot of
16 settlement in the Mississippi Embayment in the Gulf Coast
17 region, and the Atlantic Coast region also.

18 Q. Thank you. Next slide.

19 What does this show?

20 A. This just shows the natural progression of the earth as the
21 climate changed, and sea level rose and fell after a -- towards
22 the end of the Eocene.

23 Towards the end of the Eocene, something interesting
24 really happened; that is, the earth cooled dramatically. So at
25 the beginning of the Eocene glaciers melted; sea level rose.

1 By the time we -- again, close to the end of the Eocene, which
2 is around 30, 40 million years ago, glaciers started to form
3 once again in the polar regions, and so sea level fell, because
4 you had to have the water from the ocean to make the glaciers.

5 It shows, then, that you would be left here, in this
6 area, with a thick several-thousand-foot section of sediments
7 that formed from Cretaceous to Eocene, but now sea level has
8 fallen, and those sediments are exposed at the land surface,
9 and rivers are migrating across them.

10 Q. Is there anything other than just the ocean going up and
11 down that impacted the way the sediments got formed?

12 A. There could be all kinds of things. They could actually be
13 sand dunes in here; they could be river channels and
14 floodplains as rivers flood their channels and migrated across
15 their floodplains.

16 Q. Did river flow have any impact?

17 A. River flow could clearly impact the sediments of the
18 Mississippi Embayment by constantly eroding through them at
19 different times through geological history.

20 Q. Okay. Let's go to the next one.

21 This is just another one?

22 A. Just another slide to show this complex change through
23 time, shows how the shoreline is going to change.

24 Where I live, in Eastern North Carolina, was still
25 underwater 25 million years ago, and coastal Louisiana and

1 Mississippi was underwater.

2 Q. What about the next one: Let's look to the next one.

3 A. Same thing. Sea level rises and falls, and the sea level
4 change is the norm, rather than the exception, in the way
5 geologists perceive the history of the earth. And it shows
6 that you could have had rivers of different composition flowing
7 from different areas up in the area now known as the
8 Mississippi Embayment.

9 And we're almost done with these slides.

10 Q. Next one.

11 A. 8 million years ago, still a higher stand of sea level than
12 we see today. And then 3 million years ago, most of the
13 present-day area of the Mississippi Embayment was clearly a
14 highland, the sea trends had regressed. And then this is
15 the -- what happened about a couple million years ago up to
16 about 126,000 years ago, and that is the global climate changed
17 dramatically, and water piled onto the continents as ice two
18 miles thick, and inundated the continent with ice.

19 And today all those ice sheets are gone, and this is
20 what North America looks like today.

21 Q. So that's what we have now?

22 A. Yes, that's what we have now. And you actually can kind of
23 see the outline of the Mississippi Embayment here, because the
24 materials are different than the materials of the Appalachian
25 and the Ouachita.

1 Q. So the Mississippi Embayment is filled with sediments that
2 were laid down over this long period of time under these
3 conditions?

4 A. That's an accurate description.

5 Q. Okay. Now, how does -- from the geologist-hydrogeologist
6 standpoint, the history you've just given: Why is it
7 important?

8 A. It's important because you just have to think, if you're a
9 geologist, about complexity and about the different geological
10 environs that existed in this area over that roughly
11 hundred-million-year period that resulted in that almost
12 unfathomable difference in the environments of deposition and
13 the changes in the materials that existed in this area through
14 that time.

15 Q. I'm going to show you a slide that has been used a lot in
16 this case. And it's a -- it's something you even used in your
17 report. And when I'm looking at this, it appears to me that we
18 got something called Middle Claiborne, which is an underground
19 sea full of water, and it's just all flowing in these nice
20 uniform directions of these arrows. Is that what it really
21 looks like underground?

22 A. Well, I think this is designed to be a generalization that
23 can lead to the type of interpretation that you just made. But
24 I would say that just because there's an arrow there doesn't
25 mean that it's a flowing river of water underground. These

1 arrows are giving us an indication of the direction of
2 groundwater flow, not the rate of groundwater flow.

3 And the overall concept here I think is a good one,
4 because it portrays that these sediments are formed in a basin
5 that has sort of a north/south axis, and that there are
6 multiple layers, like the bottom ones of Paleocene, and the top
7 ones are really young, and there are different names applied
8 to the different geological formations that occur in the
9 Mississippi Embayment.

10 But I certainly agree that you can't look at this
11 diagram and see rivers of water underground; you have to look
12 at these arrows in terms of direction of groundwater flow.

13 Q. Okay. Well, about -- I'm not looking right now for a
14 specific, but what kind of timetable are we looking at on this
15 map from the time water enters the Middle Claiborne, as shown,
16 to the time that it makes that turn to go up?

17 A. Are you talking about in this area, where it turns and goes
18 up?

19 Q. Yeah.

20 A. So up here, the Middle Claiborne not only thins, but it
21 gets close to the land surface. So groundwater moving up in
22 this area of an outcrop area could enter and exit the
23 groundwater system in a matter of days, weeks.

24 Q. And the unconfined?

25 A. And the unconfined portions up here in the outcrop area.

1 But once the water gets into the part of the system.

2 Q. The confined part?

3 A. Into the confined part, travel time is now measured by
4 centuries and millennia. Thousands of years.

5 Q. So this would go back -- that water from the out -- once it
6 gets into the confined portion of the aquifer, it would take it
7 thousands of years to even get to the bottom; is that right?

8 A. Thousands and ten -- and tens of thousands of years.

9 Q. Okay.

10 A. Millennia.

11 Q. Also this particular diagram, you know, it's got that
12 middle area called the Middle Claiborne.

13 A. Mm-hmm.

14 Q. Is the Middle Claiborne an uninterrupted body of sand?

15 A. No. No. It's characterized by significant lateral and
16 vertical variability.

17 Q. And this is exaggerated scale, it says on there, right?

18 A. It says "Not to scale," and so the vertical scale would be
19 different from the horizontal scale. So slight exaggeration.

20 Q. Right. Okay. So what -- let me ask you, you said -- are
21 there any other recognized formations within the Middle
22 Claiborne that aren't shown on this map?

23 A. Okay. This particular -- this is not a map; it's a
24 cross-section -- shows an interpretation by some well-respected
25 hydrogeologists, Arthur & Taylor, 1990, not of the formations

1 but the lumping of formations together in what are called
2 aquifer systems, or aquifer units, or hydrologic units.

3 And so when you asked me the question about
4 formations, make sure that you understand, the geologist thinks
5 about a formation different from a hydrologic unit, and
6 these -- this stacking of these materials is designed to
7 portray the Mississippi Embayment hydrologic system.

8 Q. Okay.

9 A. Geologists look at big systems like this because they have
10 something in common. They formed in the last hundred million
11 years the same general structural feature. But we
12 hydrogeologists like to subdivide things in different layers,
13 different systems, in this case within the bigger system, and
14 then we use the term "hydrologic unit."

15 Q. Okay.

16 A. And so these are hydrologic, hydrogeologic units of the
17 Mississippi Embayment Groundwater System.

18 Q. Okay. And how --

19 A. But your question to me was, are there variations even
20 within this hydrologic unit? And my answer is yes.

21 Q. Okay. Could we -- let's pull up the next slide.

22 Do you recognize that, Dr. Spruill?

23 A. Yes.

24 Q. This is the -- a chart that you see everywhere in the
25 literature for this region that's been worked on by geologists

1 for years. It's called the hydrogeologic and geologic units
2 and their correlation across the states within the Mississippi
3 Embayment Regional Aquifer Study.

4 Q. Now, let me make it clear, this particular slide has
5 removed the last column, which we'll show in a minute.

6 A. I took the last column off.

7 Q. To just talk about the geology?

8 A. Yes. What you see here is geology, and you add
9 hydrogeology on the right-hand side when you put it back
10 together.

11 Q. Okay. So --

12 A. Should have lifted some weights before I came, because it's
13 heavy.

14 Q. Tell me, what geologic formations do you see on that map
15 that are in the state of Tennessee in the Eocene time period?

16 A. Okay. So this diagram shows what geologists refer to as
17 the Cenozoic, one of the major subdivisions of geological time;
18 and then the tertiary; and then it shows the Eocene --
19 remember, that's about 56 million years ago, and that would be
20 about 33 million years ago or so. So all of the formations
21 listed right in here are Eocene in age. These are older
22 Eocene, and these are younger Eocene.

23 So you asked me specifically, if you went to
24 Mississippi today and wanted to see the things that geologists
25 call formations, which are mappable units -- we're not thinking

1 about water; we're talking about mappable geological units.

2 Q. So what is a mappable geological unit?

3 A. A unit that has sufficient thickness and characteristics
4 that a well-trained geologist would recognize it in different
5 locations as the same unit.

6 Q. Okay. Does that mean that its composition within that
7 formation is the same as it was?

8 A. Not necessarily. It can change, but it has characteristics
9 and thickness that would be recognized by a trained geologist
10 as something that's mappable.

11 Q. Okay.

12 A. Recognizable.

13 Q. Go ahead.

14 A. So in -- with respect to the Eocene, and the great State of
15 Mississippi, you would expect to find at the base of the Eocene
16 something called a Meridian Sand member. You might find the
17 Tallahatta Formation, the Winona Sand, the Zilpha Clay, the
18 Sparta Sand, the Cook Mountain Formation, and the Cockfield
19 Formation stacked one on top of the other. And you might see
20 that in some parts of Mississippi, but you might not find it
21 everywhere in Mississippi.

22 Q. Okay.

23 A. In the great State of Tennessee, you would expect to find
24 at the same location a geological formation called the Memphis
25 Sand. And the Memphis Sand is represented by this rectangle.

1 On top of the Memphis Sand would be the same formation, and the
2 same two formations that represent well per part of the Eocene,
3 of the Claiborne group. Claiborne is a group of formations.

4 Q. Okay. It's not a formation?

5 A. It's a group of formations.

6 Q. Okay. And this lists the formations, right?

7 A. These are geological formations. The Memphis Sand is a
8 geological formation.

9 Q. Geologically, are there further breakdowns within these
10 formations?

11 A. Oh, yeah. Geologists then go from -- from group to
12 formations to members, and even submembers, but they're not --
13 that level of detail is not shown on this document.

14 Q. This, again, is a generalization?

15 A. It's a pretty good generalization.

16 Q. Okay. Now, let's put the next slide up.

17 Now, what -- this is the slide out of the USGS MERAS
18 study. So what has been added in that last column?

19 A. I added back in the hydrogeological units, just for sake of
20 clarity. Geologists look at these on the basis of their
21 compositions. And then geologists come in, hydrogeologists and
22 others, and say, "Well, wait a minute; what about the ability
23 of these formations to transmit water? Let's lump those
24 formations together that have similarity, say, of age and
25 position, and have the same tendency to transmit water; let's

1 lump them together as a hydrogeologic unit," as shown in the
2 heading at the top.

3 Q. So what is a hydrogeologic unit?

4 A. Okay. A hydrogeologic unit is a subdivision of an aquifer
5 system. This is the aquifer system.

6 Q. The whole thing?

7 A. All of this. This is the aquifer system. Hydrogeologic
8 units are subdivisions of aquifer systems, based on their
9 similarity of ability to transmit water -- or their inability,
10 so to speak -- to transmit water.

11 So hydrogeologic units can be things like the Upper
12 Claiborne Aquifer. And it can also -- hydrogeologic unit can
13 also be the Middle Claiborne Confining Unit, and I talked about
14 confining units before.

15 Q. So a hydrogeologic unit includes both aquifers and
16 confining units?

17 A. In this classification of hydrogeologic units, you can find
18 confining layers or confining units that are part of the
19 system, and you can find different types of aquifers with
20 different names as hydrogeologic units.

21 Q. So they've lumped together or put together multiple
22 formations?

23 A. Multiple formations can be lumped together in a single
24 hydrogeological unit, or it can be a single geological
25 formation that makes up a hydrogeologic unit.

1 For example, as a general rule, the Cockfield
2 Formation, over a really large area, Cockfield Formation is
3 called the Upper Claiborne Aquifer. And there isn't a lot of
4 name change from state to state.

5 Q. Okay. But these hydrologic units, I've got to make sure
6 I'm clear: Do they include the confining layers?

7 A. A hydrogeologic unit may be a confining unit. It may be a
8 group of aquifers lumped together, called an aquifer unit.

9 Q. Okay. On the right-hand side -- on the -- in that
10 particular section you're looking at, the Sparta Sand and the
11 Memphis Sand?

12 A. That would be here and here.

13 Q. Between that line and the bottom line, the Memphis Sand?

14 A. Mm-hmm.

15 Q. Over to the right, in the hydrogeologic unit, it's got
16 those funny lines. What do they mean?

17 A. Those are lines that geologists draw to represent, in my
18 opinion, some level of uncertainty about exactly where these
19 boundaries are, timewise, and how we've decided to lump some of
20 these different things together. And it can also show, when
21 the line is vertical, it has this variability, that sometimes
22 this exists in an aquifer, as an aquifer unit, and sometimes it
23 doesn't.

24 Q. Okay.

25 A. It can come and go in this particular geologic environment.

1 Q. Okay. Where is the Tallahatta Formation in the Memphis
2 Sand?

3 A. Say that again?

4 Q. Where is the Tallahatta Formation -- I see that in
5 Mississippi. Where is it in the Memphis Sand?

6 A. Geologists don't recognize the Tallahatta Formation as part
7 of the Memphis Sand.

8 Q. What about the Zilpha Clay, or Zilpha?

9 A. The Zilpha Clay, of Eocene age, is not recognized as part
10 of the Memphis Sand in this correlation chart.

11 Q. Is it recognized in this --

12 A. It's recognized in Mississippi as a geological formation
13 and part of a hydrogeological unit called the Lower Claiborne
14 Confining Unit.

15 Q. Okay. So it's a confining layer?

16 A. It's part of a confining layer.

17 Q. Oh. And so if we just decided we were going to disregard
18 the -- we were going to mix it all up, and we were going to
19 call them the same thing, what would be the thickness of the
20 Memphis Sand in Tennessee?

21 A. From the literature, I understand that the Memphis Sand is
22 probably on the order of 250 meters thick, which would be over
23 700 feet thick.

24 Q. Okay.

25 A. But variable in thickness. So if you went to the east, it

1 would become thinner.

2 Q. Right. What about the Sparta Sand in Mississippi?

3 A. Appreciably thicker, appreciably thinner in the -- in the
4 Mississippi, especially in Northern Mississippi, but attained
5 some slightly greater thickness in Southern Mississippi.

6 Q. Okay. So this -- these Zilpha Clay, the Winona Sand, the
7 Tallahatta formation, those aren't in Tennessee?

8 A. My opinion is they do not exist in Tennessee.

9 Q. Okay. Now, this chart does refer to the Middle Claiborne
10 Aquifer, right?

11 A. Yes.

12 Q. And is that anywhere on the geology part of the table?

13 A. No. The word "Claiborne" is a word that's used to describe
14 a group of geological formations without regard to its ability
15 to transmit water. So hydrogeologists simply took this name
16 and added a "Middle" designation to it, and the word "aquifer,"
17 and said, "Oh, some of these formations are capable of
18 transmitting usable quantities of water and should be lumped
19 together in something called a Middle Claiborne Aquifer."

20 Q. But that's a hydrogeological term?

21 A. It's a hydrogeological term.

22 Q. And it includes both the confined aquifer, which can
23 produce water, right?

24 A. Yes.

25 Q. Okay. And it includes the confined layers, which were

1 predominantly clay. Does anybody --

2 A. I don't agree with what you just said, so --

3 Q. Well, the confining units are of lower permeability, right?

4 A. That's correct.

5 Q. Does anybody drill wells in the confining units to produce
6 water?

7 A. Yes. What -- I've always said throughout my career that
8 one man's confining layer is another man's aquifer. For
9 example, here in Mississippi, there's a sequence of formations
10 that are relatively low in their ability to transmit water; but
11 in the middle, there's a discontinuous sand called Winona Sand.
12 And if a small company or residences or somebody wanted some
13 water, they could probably get some water out of it. But by
14 and large that's not a major aquifer, so it's lumped in -- this
15 is really important -- it's lumped in with the Lower Claiborne
16 Confining Unit.

17 Q. So it's inside the confining unit?

18 A. It is part of the confining unit.

19 Q. Okay. So -- but it's kind of walled off, generally?

20 A. Sealed off vertically, and then in many cases horizontally.

21 Q. Okay. So it wouldn't -- it wouldn't be providing water to
22 the Memphis Sand?

23 A. I can't say whether or not -- where it ends, in this
24 direction, whether it actually intersects the Memphis Sand or
25 not. I don't have that level of detail. Sorry.

1 Q. Tell me what the significance is of the name being -- of
2 the name "Middle Claiborne Aquifer" being the hydrologic unit
3 aquifer.

4 A. The Middle Claiborne Aquifer is a very important aquifer in
5 the Mississippi Embayment, which is Lower Eocene in age, which
6 has different geological formations that make it up. And
7 geologists have called these different geological formations
8 different aquifers.

9 But Middle Claiborne Aquifer is incredibly complex, as
10 is indicated by this particular pattern here, which is hard for
11 some people to understand. I would like to point out that when
12 other geologists started coming up with these names, they
13 decided that they would name an aquifer like this, like the
14 Lower Claiborne Aquifer, and the confining bed above it, they
15 would call it the Lower Claiborne Confining Unit.

16 Q. Okay.

17 A. So if there's an aquifer called the Lower Claiborne Aquifer
18 here, its confining layer is called the Lower Claiborne
19 Confining Unit.

20 Q. Are you saying that there can be multiple aquifer units
21 within different aquifers or multiple aquifers?

22 A. There could be multiple aquifers within a hydrogeological
23 unit, multiple aquifers. So the concept is system, Mississippi
24 Embayment. Hydrogeologic unit, these subdivisions, aquifers.

25 Q. Okay. So the aquifers are what would be identified in the

1 geology part; that's where they would be found?

2 A. Well, the formation, the formation, the Memphis Sand
3 carries no connotation of its ability to transmit water, other
4 than it's a sand. So what hydrogeologists would do -- and
5 look, it's not shown on this diagram -- is they'd simply say
6 the Memphis Sand has the ability to transmit usable quantities
7 of water; it's an aquifer.

8 Q. Well, are there any -- what aquifers are there in that area
9 in Tennessee?

10 A. In Tennessee, the aquifer is called the Memphis aquifer.

11 Q. Okay. In Mississippi, is there a different recognized
12 aquifer?

13 A. In Mississippi, the aquifer is called the Sparta Aquifer of
14 the Middle Claiborne Aquifer system of the Mississippi
15 Embayment Aquifer System.

16 But there's also another aquifer of Eocene age in
17 Mississippi that is called the Lower Claiborne Aquifer, and it
18 has in Mississippi a Lower Claiborne Confining Layer on top of
19 it, and it's called these formations.

20 Q. Okay. And so does the Lower Claiborne Aquifer exist in
21 Tennessee?

22 A. My opinion is that the Lower Claiborne Aquifer does not
23 exist in Tennessee.

24 Q. Okay.

25 A. Typically. Maybe right along the border at some spot we

1 don't know about, but no.

2 Q. Well, from the hydrogeologic standpoint, are the Sparta
3 Sand and Memphis Sand different aquifers?

4 A. The Memphis Sand, in my mind, and Sparta Sand are different
5 aquifers that have been assigned to the same aquifer
6 hydrogeology unit.

7 Q. But in terms of the -- it is a recognized separate aquifer,
8 Sparta Sand?

9 A. In my mind, yes.

10 Q. In your mind? I mean, is it or isn't it?

11 A. It is -- I perceive -- I would classify the Memphis Sand as
12 a different aquifer from the Sparta Sand.

13 Q. Okay. And this would mean the entire aquifer system on
14 this chart?

15 A. Well, not really. There's some over stuff down here that
16 doesn't show up on this chart, but it's usually pretty deep and
17 pretty hard to get to, so most hydrogeologists just kind of
18 focus on this.

19 Q. Well, is this intended to be a depiction of an entire
20 aquifer system?

21 A. The majority of the younger part of the aquifer system.

22 Q. Okay. Let's go to the next slide.

23 Can you tell me, is this depicted on the last two
24 documents we've looked at, or is this another layer down?

25 A. To me, this is an attempt to portray in a geological

1 cross-section all those words that we see in that table.

2 Q. Okay.

3 A. It's a way to get people to understand what all those words
4 mean in terms of how aquifers in confined layers are stacked
5 one on top of the other.

6 Q. Okay. Now you said the Sparta Sand is separate in
7 Mississippi or the Memphis Sand. Can you show even how you
8 would indicate that?

9 A. The words "Memphis Sand" and "Sparta Sand" will not show up
10 on this diagram. But here's the difference: This is a
11 geological cross-section that you would get if you went way up
12 north of Memphis, almost in Kentucky; split the earth right
13 here, and split it all the way down to Southern Mississippi,
14 and lifted it up and looked at it from the side.

15 And what you would see is that the geological
16 formations are getting thinner up here, but in the vicinity of
17 the Tennessee-Mississippi State line, there's a lot of
18 interesting geological things going on.

19 So this diagram shows -- as I know, the interest is in
20 the Middle Claiborne Aquifer; it shows a thick Middle Claiborne
21 Aquifer. And it shows, right here, this area that doesn't have
22 the blue color --

23 Q. The white part of the ragged edge?

24 A. The white part of the ragged edge is called a Lower
25 Claiborne Confining Unit. So this thing is a Lower Claiborne

1 Confining Unit, and it dies out or pinches out in Northern
2 Mississippi. When a geological formation pinches out in the
3 subsurface, and we can't see it down there, we simply show a
4 symbol that kind of looks like a flame, and we say that in this
5 general area, this thing pinches out. This thing disappears.
6 Could have been by erosion, or it could have just never been
7 deposited there.

8 So what's really critical is that the Middle Claiborne
9 Aquifer right here is real thick; probably it's 1,000 feet
10 thick. But right here, there's a fundamental change, and a lot
11 of clay is found in this middle section. And so that's called
12 the Lower Claiborne Confining Unit.

13 Q. And what is above the Lower Claiborne Confining Unit?

14 A. Geologists have stipulated that at this boundary -- and
15 this is a diffuse boundary, the transition from the Middle
16 Claiborne Aquifer occurs. And instead of calling it the
17 Memphis Aquifer, we'll call it the Sparta Aquifer, Memphis
18 Sand, Sparta Sand, Memphis Aquifer, Sparta Aquifer.

19 Q. And I think you've said that an area in between the State
20 line and the beginning of the Lower Claiborne Confining Unit
21 has been referred to as a transition zone?

22 A. Yeah, transition zone. Would be best if I could draw it,
23 but I can't do; but that squiggly line there, representing a
24 facies change, the change in the subsurface from predominantly
25 sand to a lot more clay to a predominance of clay as you go in

1 this direction.

2 Q. Okay.

3 A. So we call that a facies change. And so it's not a sharp
4 line; rather, it's a boundary that you can see if you look down
5 from the surface, if you could see into the subsurface.

6 Q. Okay.

7 MR. ELLINGBURG: Excuse me, your Honor, can we put up
8 something so he can draw what he's talking about?

9 THE COURT: Sure.

10 (Discussion held off the record)

11 BY MR. ELLINGBURG:

12 Q. Dr. Spruill, we've been talking about this transition zone.

13 A. Yes.

14 Q. Could you draw an illustration of it? Because we don't
15 know exactly what it looks like.

16 A. So on this limited space I have, I'm going to try to draw
17 the geology right at this area of the Tennessee/Mississippi
18 line. But if you would, I'm just going to reverse it, to make
19 it a little bit easier to label, because I'm right-handed.

20 So here I'm going to draw the land surface, and
21 there's going to be the Tennessee --

22 Q. You might turn it just a little bit more so the judge can
23 see it.

24 THE COURT: I can see it. I can see it.

25 A. There's the Tennessee/Mississippi line on the land surface.

1 For example, there's a tree, so that's the land surface. Down
2 beneath the land surface, hundreds of feet, there's the top of
3 a series of geological formations that represent a horizontal
4 line.

5 And so now this is the south and this is the north.
6 And down in the subsurface, further down, a thousand feet or
7 more, there's another boundary. And this boundary represents
8 the lower part of the Eocene, the sediments and geological
9 formations during Eocene.

10 And somewhere right in here, near Mississippi -- might
11 make that smaller -- because the northern border of
12 Mississippi, here's what you have. (Indicating.)

13 You have a preponderance over here of sand. And you
14 have sand over here -- and I'm speaking in real general terms
15 first -- and you have some sand over here. And I'm not saying
16 that this sand is exactly like this sand; I'm just saying right
17 now, it's sand.

18 Q. By "this" and "this" --

19 A. I'm not saying that the dots that I'm putting here under
20 "Tennessee" are the same as the dots I'm putting here in terms
21 of grade size.

22 Q. Maybe a different mixtures of --

23 A. Different mixture, different amount of clay, which I
24 haven't shown, and so forth. So I'm just kind of working
25 towards the major points.

1 Down in Mississippi, not far from the Tennessee
2 border, you can find the layer of sand -- and frankly, I don't
3 think we know enough about it to know how far it extends in a
4 north/south direction, but it's referred to in that previous
5 chart as part of the Lower Claiborne Confining Layer.

6 On top of it is some clay. We use this symbol for
7 clay, because that's what's geologists do.

8 So what we have here is a layer that starts to appear
9 as you go southward into Mississippi. That doesn't exist in
10 Tennessee, in any information I've ever seen. And this thing
11 has a name. And this thing has a name, and this one and this
12 one have a name.

13 Q. Okay.

14 A. So if you go back and look at that chart -- which is now
15 gone, so could we go back one slide, please.

16 I draw now the Memphis Sand, and this is the Memphis
17 Sand, or the Memphis Aquifer. And I draw this sand, which I'm
18 going to call the Sparta Sand.

19 This geological formation and this geological
20 formation have specific names in this chart. And they are part
21 of hydrogeologic units. This Zilpha Clay, Winona Sand,
22 Tallahatta Formation, are part of what's called the Lower
23 Claiborne Confining Unit. That's this thing.

24 Q. By "this thing," you're pointing to --

25 A. The Lower Claiborne Confining Unit.

1 Q. -- the chart?

2 A. Strange thing in the chart for --

3 Q. That's under "Hydrogeologic Units"?

4 A. This thing is a hydrogeologic unit, called a Lower
5 Claiborne Confining Unit. So if you have a Lower Claiborne
6 Confining Unit, by definition, there's going to be a Lower
7 Claiborne Aquifer. So this thing is the Lower Claiborne
8 Aquifer.

9 Q. Okay.

10 A. Lower Claiborne Aquifer, Lower Claiborne Confining Unit,
11 Sparta Sand of the Middle Claiborne Aquifer, Memphis Aquifer
12 Sand of the Middle Claiborne Aquifer.

13 So if you have a Middle Claiborne Aquifer -- here it
14 is.

15 Q. Just pausing for one second, so you're saying that a
16 hydrogeologic unit can have -- and in this case does have --
17 multiple aquifers; is that correct?

18 A. Yes. A hydrogeologic unit called an aquifer can have
19 multiple aquifers.

20 Q. Okay.

21 A. Multiple names for aquifers, for example. Types of
22 aquifers.

23 Q. But the hydrogeologic name is depicting something different
24 than the aquifer names?

25 A. It's a bigger classification. It's a classification for a

1 group of aquifers or a group of confining layers.

2 Q. Okay.

3 A. So if you take the position of the Lower Claiborne Aquifer
4 Confining Layer, this thing, and you show where it sort of
5 starts to really get thick and where it disappears, and then
6 you project that up to the surface, like this -- just a
7 theory -- right here, you're projecting it up to the surface,
8 and then draw it across the land surface where it occurs, you
9 would say that everything in this zone called -- I'll call it
10 the transition zone, "TZ," the transition zone, everything in
11 this zone is transitioning from what you have over here to what
12 you have over here. That's why it's called a transition zone.

13 Q. Okay. And is that -- as you move closer to Tennessee, is
14 it all pure sand?

15 A. No. Mixed in with the Memphis Sand or some sand -- some
16 clay layers, as we all know, and mixed in with the Sparta Sand
17 are some clay layers. But in addition, the Memphis Sand has
18 some really nice sands in it. The sands tend to get smaller in
19 size, and could tend to get more clay mixed in when you go in
20 this direction, and that's well known.

21 And so at some point right in here --

22 Q. When you said the sands get smaller in size, and there's
23 more clay as you go in the direction you were pointing, the
24 direction from Tennessee to Mississippi; is that correct?

25 A. More clay, smaller grain size of the sand.

1 Q. Okay. Now you just drew a line on there. And if you --

2 A. Okay. So --

3 Q. You can put an arrow or something. I mean, and -- but we
4 just need to make sure we know what you're talking about.

5 A. In this direction.

6 Q. Okay.

7 A. In this direction, the --

8 Q. Well, what is that?

9 A. The coarser grain materials that make up the Memphis are
10 getting smaller as you go in this direction, and you're getting
11 more clay in the aquifer.

12 Q. Now, remind us: If you have smaller grains instead of
13 larger grains, what does that do?

14 A. It would affect the ability of the material to transmit
15 water. So it would have a different permeability here than
16 here.

17 Q. Is it lower with the smaller grains, or higher?

18 A. As a general rule.

19 Q. Okay. Okay. Are you finished with that?

20 A. I am, except that this transition zone -- I keep pointing
21 out that the transition zone, lots of things happen. One, the
22 Memphis Sand transitions to the Sparta Sand, and the Memphis
23 Aquifer becomes the Sparta Aquifer of the Middle Claiborne.
24 The -- that's true because the thickness is dramatically less,
25 and the grain size decreases, and more clay enters the picture

1 as you go in that direction; that is, to the south.

2 The Lower Claiborne Confining Layer does not exist
3 north of the transition line, the Lower Claiborne Aquifer does
4 not exist north of the transition line, according to all the
5 information that I see in our reports and literature.

6 Q. Okay. Does that have anything to do with the hydrogeologic
7 properties of the aquifer in those locations?

8 A. The dramatic thinning of the Memphis Sand Aquifer to the
9 Sparta Sand Aquifer is significant in itself, because thinned
10 aquifers have different ability to transmit water relative to
11 thick aquifers.

12 Q. Okay.

13 A. In addition, the transition from lower -- to smaller grain
14 sizes as you go to the south would have a profound impact on
15 the ability of aquifer materials to transmit water.

16 Q. This transition zone, its exact location certainly on this
17 map has not been identified, has it?

18 A. Let's see.

19 Q. I mean, they show it on the -- on the border, the change?

20 A. I've seen it on a lot of different figures.

21 Q. Well, let me show you some, okay?

22 Let's go to the next slide, Charles. And just leave
23 that there. We'll figure out how we're going to deal with that
24 on the record.

25 A. Is this okay?

1 Q. Yes. Okay.

2 Now, what does this slide show?

3 A. Okay. This is a map from MERAS, which is a USGS report. I
4 forget the date. But what this map shows is the states of
5 Louisiana, Mississippi, Tennessee, and so forth. And it is a
6 map designed to use colors to show the thickness of the Middle
7 Claiborne Aquifer.

8 In the Middle Claiborne Aquifer is the Sparta Sand --

9 Q. You mean the hydrogeologic unit?

10 A. Hydrogeologic unit.

11 Q. Okay. It's designed to show both the Sparta Sand and the
12 Memphis Sand, which is part of the hydrogeologic unit.

13 Q. Okay.

14 A. And it shows in color the different colors of the
15 thickness. For example, the white color right here, up in
16 west -- Southwestern Tennessee indicates a thickness of up to
17 1,100 feet. The green color and the yellow colors would
18 indicate thicknesses of no greater than about 400 feet.

19 And so what's conspicuous is this line running across
20 the land surface here, on this map view, in which the Middle
21 Claiborne Aquifer is really thick up there, and suddenly
22 becomes thin at that line. And that line is indicated as the
23 facies transition, that line.

24 Q. That's what you were drawing?

25 A. As the transition zone.

1 Q. Okay. And the -- I think the brown color shows that you
2 have, what, 601 to 800 feet?

3 A. Well, color shows an aquifer unit whose thickness would
4 range from 600 to 800 feet, approximately.

5 Q. Okay. And then the darker kind of sand color, that shows
6 4 to 600 feet?

7 A. This shows 4 to 600 feet.

8 Q. Okay. So --

9 A. Yes, this color.

10 Q. So where do you see either the brown color, 6 to 800 feet,
11 or the lighter sand color, 4 to 600 feet, or the white, 800 to
12 1,000 feet: What do you see there, below the transition zone
13 in North Mississippi?

14 A. I don't see it in North Mississippi. I don't see it until
15 you go much further south. I don't see it in Northern
16 Mississippi at all. I don't see the -- if you're asking me
17 about the brown and light colors indicate great thickness, I
18 don't see that in Northern Mississippi. I see it in Southern
19 Tennessee, Western Tennessee, and maybe just across the border,
20 because this is a very irregular pattern we're showing with
21 some uncertainty.

22 Q. But that -- that sand map of the USGS and MERAS, you've
23 shown the digital map north of that transition zone extends
24 pretty much all the way up through West Tennessee, doesn't it?

25 A. Extends all the way up to approximately here, according to

1 this map. That's the end of that zone, where the thickness
2 would be up to 800 feet.

3 Q. Okay. So it extends up there -- it looks like Kentucky and
4 a little bit of Missouri?

5 A. Yes.

6 Q. Okay. Now let's go to the next map.

7 What does this show?

8 A. This map is also in the MERAS report, and it shows the
9 thickness of the Lower Claiborne Confining Unit. And the Lower
10 Claiborne Confining Unit, referring to my sketch, is this clay
11 layer, this persistent thick clay layer that you find down in
12 Mississippi but don't find over in Tennessee.

13 Q. Now, you were just referring to the hand-drawn sketch that
14 you put on the whiteboard with the detailed picture?

15 A. That's right. I was referring to the Lower Claiborne
16 Confining Layer.

17 Q. Okay.

18 A. And the fact that it disappears here -- well, it's
19 portrayed on this diagram as the thickness of the Lower
20 Claiborne Confining Unit, in feet. And here it's saying that
21 this is the extent of the Lower Claiborne Confining Unit and
22 that small yellow -- red line.

23 So this small red line says that right there, it
24 exists to the south of the line, does not exist to the north of
25 the line, as I -- as suggested in my hand-drawn sketch. The

1 Lower Claiborne Confining Unit does not exist north of the
2 transition zone.

3 Q. All right. Right at the Tennessee/Mississippi State line?

4 A. Which is that.

5 Q. And by "that," you're pointing at that -- the very top of
6 the colored part of this particular slide, that ends right at
7 the edge of the Mississippi/Tennessee State line, right?

8 A. That is correct. I'm pointing at this light red line that
9 parallels the Mississippi/Tennessee line east of the
10 Mississippi River, off to the edge of the Mississippi
11 Embayment.

12 Q. Thank you. Let's show the next slide.

13 Now, what is shown on this slide?

14 A. This is the thickness of the Lower Claiborne Aquifer. By
15 reference, the Lower Claiborne Aquifer is this thing.

16 Q. This thing you're pointing to -- you're drawing?

17 A. This thing on my drawing being the --

18 Q. The space beneath the confining unit that disappears in the
19 transition zone?

20 A. It is a hydrogeologic unit beneath the lower confining
21 layer called the Lower -- Lower Aquifer, Lower Claiborne
22 Aquifer.

23 Q. All of that would be part of a hydrogeologic unit, as is
24 the rest of the formations?

25 A. This is a hydrogeologic unit. This is a hydrogeologic

1 unit. This is a hydrogeologic unit. It gets thicker as you go
2 in that direction.

3 Q. But it includes the confined ones?

4 A. Hydrogeologic units, including the confining layers. I
5 would like to do this. (Indicating.)

6 That's a hydrogeologic unit.

7 Q. Okay. Now, you -- what you've done now is you've just
8 taken a red Magic Marker, and you have drawn off an area below
9 the Lower Claiborne Confining Unit, and then you put some kind
10 of hatch lines across it. And you're saying that is a what?

11 A. This is a depiction on this geological cross-section of the
12 nature and extent vertically, laterally, of the Lower Claiborne
13 Aquifer.

14 Q. Okay.

15 A. I'm showing it does not exist to the north of the
16 transition zone.

17 Q. Right.

18 A. I would then show, using a blue line that outlines the
19 Lower Claiborne Confining Unit, illustrate that it can have
20 variable thickness, but it does not extend to the north of the
21 transition zone.

22 Q. Okay.

23 A. And then finally, and I think this is critical, the Middle
24 Claiborne Aquifer, composed of the Sparta Aquifer and the
25 Memphis Aquifer, is all of that.

1 Q. Okay. That's the hydrogeologic unit?

2 A. That's the hydrogeologic unit composed of the Memphis
3 Aquifer, transitioning to the Sparta Aquifer, all called part
4 of the hydrogeologic unit called the Middle Claiborne aquifer.

5 Q. Okay. Let's go to the next slide.

6 Now, what did you -- what do you want to show in this
7 slide? Or is it just the language, primarily, this -- what is
8 this slide?

9 A. This is the potentiometric surface of the Sparta Sand and
10 Memphis Aquifer as portrayed in 19-- 1886, projected in 1886,
11 by the researcher Reed. I guess it's published in 1972. And
12 this particular figure shows running across the -- in an
13 east/west direction across the state of Mississippi a
14 pattern -- it's hard to estimate its width, but several miles
15 wide, extending for a substantial distance across the northern
16 part of the state. And it's called the approximate position of
17 the transition, where things change.

18 Q. Okay.

19 A. And if you read the statement in this caption, which he
20 wrote, and the explanation, it says this zone I'm pointing to,
21 called this transition zone, marks the southern limit of the
22 Memphis Aquifer.

23 Q. So in this USGS report, he's identified the bottom line in
24 that transition zone between the Memphis Sand Aquifer and the
25 Sparta Sand Aquifer?

1 A. Yes.

2 Q. Okay.

3 A. Showing it not only in the confined portions of the
4 aquifer, but also in the unconfined portions of the aquifer,
5 indicated by this darker pattern.

6 Q. Right. What is that gray area on that map?

7 A. So remember, the geological formations in the Mississippi
8 Embayment are down to what they did -- from the east to the
9 west, from the west to the east. So they come up close to the
10 land surface, they outcrop; you can actually go and see them.
11 They're not covered by clay. And so geologists would call this
12 the outcrop area, where you could actually go and see it, Fort
13 Dodge underground to the west.

14 Q. And is that where the water that migrates from the surface
15 primarily comes from?

16 A. Primarily. Not all of it, but primarily.

17 Q. All right. So that gray area, the outcrop area, is on
18 that -- is where the -- that kind of I guess is very
19 bended-down sort of U-shaped -- whatever comes to the surface?

20 A. Yes. Yes.

21 Q. Okay. And that's where the water originally came from, on
22 the whole, during predevelopment conditions, and found its way
23 down into the system?

24 A. Even in modern times, this is a major area of recharge of
25 the deeper aquifers, because when it rains here, it can enter

1 directly into the aquifers without having to go across the clay
2 layer.

3 Q. Now, we've mentioned that it moves. Do you have, or have
4 you looked at approximately how long it would take that water
5 entering that recharge area, or the outcrop, to be discharged
6 from the confined Middle Claiborne Aquifer -- or Middle
7 Claiborne hydrogeologic unit in Mississippi?

8 A. Travel times in an aquifer composed of this type of
9 material could be measured in terms of inches per day. Most
10 likely in terms of inches per day. An inch a day might be a
11 good average value, because it's not all sand; some of it's
12 clay. And so at an inch per day, it would take about 30 -- it
13 would take about a couple hundred years to move a mile. And an
14 inch per day, or once it gets into this aquifer, is moving down
15 through the aquifer, would travel -- reasonable -- reasonable
16 estimates would be, oh, 150, 180, 200 years to travel a mile,
17 depending on the specifics of the aquifer at this location.

18 Q. Okay. So those -- that water, those water molecules
19 entering that outcrop are going to be within that formation for
20 a very, very long period of time?

21 A. Especially in human terms; very, very long period of time.

22 Q. Human terms, right, at least 200 years?

23 A. Per mile.

24 Q. Per mile. Okay.

25 A. Per mile. Per mile of travel.

1 Q. Thank you.

2 MR. ELLINGBURG: Your Honor, would this be a good time
3 to break for lunch?

4 THE COURT: Okay. It may be appropriate. We will
5 recess until 1:15; is that okay with people?

6 All right. We'll come back at 1:15. Court stands in
7 recess.

8 (Luncheon adjournment)

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1 AFTERNOON SESSION

2 1:15 p.m.

3 THE COURT: You may resume your direct examination.

4 MR. ELLINGBURG: Thank you, your Honor.

5 BY MR. ELLINGBURG:

6 Q. Okay. Going back to kind of pick up, a little overlap.

7 Can you hear me?

8 A. Yes.

9 Q. Can everybody hear me? Can you hear me now? Thank you.
10 Okay.

11 Dr. Spruill, we were talking before lunch, and it is
12 kind of an extension leading into the next area, but of the
13 aquifers, in the Middle Claiborne Hydrogeological Unit, do
14 those aquifers contain areas that are confined and also areas
15 that are unconfined?

16 A. Yes.

17 Q. Where -- I've put a map up here. Can you show us where the
18 unconfined areas are? The map is --

19 A. Yes.

20 Q. And just try to be a little clearer than we have been.
21 This is a digital map from the USGS MERAS report, titled
22 "Surficial Geography of the Mississippi Embayment Region
23 Aquifer Study Area." Is that correct?

24 A. Yes. This is surficial geology; that which you can see at
25 the surface, not necessarily what you could see below the land

1 surface. So this map predicts with -- or shows with different
2 colors the different hydrogeologic and geologic units in this
3 part of the Mississippi Embayment.

4 Q. And can you tell me where the outcrop areas are?

5 A. Well, since this is a surface geological map or surficial
6 geology, these patterns would represent where you can see these
7 units exposed at the land surface, and hence they would be the
8 outcrops.

9 For example, this -- this color, I guess, which is
10 sort of a brown-orange color, according to the chart, would be
11 the outcrop area for what's called the Middle Claiborne Aquifer
12 (Memphis Sand). And in contrast, the blue area, the blue area
13 is south of it, south of this -- of roughly east-west trending
14 line that parallels the border some distance below the
15 Tennessee/Mississippi border is labeled "Middle Claiborne
16 Aquifer," and in parentheses, "Sparta Sand."

17 Q. Okay. And then what does the green show?

18 A. The green area I'm quite sure shows the -- what they call
19 the undifferentiated Claiborne group; that is other geological
20 formations elsewhere in the Claiborne group.

21 Q. And in West Tennessee, appears that you have those two
22 formations, the outcrops for the Memphis Sand and the outcrop
23 for the undifferentiated Claiborne?

24 A. At the land surface, yes.

25 Q. At the land surface. And then in Mississippi, what do we

1 have in terms of outcrop areas?

2 A. We have a wide range of geological formations. Some of the
3 color patterns are hard for me to see up here. I suspect,
4 maybe Lower Claiborne Confining Layer disappeared --
5 disappearing Sparta Sand, disappearing, and then disappearing
6 here at this east-west trending line south of the border.

7 Q. And by "east-west trending line," you're talking about the
8 bottom of the orange section that covers all West Tennessee?

9 A. I am.

10 Q. Okay.

11 A. And then in the green, some up -- the Claiborne group,
12 undifferentiated, which I would assume is younger in age than
13 the Sparta Sand, and then this very large color pattern here.

14 Q. And is that representative of the eastern boundary of the
15 Mississippi Embayment in the entire Embayment on the east side?

16 A. More or less. The -- yeah, this is a study outlined in
17 red, and I would assume that this is -- this line I'm
18 illustrating is east of the study area of the Mississippi marks
19 the west -- eastern limit of the geological units of the
20 Mississippi Embayment that are exposed at the land surface.
21 Hence they are outcrops.

22 Q. So how does surface water or surface precipitation find its
23 way into the confined aquifers in the two -- in both
24 Mississippi and in Tennessee?

25 A. Well, I'm fond of saying that water moves into and out of

1 aquifers from all directions. But the preponderance of water,
2 in my opinion, in these confined aquifers, this part of the
3 Mississippi Embayment, probably enter the -- does enter the
4 aquifer system in the unconfined portions of the aquifer, where
5 a substantial part of that water is discharged locally to
6 creeks and rivers, and some percentage finds its way down into
7 the confined aquifers, confined aquifer flow.

8 Q. Okay. Is the outcrop and the unconfined portion of the
9 aquifer the same thing?

10 A. Generally speaking, yeah. I would say that.

11 Q. In this case?

12 A. Yes.

13 Q. Okay. Do you have some slides to show generally how water
14 moves from the outcrop into the confined aquifer system?

15 A. Yes.

16 Q. And what was this?

17 A. This is a -- the first of a series of slides designed to
18 show, hypothetically, flow paths in the confined portion of the
19 groundwater system in an area of Northwestern Mississippi and
20 over into the State of Tennessee. And so on this map, that
21 gives you some indication of land forms, so that you can see
22 some elevation over here as relative to the flat terrain here
23 associated with the position of the Mississippi River.

24 I've indicated with letter "A" that in Mississippi,
25 the beginning of a -- what I call a line of section extending

1 upward into Memphis, terminating at A prime geologists call
2 this "the line of section." And the concept is that -- try to
3 envision lifting up the earth along this line of section and
4 seeing what's below the surface of the earth in terms of the
5 geological formations, etc.

6 Q. And have you prepared some slides to illustrate that?

7 A. Yes.

8 Q. Now, the slides we're going to show, they're not to scale,
9 are they?

10 A. Not to scale.

11 Q. And they don't depict specific flow directions; is that
12 correct?

13 A. They're designed to illustrate how groundwater flows
14 through the unconfined and confined portions of the aquifer.

15 Q. Okay. And they -- and they depict what would be natural
16 for -- in the absence of any pumping; is that correct?

17 A. That's correct.

18 Q. Well, let's put the first slide up. Now, would you explain
19 what this shows.

20 A. Okay. This is a -- what I call a groundwater residence
21 time slide, which sort of starts the process. I point out that
22 it's not to scale. Inset, once again, is the line of section,
23 so that the line of section would begin at A, would be
24 analogous to this point on the left-hand side of the diagram of
25 the land surface, and the red line running across the land

1 surface would intersect the Tennessee/Mississippi line there
2 and there. And I'm indicating inner section of this
3 Mississippi/Tennessee border, with the red line on the map view
4 and on the cross-sectional view.

5 Q. Thank you.

6 What part of the -- if you would describe what's
7 shown, in terms of -- again, in illustrative form, in terms of
8 the earth in that area, before moving to the next slide.

9 A. I'm describing a geological formation similar to the
10 Memphis Sand and the Sparta Sand, with -- represented by this
11 pattern of closed circles, representing sand of varying sizes,
12 and maybe use some gravel with some interlayers of clay.

13 I'm showing that this continuous layers in this
14 general -- general diagram that does not -- displays how an
15 aquifer can be inclined from the land surface, getting deeper
16 below the land surface off to the left here.

17 On top of the sand layer, I'm showing some layers of
18 clay, which would effectively confine below and confine above.
19 These are the extending gray layers that I'm showing,
20 effectively confine the aquifer. Within the aquifer and down
21 dip in the aquifer, I'm showing a transition zone between
22 mostly sand. And we pick up a layer of clay and other
23 materials here, predominantly clay I'm showing on this
24 generalized diagram.

25 Q. That's the dark part within the confined aquifer?

1 A. That's this dark part that's -- it has this kind of
2 flame-looking pattern on the right hand, in down inside the
3 combined aquifer.

4 Q. To the left?

5 A. To the left.

6 Q. Okay. And what are those cone-shaped-looking things at the
7 very top that come from the surface, or below the surface, it
8 looks like?

9 A. Well, they are -- is this going to work? That thing is
10 really, really heavy and hard to hold and deal with.

11 Can you hear me if I speak without it?

12 Q. Can I -- why don't you use this -- which I haven't broke it
13 entirely yet, and see if that helps. And I'll speak louder in
14 the mics, which I will lean in and move for David's benefit.
15 You better put it up real close.

16 A. Yes, sir. How does that work? Good? Okay.

17 So would you repeat your question? I'm sorry.

18 Q. What are the cone-shaped figures within that slide that
19 start at or near the surface and come down?

20 A. These are my attempt, as not such a good artist, to portray
21 that there are variations in the materials above this confined
22 aquifer that could be filled with geological material of
23 different composition than that which surrounds it.

24 Some people might say, well, this could be an
25 erosional window. It could be a paleo channel caused by the

1 prior position of a river migrating across this area, and then
2 the backfilling of that river channel with gravel.

3 And I'm proud to illustrate that some of them actually
4 could reach the confining layer, and that's the case of the
5 middle one, it actually provided a breachment of the confining
6 layer, whereas the other two, I didn't show them breaching the
7 confining layer, but my concept was to get across the idea that
8 these aquifers aren't just beautifully confined everywhere.
9 There are places where the confining layer thins and it's more
10 permeable, and there are places where the confining layer is
11 actually breached by erosion, paleo channels and things of that
12 nature.

13 Q. So does that depict the actual complexity, or is it just
14 something used to illustrate --

15 A. Just an -- just to get across the idea of some of the
16 complexity involved in these kinds of geological systems.

17 Q. We'll go to the next slide.

18 Okay. So what have you shown here?

19 A. The next slide is a blowup. Take this rectangle and draw
20 an arrow to the formation to say that --

21 Q. Now, you're referring to the rectangle in the lower
22 right-hand corner, which is a blowup of some geologic material,
23 and it's an arrow pointing to what you have defined as the
24 confined aquifer illustration. Correct?

25 A. I'm sorry.

1 Q. I'll try to stop dropping off at the end.

2 THE COURT: I'm sorry, I didn't hear. Did somebody
3 say something?

4 MR. ELLINGBURG: The court reporter -- I'm dropping my
5 voice.

6 Q. Go ahead, Mr. Spruill.

7 A. I agreed with your more detailed analysis of my description
8 that this box is a representation of material from the confined
9 portion of the aquifer. And I've enlarged it, but it's not to
10 scale. And the blue line here represents -- the blue line in
11 the rectangular box represents a concept of how a molecule of
12 water might move through the geological materials in the
13 confined aquifer. It can't move through the sand grains or the
14 silt grains. It's required to move around the sand grains as
15 it flows in a given direction, in this case from the top of
16 this rectangle to the bottom left of this rectangle.

17 Q. Is the next slide -- let's show the next slide. Okay.

18 So if you would now, I think this would be easier to
19 follow. We've blown up the small box from the prior one, and
20 the top says "Illustrative path of groundwater through sand."
21 And then at the bottom it says "Groundwater flow direction."
22 Is that correct?

23 A. The bottom says "Groundwater flow direction," which really
24 doesn't have an arrow on it, but it would indicate the
25 groundwater flow direction was to the lower left of this box.

1 Q. Okay. Now, would you describe what you -- what that is
2 illustrating?

3 A. So once again, I tried to illustrate a not-to-scale sand
4 grains. But if these were sand grains, then they would, by
5 definition, between a 16th -- be between a 16th of a millimeter
6 and 2 millimeters. So there's some small sand grains and some
7 larger sand grains within this -- within this unit.

8 A molecule of water entering this segment of the
9 groundwater system might follow this flow path as it flows
10 around --

11 Q. Now, "this flow path," you're talking about the blue line?

12 A. This blue line.

13 Q. Okay.

14 A. I've illustrated here with my finger, following a blue path
15 as it goes from the upper part of the diagram to the lower
16 left.

17 Another molecule of water in really close proximity to
18 this molecule of water might follow a slightly separate
19 circuitous path as it flows through these materials, but the
20 general pattern would be for the water that enters this part of
21 the aquifer system alert -- or this porous media to flow along
22 tortuous flow paths, as I've illustrated in this diagram.

23 Q. Okay. And as you said, some of that water comes in at the
24 very top of the arrow is -- may very well follow a different
25 path now?

1 A. That's correct.

2 Q. And we're talking about very, very small amounts of water?

3 A. Well, we could be talking about very large amounts of water
4 flowing through a sand, a sand body, at a very slow rate.

5 Q. Okay. And this particular diagram, the water flowing on
6 that path is the -- a small amount of water, isn't it?

7 A. I'm simply trying to illustrate the path and direction that
8 a single molecule of water might follow as is flowing through
9 the groundwater system.

10 Q. Okay. Now, as far as these sand particles, why aren't they
11 all uniform?

12 A. The nonuniformity of grain sizes in the geological
13 environment, to me, is the rule, not the exception. There are
14 certainly some fairly uniform geological deposits that we find
15 in nature. I would hold up a sand dune deposit, for example,
16 as one in which many of the grains are about the same size, but
17 most geological formations have a variety of particles within
18 them.

19 Q. Okay. If we could move to the next slide.

20 So now what are we showing here?

21 A. Just the same slide over again, but I had this idea that
22 you could get across how aquifers become charged with water by
23 recognizing precipitation. So these were rain drops at the
24 top, above the land surface, so precipitation. These little
25 dots falling on the land surface either runs off the land

1 surface, evaporates, transfers, or enters the groundwater
2 system.

3 Q. Okay. And so what's -- let's put the next slide.

4 A. So we get across this concept of travel time and residence
5 time in the groundwater system, trying to illustrate that as
6 water moves into the groundwater system, it might take a series
7 of days for water to flow from recharge areas to discharge
8 areas in the unconfined portions of the groundwater system.

9 Q. Okay. So this is the unconfined portion?

10 A. Well, it could be the unconfined system. Clearly over here
11 the system might be slightly confined, but I'm saying
12 consistent with what Ralph tells us, that in the upper parts of
13 the groundwater system, it's not unusual to have water that can
14 move through the groundwater system and discharge over
15 distances of -- over time frames of days.

16 Q. Okay. So let's move to the next slide.

17 A. The next slide, I'm just trying to get across the idea of
18 the slow movement of water through the groundwater system. So
19 now movement of a molecule of water might require a time frame
20 of ten years to move some reasonable distance through the
21 groundwater system, measured in feet to miles.

22 Q. Now, are you in the confined part of the aquifer now?

23 A. I'm defining now the flow down in the confined portion of
24 the groundwater system.

25 Q. Okay. That's not in the outcrop area?

1 A. No, it's in the groundwater system. But it's confined.

2 Q. Can we kind of follow that particle along?

3 A. Sure. So follow that particle along, travel time of
4 100 years might be shown in this general sketch, followed by
5 more travel time of 1,000 years. Flows slowly through the
6 individual pore spaces at rates measured in inches per day.

7 Q. This is all under natural conditions?

8 A. This is all under natural conditions.

9 Q. All right. Let's move to the next one.

10 A. And then the next one, just a final illustration to show
11 that groundwater in the groundwater system has been shown to be
12 old. It takes a long time for water to reach the deeper parts
13 of our groundwater system.

14 In the coastal plain of North Carolina, where I live,
15 we know that the water in the deeper aquifers is almost
16 20,000 years old. So as it moves from the land surface across
17 this long history, it resides in the groundwater system as it's
18 slowly moving through the system for incredibly long periods of
19 time.

20 Q. Okay. And this is all looking at the water as it moves
21 from the outcrop area of recharge down in the system?

22 A. Yes.

23 Q. And through the system?

24 A. Yes.

25 Q. Thank you.

1 Now, I think you may have mentioned this earlier, but
2 what is the approximate rate in the actual Sparta Sand and
3 North Memphis Sand in Tennessee, both the actual natural --
4 under natural conditions, the actual estimated rate of movement
5 of the water?

6 A. Well, it depends on a lot of different factors, whether you
7 talk about water moving through some of these clay lenses or
8 water moving through sands. But I've stated already I think a
9 reasonable value is, for velocity of groundwater in the
10 groundwater system, is inches per day.

11 Q. Okay. Which would convert to how many feet a year?

12 A. At an inch -- at an inch per day, I'll have to do that
13 calculation.

14 And that would be 365 inches in a year, 30 feet.
15 Maybe the width of this room in here.

16 Q. About 30 years?

17 A. In a -- in a year, 30 feet.

18 Q. 30 feet in a year?

19 A. 30 feet a year, which would be about the width of this
20 room, I would suppose, though I haven't measured it.

21 Q. If we change that from a year to the time it would take for
22 it to travel from the outcrop down through the aquifer, under
23 natural conditions, for a mile, about how long would that take?

24 A. Thirty feet a year; 30 into 5,280 is around 200.

25 Q. Okay. Thank you.

1 A. Around 200 feet of travel in about a year.

2 Q. Okay.

3 A. So --

4 Q. Is 200 feet in a year what you meant to say?

5 A. I think about a mile, travel about a mile in about --
6 200 days, 187 days or something, however you calculate.

7 Q. Is that years or days a mile?

8 A. I'm sorry. So we're talking about the amount of time it
9 takes to travel an inch. That was about an inch a day.

10 Q. Right.

11 A. So to travel a mile would probably take around 200 years,
12 185 years, 200 years. We're talking about a mile.

13 Q. Okay.

14 A. I'm sorry for the confusion.

15 Q. Okay. I just wanted to make sure we had it clear.

16 So in your illustration, what would be the approximate
17 time from the area of recharge in the outcrop to the discharge
18 of the groundwater? Although I know you're not showing the
19 discharge point.

20 A. It depends on too many factors for me to answer that,
21 because the discharge area for all parts of the groundwater
22 system is not the same. But I would say that we know that
23 residence times in the groundwater system could be measured in
24 thousands of years. It can also take thousands of years for it
25 to move upward across confining layers and into other aquifers

1 before finally being discharged.

2 Not all groundwater discharge is locally; some
3 groundwater can actually flow in circuitous paths and flow, for
4 example, down the axis of the Mississippi Embayment before it
5 discharges much further away.

6 Q. So if you give it 10, 20, 50, 100, 200, 300,000 years, it
7 will get out?

8 A. It will get out over a long period of time.

9 Q. Okay. Now, I want to compare this inch a day to some
10 surface water.

11 A. Okay

12 Q. Okay. And so I'd like to look at the next slide.

13 Now, could you tell me what you're showing here.

14 A. I took a map of the Mississippi River, looked for some
15 velocity data on the website, that is a government website,
16 shown in the lower left-hand corner. And I chose three
17 locations to illustrate the velocity of water, and fluvial
18 system -- river system.

19 So I chose first --

20 Q. Let's pause for just a second. This is something that you
21 actually culled data from the government site
22 www.mps.gov/mississippi/riverfacts; is that correct?

23 A. Yes, sir.

24 Q. And you used that to calculate what you're about to show
25 us; is that correct?

1 A. Yes.

2 Q. And did you also use the map from
3 americanrivers.org/river/mississippi?

4 A. Yes.

5 Q. Okay. Now go ahead and explain to us what it shows in
6 terms of the travel time of the surface water in the
7 Mississippi River.

8 A. This map, I use flyins that my daughter helped me with.
9 And I picked three locations. I flew in the position of the
10 Mississippi River headwaters up in Minnesota, indicated by the
11 uppermost box. I flew in locations of the Memphis --
12 Mississippi River in Memphis, Tennessee, indicated by this box,
13 this arrow pointing to Memphis. And I selected New Orleans,
14 Louisiana, indicated in this box, and an arrow indicating
15 New Orleans.

16 And using this information, I've simply calculated or
17 simply related to you the velocity of water in the river. And
18 this is sort of an average velocity, so I've been -- the
19 headwaters of the Mississippi River in Minnesota, a more
20 reasonable velocity would be about 1.2 miles an hour. And you
21 can translate that into miles per day, so that would translate
22 to about 28.8 miles per day of movement of the water in the
23 river.

24 Q. Okay.

25 A. And you can contrast that with an increase in velocity

1 further downstream in the mighty Mississippi of about two miles
2 per hour and a velocity of almost 50 miles per day. And
3 further south, velocity could increase to 3 miles per hour,
4 which would translate to a velocity of about 72 miles per day.

5 Q. Okay. So the water flowing at Memphis, how many miles per
6 hour did you say that was?

7 A. About 50 miles per day. Per day.

8 Q. About 50 miles per day. Okay. And I think you said
9 that -- let's see. In a year, an inch a day for groundwater,
10 the groundwater might travel about 50 -- about 30 feet?

11 A. I used that example.

12 Q. Okay. And so the amount of water that flows down the
13 Mississippi River within a reasonably short period of time
14 would be a great deal more water than would flow through this
15 aquifer system in 20, 30, 40 years?

16 A. That would be an understatement.

17 Q. Understatement. Okay. Thank you.

18 Now, the Mississippi River obviously is not
19 representative of all rivers?

20 A. Definitely not.

21 Q. Okay. But in terms of flow rates, if we come down to, say,
22 a stream or small tributary river, would the flow rate again be
23 measured in -- more likely in miles a day?

24 A. Could be, or at least hundreds of feet per day.

25 Q. At least?

1 A. Hundreds.

2 Q. Well, a small trickling stream might only go hundreds or
3 thousands of feet a day, but most significant tributaries have
4 significant surface water velocities.

5 Q. Okay. Now, what can you, as a hydrogeologist, tell us
6 about the flow direction of groundwater in the unconfined and
7 confined portions of an aquifer such as the one you illustrated
8 earlier?

9 A. Generally, groundwater in the -- well, I would say
10 generally that groundwater in the unconfined portions of the
11 groundwater system is typified by complex flow patterns, and
12 then the deeper parts of the groundwater system is typified by
13 more consistent regional flow patterns. But both of them
14 can -- both -- in both examples, the flow patterns can be
15 complex.

16 Q. Let's look at the next slide.

17 If you would explain what that shows.

18 A. Okay. This is a slide from the freshman textbook that I
19 used, called Tarbuck and Lutgens, 2010 publication, and it
20 shows a land surface typified by a couple of rivers, a major
21 river, a stream and a couple of lakes here, clearly labeled,
22 with some interstream areas with higher topography.

23 And the general concept here is that we would see what
24 I call local versus regional flow patterns. I'll describe what
25 I mean.

1 The unconfined aquifers, typified by a water table --
2 that's the boundary between unsaturated and saturated
3 conditions, and that water table generally mimics the land
4 surface. And what I mean by that is where the land surface is
5 low, like next to streams, the water table is low; and where
6 the land surface is -- has the higher elevation, the water
7 table has a higher elevation.

8 So it -- I always say that the water table in the
9 unconfined aquifer is a subdued reflection of the land surface.
10 The inclination --

11 Q. Why do you say it's a subdued reflection?

12 A. Because the water table here, if you just notice, is a
13 relatively flat surface; some inclination, but it doesn't have
14 the same curvature.

15 Q. Now, you're pointing to the first -- it looks like kind of
16 an upward-curved area to the right of the river, on the left of
17 your drawing; is that correct?

18 A. That's correct.

19 Q. Okay. And --

20 A. Same thing would be true in any part of the surficial
21 aquifer on this document.

22 Q. Okay. Because you have a whole series of lines that show
23 water basically entering at the surface and then discharging
24 into the surface water, correct?

25 A. Yeah. These are general flow lines. It's really important

1 for everybody to realize that it doesn't just rain up here.
 2 Water doesn't just enter the aquifer here. Water enters the
 3 aquifer everywhere when it rains. It also covers the land
 4 surface, and there's infiltration.

5 But this is -- the concept here is just one of
 6 understanding how local flow patterns develop in the unconfined
 7 portions of the groundwater system, where water -- groundwater
 8 flows from interstream areas, as a general rule, downward
 9 before it takes the turn, and actually flows upward and
 10 discharges to local discharge areas like lakes and rivers.

11 Q. So on your slide, you have light blue lines at the top --

12 A. Mm-hmm.

13 Q. -- that were -- you've been pointing to in your
 14 description?

15 A. Yes.

16 Q. So what are the red lines, the red --

17 A. The red lines indicate that you can have multiple scales of
 18 groundwater flow patterns as you transition from an unconfined
 19 aquifer system to a confined aquifer system. And the idea of
 20 this diagram is that these clay lenses that actually have
 21 breaches in them are confining layers for a deeper aquifer
 22 system that is confined.

23 And so I'm illustrating a shallow aquifer flow
 24 pattern, an intermediate groundwater and what's called the
 25 subregional groundwater flow pattern, indicated by the red

1 lines.

2 And then some of this groundwater must make it into
3 the confined aquifer system in areas like this. Otherwise we
4 would never have consistent volumes of water, under nonpumping
5 conditions, flowing through our groundwater system.

6 Q. Thank you.

7 Now, the next line, if you would pull the next slide,
8 then let's look back, and if you would tell me what you want to
9 show.

10 A. I use this slide all the time to indicate what's necessary
11 to really understand the general groundwater flow patterns in
12 the unconfined portions of the groundwater system. And it's
13 quite a complex diagram that shows the land surface, the top of
14 the diagram indicated by the word "land surface." And it shows
15 the water table that would develop in this area following
16 precipitate, long-term precipitation and the establishment of a
17 groundwater system. And it shows the position of the water
18 table with this dotted line, that's at some distance from the
19 land surface and is mimicking the land surface.

20 Q. If I could just get -- before we move on, it says "Modified
21 from Winter, et al. '98."

22 A. Mm-hmm.

23 Q. Is that a USGS publication?

24 A. I don't remember if it's USGS or not.

25 Q. Okay.

1 A. I don't remember.

2 Q. But that's a published document that has been taken from --
3 and what is the purpose of this slide?

4 A. The purpose of this slide for me always is to get people to
5 understand how you determine groundwater flows down in a
6 recharge area in an unconfined aquifer, then flows laterally,
7 and then can actually flow upward.

8 I'm always frustrated when people say groundwater
9 flows in response to gravity. If groundwater flows in response
10 to gravity, it's hard to get groundwater to flow upward in the
11 face of just the gravitational force. And so what geologists
12 have come to recognize is that the lines of equal pressure in
13 the unconfined system are complex and variable, and that what
14 you need to do, if you really want to understand how
15 groundwater flows in the unconfined system, is to use a series
16 of monitoring wells, which are on this diagram called
17 piezometers. I equate monitoring wells with piezometers, and
18 there may be some differences, but I'm talking about a well
19 that we can install that can measure the pressure over a short
20 vertical distance. It doesn't have a pump in it.

21 Q. So none of those are pumping; they just measure pressures
22 at specific locations?

23 A. That's correct.

24 Q. And depths?

25 A. And depths.

1 Q. Okay.

2 A. So all of these are designed with what I call short
3 screens. In other words, I only want to measure the pressure at
4 that spot. So I'm going to put 40 feet of screen in it. So by
5 having a piezometer at sea, for example, that extends to a
6 depth of -- to this depth, by measuring the water level in this
7 well, which would rise to about 80 feet -- there's 80 feet -- I
8 can measure the pressure in this well, and I can construct this
9 surface, called the potentiometric surface or the pressure
10 surface; a line of equal head within the aquifer itself.

11 So the concept here is an important one. If you go
12 anywhere else on this diagram in this area, and you drill a
13 well to 80 feet, I expect the water in that well with a short
14 screen to rise to 80 feet above sea level.

15 Similarly, if I put in a shallower well, I would
16 measure a pressure of 90 feet. Put in a shallower well still
17 that has a short screen in it, I measure a pressure of
18 110 feet.

19 By putting in these wells, we can construct these
20 lines. We don't construct these lines and then put in the
21 wells.

22 Q. So how are those used to determine direction?

23 A. Groundwater flows in the direction of decreasing pressure,
24 at right angles to lines of equal pressure. These are lines of
25 equal pressure in the subsurface. Groundwater flows at right

1 angles to lines of equal pressure, in the distribution of
2 decreasing pressure.

3 So this area, the pressure I'm showing in the upper
4 right-hand corner is 120 feet; here, along this blue flow line,
5 it's 110, 100, 90.

6 So we know that groundwater has to flow at right
7 angles to those lines of equal pressure, and in the direction
8 of which the pressure is decreasing. And so what we do as
9 hydrologists is we define the recharge area. We define the
10 recharge area of aquifers as those places where there is an
11 increase in pressure -- sorry, a decrease in pressure with
12 increasing depth, and decrease in pressure with increasing
13 depth. And we say that's a recharge area.

14 Our opinion as hydrologists is that you can't walk out
15 on the land surface and just say, "That's a recharge area."
16 You might be right. But a recharge area is that part of the
17 groundwater system where, with increasing depth, there's a
18 decrease in pressure.

19 Q. Why can't you just look at a geological map and some data
20 you get and say, "Well, this is how the groundwater is flowing
21 in the unconfined aquifer"? Why can't you do that?

22 A. Too complicated. Groundwater is not just flowing
23 horizontally in the groundwater system. It has a downward flow
24 compound, and in some places near horizontal flow compounded
25 into others, and a upward flow compounded into other places.

1 For example, if you were to go to this location, which
2 I've labeled "B" on this diagram, and put in two, three, four
3 wells -- as many as you want, as long as they have short
4 screens -- at this particular location, you would measure the
5 same pressure. And so the line of equal pressure is vertical,
6 which means that the flow pattern is at right angles to that
7 line. And so I'm showing you this blue line, a right-to-left
8 groundwater flow.

9 So groundwater enters an unconfined aquifer system
10 here, flows horizontally at the boundary between -- at this
11 subboundary I call the groundwater recharge boundary right
12 there, and then from here over towards a stream, there might be
13 a creek or a river here.

14 Q. Okay.

15 A. The groundwater system is different. So if I put in a deep
16 well, I get a pressure of 20.

17 Q. All right.

18 A. If I put in an intermediate well I get a pressure of 10.
19 Well, that means that with increasing depth, the pressure
20 increases. So the deeper I go in the groundwater system, the
21 greater the pressure. Groundwater flows in the direction of
22 decreasing pressure, at right angles to lines of equal
23 pressure; 30 feet of pressure, 20 feet of pressure, 10 feet of
24 pressure. It's that pressure gradient that's driving this
25 water upward, so it discharges.

1 Notice this: There's recharge in the groundwater
2 system everywhere. When it rains, water infiltrates the
3 groundwater system. And so we define groundwater discharge
4 areas as the area where there is an upward decrease in pressure
5 and upward flow, and here a downward flow and a downward
6 decrease in pressure.

7 And recharge areas and discharge areas are defined on
8 this, not necessarily topography.

9 Q. Okay. We've talked about that a lot now. Let's -- we've
10 talked also about confined aquifers, and we've talked about
11 unconfined aquifers. The question is, how do you get water out
12 of a confined aquifer for use?

13 A. More often than not, it has to be done by designing,
14 drilling, constructing a well into that aquifer and removing
15 that water from that aquifer. Unless it's a free-flowing
16 Artesian aquifer, you remove it by pumping.

17 Q. Okay. Let's go to the next slide.

18 What does this slide show, Dr. Spruill?

19 A. It's a picture of a typical well.

20 Q. At the top it says -- the title says "Supply Well"?

21 A. Okay. So it says Supply Well, Multiscreen, Gravel Pack.
22 But it's a figure that I took -- no surprise -- from Ralph
23 Heath's classic groundwater supply book, the groundwater
24 hydrology book. And so it shows the construction details for a
25 multiscreen, gravel pack, supply well.

1 Q. Okay. And is that representative of the wells that are
2 typically used to commercially pump water?

3 A. These are the types of wells that I design and supervise
4 the construction of or the removal of water pump -- mostly for
5 a larger-type well, based on the style of pump that I see here.

6 Q. Okay. And so the top -- top surface, it shows sand, right?

7 A. Up at the surface it shows a layer of sand underlain by a
8 layer of clay, another sand, layer of clay, sand, clay.

9 Q. Is this well producing any water on that top layer of sand?

10 A. No. We're intentionally precluding that upper sand that
11 I'm pointing to here now. That's just the first sand that you
12 encountered in this particular situation below the land
13 surface, by taking special precautions to seal it off by
14 putting in a casing and using cement. We only use Portland
15 cement, or we could use other types of materials that have
16 really low permeability, to prevent or preclude not only the
17 migration of water from the sand into the well, but also the
18 migration of water down the well from one layer surface towards
19 another. We call that grouting.

20 Q. Okay. So you've -- this illustration shows two additional
21 sand layers and shows a total of three clay layers, is that
22 correct?

23 A. That's correct.

24 Q. So there's multiple zones of sand that this well is
25 penetrating?

1 A. Yeah. And that's pretty common. It's wonderful to find a
2 single sand that will produce the amount of water that you
3 need, but most often you'll find the sand layer, and you'll put
4 a solid piece of casing into the subsurface in this hole and
5 allow -- put into the design some openings here that might be
6 20/1,000ths of an inch, or something like that, that will allow
7 the water from the sand to come in and preclude the sand from
8 coming in. It will also put maybe a gravel pack illustrated by
9 this, so the material that we generated put underground.

10 Q. Before you drill this well, how do you determine the
11 potential zone of sand in the subsurface that you might be
12 trying to obtain the water from?

13 A. Well, a lot of ways to do that. One would be to rely on
14 what people have already learned from drilling wells at a given
15 location, is go to the literature, go to more purveyors, find
16 out what's known about the groundwater system, and begin to get
17 a picture of what's underground.

18 The second way would be to go to the literature.
19 There's a tremendous amount of literature in some locations in
20 this country, and other locations we don't know much about the
21 groundwater system at all. But ultimately we use what I call
22 the great truth machine. And the great truth machine is a
23 drill rigger. And you can stand at the land surface and
24 pontificate about what's underground all you want to, but you
25 really don't know the details until you drill a hole in the

1 ground.

2 And so we would pick a spot and drill an exploratory
3 hole in the ground. It would be called a pilot hole. And
4 while we're drilling the pilot hole, a good geologist would
5 stand there with his or her hand lens and study the materials
6 that are coming up while we're drilling this hole, and develop
7 a picture in their mind of what's underground from looking at
8 the cuttings. And on the basis of that, then you have this
9 initial picture of where some units underground might be
10 potential good candidates for construction of well screens that
11 will allow you to tap that water anywhere there are places that
12 would be problematic, because you don't want these teeny
13 clay-sized particles to come into your well.

14 Q. So the water is not coming in the entire well depth; it
15 comes into the screens?

16 A. If you construct it that way, water will come in through
17 the areas that are opposite screens, and for short distance
18 above and below that through the gravel path.

19 Q. Okay. And once you've -- once you drill the well, is there
20 information you can obtain from down in the well before you
21 start pumping it?

22 A. We're in an age of electronics, and so we have these
23 sophisticated instruments that we use that you can generally
24 describe as geophysical logging tools. I spent a tremendous
25 amount of my career learning how to deal with these geophysical

1 logging tools and interpret the results of them.

2 Q. Okay. Let's look at the next slide.

3 A. Okay.

4 Q. Could you tell us the next slide, which on the bottom it
5 says "Figure 9, Geologic Section C-C Tennessee Valley
6 Authority, Allen Combined Cycle and Allen Fossil Plants Area."

7 Is that what this slide was taken from?

8 A. That's exactly what it says.

9 Q. Okay. And is this -- is this from the area where the -- or
10 near the Davis wellfield?

11 A. Yes. Yes, it is.

12 Q. Okay. Can you tell us what that log shows.

13 A. Well, there are a series of logs here. And so just to lay
14 the groundwork, in this diagram there's a vertical scale
15 indicating the altitude in feet above sea level, NGBV. This is
16 altitude relative to sea level.

17 (Reporter interruption)

18 A. There's a vertical scale showing depth below sea level in
19 feet; minus 100, minus 600 feet below sea level.

20 The land surface or the approximate land surface is
21 shown as this subhorizontal line, and there is a break over
22 here in topography, and there's more topography or more
23 elevation in the land surface on the right-hand side of the
24 diagram.

25 I selected this diagram because it illustrates the

1 kind of geophysical logs that you would see in the Memphis
2 Sand, as indicated by this -- these two words. So in this
3 diagram, someone has --

4 Q. The two words you pointed to are over to the right box,
5 with the various explanations at the very top; it was "Memphis
6 Sand"?

7 A. "Memphis Sand" is shown on this diagram in at least two
8 places. It's shown at this location right above the word
9 "Explanation," and it's also shown on the extreme right of the
10 diagram, about a third of the way down the document.

11 Q. So go ahead. So what does it actually show, that you're
12 trying to illustrate?

13 A. So you had asked me about geophysical logging techniques
14 and how they're used and what they tell us. I would just pick,
15 for the sake of brevity, a well that was drilled at the
16 location here, called PW1, right in the center of this diagram.
17 And I interpret that this horizontal -- this vertical line, the
18 dark black vertical line represents more or less the center of
19 a well. And after a hole in the ground was drilled, and they
20 kept it from collapsing by, say, keeping heavy drilling mud in
21 it, someone lowered a geophysical logging tool down to the
22 bottom of the well.

23 One of the logging tools -- and there are many that we
24 could utilize -- would be what's called a gamma logging tool.
25 Gamma rays are part of the natural electromagnetic spectrum,

1 like X-rays and visual light, etc. Naturally occurring
2 formations give off varying amounts of gamma radiation.

3 Sands composed of quartz predominantly tend to not
4 produce much gamma radiation. Clay fine-grain material, that
5 tends to be heteromineralogic, tends to be composed of several
6 different minerals, some of which give off gamma rays.

7 Then that distinction between a formation that doesn't
8 produce a lot of gamma rays and one that does produce a lot of
9 gamma rays is applicable to this diagram, because it shows --

10 Q. Here you're pointing again to PW1.

11 A. I'm pointing to PW1. I'm going to focus all my discussion
12 on PW1 for the time being.

13 Q. Okay.

14 A. And in this diagram, I'm just going to start at the Memphis
15 Sand Cook Mountain sand boundary, and show that the gamma
16 radiation, NGR -- natural gamma ray -- NGR log shows a
17 variation from -- kicks to the right, to the left, right again,
18 left again. And so I'm following with my finger down the water
19 hole, showing the differences and variation of the amplitude of
20 this gamma ray log.

21 Q. So would you convert that the layers of --

22 A. So based on my experience with these kinds of geophysical
23 logs, I would make the generalization that this zone, from
24 right above 300 feet below sea level, is sand.

25 Q. That's basically 250 to 350?

1 A. Okay, if you want that level of specificity, I can provide
2 it. And so I see that minus 250, minus 300 sand.

3 Q. Okay.

4 A. And then I see a clay layer that extends downward probably
5 to about 350 feet. Another small sand, maybe 350, 360,
6 something like that. Another clay layer that would take me
7 down to 400 feet. Below that, another sand layer, maybe 400 to
8 440 feet below land surface, underlain by clay, underlain by
9 now pretty thick-looking sequence of sand, that just happens to
10 be around 500 feet below sea level.

11 And -- but even with, then, this layer of sand that I
12 see from about 500 feet below sea level to nearly 800 feet
13 below sea level, I see indication of gamma emissions that could
14 represent different compositions of the sand, but could also
15 represent clay layers.

16 Q. Okay. And so in terms -- just in general terms, would you
17 describe this as a simple area, in terms of subsurface geology?

18 A. I would describe it as relatively complex. It's not in one
19 homogeneous sand body from top to bottom. It's typified by
20 sand layers and intervening layers of lower permeability. I
21 would know or have a good feel for whether this is -- what type
22 of sand this is and what type of finer-grain material this is
23 if I was paying special attention while we were drilling this
24 hole initially.

25 Q. And all those things go into how much water can be produced

1 from those various -- we'll call them zones?

2 A. Well, yeah, the hydrogeologists would be faced with the
3 wonderful of task of deciding -- well, it could build a well
4 screen, or something like this, or screen in this unit,
5 excluding these finer-grain materials. Or you would want to
6 build a well that has screens set in a few of these sands, and
7 so you might actually do an exploratory program where you
8 design some wells to test these individual zones for yield and
9 water quality.

10 Q. Based on what you know about the geology in this area of
11 the Mississippi/Tennessee border, if you moved from that
12 location, say, to the east or the southeast 200 yards, would
13 you expect to see exactly the same thing?

14 A. Not exactly the same thing. I think there's some
15 generalities. I would think that -- a pervasive and
16 significant sand layer might be able to trace that across some
17 areas, but there would be local variations within even that
18 thicker sand deposit.

19 Even looking at this sight, looking rather at PW1 over
20 to PW -- PW2, all the scales and the geophysical log are not
21 the same. I can see some variations in the composition of the
22 earth materials from this position to this position, over
23 whatever horizontal this distance this is, and I forget,
24 including the horizontal scale.

25 Q. Thank you.

1 But this isn't -- this isn't pure sand down there
2 you're pointing to?

3 A. "Pure sand" meaning sand all one size and nothing else?

4 Q. Or all sand and no clay.

5 A. It's definitely not all sand and no silt or clay.

6 Q. So this is --

7 A. It's sand interlayered by lower permeability or finer-grain
8 materials, in my opinion.

9 Q. Okay. Thank you.

10 Now, on this slide there is another -- is there
11 another feature, geological feature of the clay?

12 A. Well, there are a couple geological features. The one of
13 most interest to me as a field geologist, because I spend a lot
14 of time unpacking these kinds of structures, is the fault
15 that's indicated on the east side of the diagram by the
16 vertical dash-dot-dash-dot line that's located here.

17 And it has the two arrows down and up, which indicate
18 someone -- someone's interpretation of the relative movement
19 along this feature, which is -- and this diagram, classified as
20 a fault. A fault is a line -- is a boundary between parts of
21 the earth that have moved relative to each other.

22 And so the location of the work done in this location
23 is that the top of the Memphis Sand, which is shown here on the
24 left side of this fault, disappears and shows up on -- maybe a
25 little more than 100 feet, just -- about 100 feet higher on the

1 right-hand side of the fault. So the implication is that this
2 block went up on the right, and this block on the left went
3 down.

4 Q. And so would you expect the geology to be somewhat
5 different at the same location below sea level to the right?

6 A. No. It's -- things are going to be different by 100 feet,
7 just based on the fault; and they could be different just based
8 on their lateral change relative to some other location on the
9 diagram.

10 Q. So is the Memphis Sand a simple sand formation?

11 A. Memphis Sand is a complex geological formation, with sand
12 layers and intervening lower-permeability layers, and some
13 relatively thick and very nice sand layers.

14 Q. So I forget what you called test wells. What did you call
15 them? Test wells?

16 A. I call them -- well, that I put a pump in a test well. If
17 I don't put a pump in, I call it a what -- if I put a pump in a
18 well, I call it a test well, or production well. If I don't
19 put a pump in it and just measure things, I call it a
20 monitoring well.

21 Q. So just explain, I guess, briefly: Why do you drill test
22 wells at all?

23 A. In an unknown area, you can drill a test well, and you can
24 learn a tremendous amount about the geological formations at
25 reduced expense and reduced liability. Risk, I might say.

1 Suppose I never drilled in this location at all. I
2 might decide to drill a small-diameter hole and put in a 4- or
3 6-inch diameter casing with screens. Or I might, after running
4 the geophysical log to the core hole, put in a 40-foot screen,
5 and I might just pull it up little bit at a time, testing these
6 different zones in the subsurface.

7 Q. So what kind --

8 A. Or yield.

9 Q. -- of information could you obtain from the test well, as a
10 hydrogeologist planning wellfields or well -- individual wells?

11 A. Other than first I'd be able to interpret -- obtain
12 information about the yield of the individual zones that I've
13 been testing. That is, how many gallons a minute do I think I
14 could get out of it? I would gain valuable information about
15 the quality of the water in the individual zones if I tested
16 them individually.

17 Q. Okay.

18 A. But more importantly, if I employ some really sound aquifer
19 test procedures and analyses, I can begin to determine the
20 hydraulic properties of the aquifer.

21 Q. Okay. And why is it important to know the hydraulic
22 properties of the aquifer at that point, before the well is
23 drilled?

24 A. Well, modern wellfield design has to be based on really
25 detailed knowledge of the hydraulic properties of the aquifer

1 in which you're going to install wellfields.

2 Q. Okay. And when you say "modern," how long has that been
3 around?

4 A. Well, we've known about a lot of these techniques for
5 evaluating the groundwater system, really, since the 1800s.
6 But our knowledge was of a meager kind, and we had a few basic
7 equations like the -- like Darcy's Law and the 10 Equation, but
8 the whole science of hydrology and hydrogeology and aquifer
9 understanding revolutionized in the 1930s, with the advent
10 of -- sorry, with the publication of papers by the US
11 Geological Survey, and a man named CB Tatis in 1939, in which
12 he described the impacts on the groundwater system associated
13 with withdrawal of water.

14 Q. Okay. Let's move to Slide 43. I think we've seen this
15 before, and I just want to ask you a few questions about it.

16 A. I'm ready.

17 Q. Okay. Now, briefly again, we touched on it earlier, what
18 is the potentiometric surface?

19 A. Potentiometric surface is the indication of -- an
20 indication of the pressure in an aquifer at the spot where you
21 measure it. I measured the pressure of this aquifer by tapping
22 the aquifer with a monitoring well that doesn't have a pump. I
23 record the height of the water standing in this well, and
24 relate it to sea level.

25 And so we relate the pressure of the aquifer, the

1 potential of the aquifer, to the height of the water that would
2 rise in a well that taps the aquifer location. If I put a well
3 in the same aquifer in this location, and the water is moving,
4 then by definition the potentiometric value of the terminal
5 will not be the same.

6 Q. So can you map potentiometric pressures in an aquifer
7 system or in --

8 A. We can, and I --

9 Q. -- hydrogeologic --

10 A. We can, and that's a significant thing that hydrogeologists
11 do, is to put monitoring wells into aquifer systems, measure
12 the head in the aquifer system relative to sea level, and then
13 contouring or evaluating the differences in head in the
14 groundwater system. Mainly for the purposes of determining
15 direction of groundwater flow and hydraulic gradient.

16 Q. Okay. So what information can get -- can you get from a
17 pot map in terms of direction of flow?

18 A. Well, I don't use the term "pot map," because it will get
19 you in trouble at the university, so I use the word
20 "potentiometric surface map." I don't know what you're talking
21 about. Little levity here.

22 A pot map is a abbreviation of potentiometric surface
23 map.

24 Q. So potentiometric surface map?

25 A. Potentiometric surface map is a map indicating the

1 variation in the pressure in an aquifer as a function of
2 different positions in the aquifer. And so once you know some
3 of these numbers, by putting in a well, measuring that height
4 relative to sea level, and you have a bunch of those numbers,
5 you can start to contour.

6 Contours are lines of equal pressure. And once you
7 have those contours, you can begin to figure out the direction
8 of groundwater flow in the aquifer as well as the steepness,
9 the inclination of a potentiometric surface.

10 Q. So it will help you determine both the direction of the
11 groundwater at that point in time and the slope?

12 A. And the slope, but it will also give you an incredibly
13 valuable piece of information about how far the potentiometric
14 surface is above the top of the aquifer. And later on, I hope
15 I'll talk about available drawdown.

16 Q. We'll --

17 A. So that number right there, the distance from the
18 potentiometric surface to the top of the aquifer, really also
19 important.

20 Q. Let's look at the next slide.

21 Now, what are you showing in this slide, that's
22 entitled "Cone of Depression"?

23 A. This is a figure from Ralph Heath, shows both the
24 unconfined aquifer system, which I don't want to say anything
25 about, and the confined aquifer system in the right-hand block.

1 And the major point of this discussion would be to get
2 across the idea that once you drill and constructed a well, if
3 you want to get water out of that well, the only way you can do
4 it is by lowering the pressure in that well. Before any
5 pumping is done, the pressure would rise to the height of the
6 potentiometric surface, and is shown as this horizontal line
7 located parallel with the land surface, this particular
8 diagram, and so labeled "Potentiometric Surface," that line.

9 Q. Okay. There's an edge of that potentiometric surface?

10 A. There's a what?

11 Q. Seems like there's an edge on the surface; I mean, is that
12 curved line? What does that reflect?

13 A. So when you put a pump in the well, and geologists always
14 indicate "cubed," which indicates we are taking water out at
15 some number of gallons per minute; that's the flow rate. So
16 when you're taking water out of this well, this water level is
17 going to fall. When the water level falls, the pressure in the
18 aquifer in the vicinity of the well decreases, and that causes
19 water to flow towards the well.

20 And so there are lots of important things about this
21 diagram. One is, Ralph developed a tendency early on in his
22 writing that he could show a circle to represent a molecule of
23 water. And so all he's showing here is that a molecule of
24 water will flow towards the well from this side of the well,
25 this side, and actually it will flow radiantly toward the well

1 in this case.

2 And so when you remove water from a well, the pressure
3 in the aquifer next to the well decreases, and that pressure
4 propagates -- pressure decline propagates outward.

5 Q. And that's a confined aquifer?

6 A. This is a confined aquifer.

7 And the net result is a lowering of the potentiometric
8 surface, in this case well above the top of the aquifer. And
9 it has the shape of a cone.

10 You really can't see it here so much, but you can
11 imagine this thing is a three -- as a three-dimensional
12 theoretical feature, and it's cone-shaped; it's roughly
13 circular in this case, centered on the well. And it represents
14 a lowering of the pressure in the vicinity of the well. And
15 hydrologists call it the cone of depression, but it's the cone
16 of depression in the potentiometric surface. Groundwater flows
17 in the direction of decreasing total pressure.

18 So look, the pressure here now, which was at the
19 original and potential surface, is lower, but the pressure here
20 is even lower. So groundwater flows in the direction of
21 decreasing pressure; it must flow from right to left towards
22 the well.

23 The opposite is true over here. The pressure here is
24 high -- I'm talking about the left-hand side of this diagram --
25 and the pressure here is lower. So groundwater will flow in

1 the direction of decreasing pressure towards the well.

2 Q. Okay. So the well is creating negative pressure in the
3 area of the pumping?

4 A. It's reducing the pressure.

5 Q. Okay. The pulling down of pressure, and it's pulling that
6 water out of the confined aquifer?

7 A. Right. But the flow is not like here; the flow is down
8 here, in the confined aquifer. But the pressure surface, which
9 you really can't see unless you put in the well, is above the
10 aquifer.

11 Q. But why isn't the water coming out of the confined aquifer?
12 I don't see any water coming out of that -- the aquifer; I just
13 see the dotted lines involved.

14 A. The water is flowing in this direction in response to
15 pumping, entering the well and going up to the pump. And the
16 pump is stabilizing the water level here for a time, and
17 probably increasing with increasing pumping time. So water is
18 coming out of the confined aquifer and leaving the well.

19 Q. What does "drawdown" mean?

20 A. "Drawdown" is a hypogeological term used specifically and
21 often to hydrologists to represent the difference in pressures
22 at different distances, specified distances and specified
23 times.

24 For example, if I've just pumped this well at
25 300 gallons a minute for four hours at a distance of 12 feet

1 from this well, I could measure the difference between the
2 original potentiometric surface and the potentiometric surface
3 that the cone can calculate that in feet. And I might say,
4 "Well, the potentiometric surface has been lowered at that
5 distance, at that pumping rate, at that time, by four feet."

6 Q. Okay.

7 A. That's called drawdown. Drawdown in a cone of depression
8 is greater near the well and less further and further from the
9 well.

10 Q. Okay. So the change in pressure created by the pumping of
11 the well is pulling water in from all directions toward the
12 well?

13 A. Yes, in the confined aquifer.

14 Q. In the confined aquifer.

15 A. Yeah.

16 Q. Now, what is total available drawdown?

17 A. Total available drawdown is a very important hydrological
18 concept that says measure the pressure surface relative to the
19 top of the aquifer --

20 Q. Okay.

21 A. -- and convert that number to feet.

22 For example, if sea level is here, and the
23 potentiometric surface is above sea level, and the top of the
24 aquifer is 60 feet above sea level, 100 minus 60, there would
25 be 40 feet of total available drawdown. Total available

1 drawdown is simply the distance from the potentiometric surface
2 to the top of the aquifer.

3 Q. How does it affect the amount of water you can pump out of
4 a well?

5 A. That's a really great but complicated question. And in the
6 great Tar Heel state, we're not allowed to pump water level
7 over the top of our aquifer. So if we use that as an example,
8 if I put a pump in this well and I continue to pump the water
9 level down, I'm going to be limited in terms of how much I can
10 pump the water level down in my state to the top of the
11 aquifer.

12 So if I know how many feet that is, if it's 40 feet or
13 100 feet, it's some number, I know how much I can lower the
14 water level in my well. And I'm going to assume the water
15 level is going to be lowest in my well, unless depressed
16 outside the well.

17 So then I'm going to calculate something called the
18 specific capacity of the well; that's how much water you can
19 get out of a well at a given flow rate, relative to the
20 drawdown at a specific time and specific distance.

21 I know it's a lot.

22 Q. Okay. But let's just pause for a second, and we'll come
23 back to this, maybe.

24 Within that cone of depression, if I drop another
25 well, can I recover as much water as I could before this well

1 was put in?

2 A. No.

3 Q. Why?

4 A. You reduce the total available drawdown. So you're saying
5 if I put -- would have put in a well right here, at the
6 location of this level arrow --

7 Q. Yes, sir.

8 A. -- the total available drawdown at this location, if I put
9 in another well within the cone of depression, that's been
10 reduced by the difference between the original potentiometric
11 surface and the position of the cone of depression at that
12 distance.

13 Q. Okay. And so dropping the pressure down to the confined
14 aquifer within the area of the cone of depression of that well,
15 I have reduced the amount of water someone else could pump out
16 of it?

17 A. The maximum amount they could pump out.

18 Q. Okay. Thank you.

19 A. Yep.

20 THE COURT: I think we'll stop for a short recess.
21 We'll have a ten-minute recess.

22 (Recess)

23 THE COURT: You may proceed with your witness.

24 BY MR. ELLINGBURG:

25 Q. Are you ready, Dr. Spruill?

1 A. Yes.

2 Q. Oh, okay.

3 Dr. Spruill, earlier we talked about how you
4 determined the direction of groundwater flow at an unconfined
5 aquifer at some point. And I don't want to revisit that. But
6 it looked like I forgot to ask you about how you determine the
7 flow on direction of groundwater in a confined aquifer, and if
8 that's different than an unconfined aquifer.

9 A. In a confined aquifer, if you want to determine the
10 direction of groundwater flow, you need at least three wells,
11 in my opinion, that do not have pumps in them, called hydro
12 wells, in which you measure the elevation of the water in the
13 monitoring wells and then the head, and then you can start to
14 get a feel for direction of groundwater flow. That gives you a
15 general understanding of which way groundwater is flowing.

16 If you want to determine the direction of groundwater
17 flow with any reasonable degree of accuracy, it requires a
18 fairly large number of monitoring wells, or a monitoring well
19 network, such that you can measure the head at each of those
20 wells and the pressure at each one of those wells, and then use
21 those data to determine direction of groundwater flow.

22 Q. So what influences the direction of groundwater flow in a
23 confined aquifer?

24 A. A lot of different things. The inclination of the aquifer,
25 its dip, relationship between recharge areas and discharge

1 areas would be two of the key factors. The amount of recharge
2 that you get into the aquifer within control flow through the
3 aquifer, and under nonpumping conditions you can establish a
4 state of equilibrium in which water flows from the recharge
5 areas to the discharge areas, say, at an inclined aquifer
6 system.

7 So those would be some of the factors that would
8 control the direction of flow.

9 Q. Can you -- have you developed an opinion, based on
10 everything you studied, of the flow direction of the
11 groundwater in a confined portion of the Mississippi aquifer
12 system before it was ever pumped?

13 A. The Mississippi Embayment Aquifer System?

14 Q. Yes, within the State of Mississippi.

15 A. I would have to describe it in the general terms indicated
16 on an earlier illustration for the entire Embayment; that
17 basically water flows from the outcrop areas to the east, with
18 a generally westward groundwater flow pattern, increasing
19 downward into the aquifer before the -- before there's a
20 transition from downward movement to upward movement towards
21 recharge areas to the west, or even to the south.

22 Q. And within that confined portion of the aquifer system
23 within the State of Mississippi, I think you've given us some
24 estimates of how long it takes the groundwater to move?

25 A. Yeah. I've indicated several times that groundwater moves

1 really, really slowly, and its long path from recharge to
2 discharge areas could be -- could literally be thousands or
3 tens of thousands of years.

4 Q. Okay. And so that would be true without regard to which
5 direction that water was flowing, wouldn't it; that it would be
6 under natural conditions, that it would take many, many years
7 to cover short distances? Is that correct?

8 A. Correct.

9 Q. Thank you.

10 Now, you said that -- you talked about a discharge
11 area. Does the water in the confined aquifer under -- or did
12 the water in the confined aquifer under natural conditions
13 ultimately discharge from the State of Mississippi?

14 A. Yes. Water that knows the aquifer -- hydrologists are fond
15 of saying what goes down must come up; water that goes down
16 into these inclined aquifers eventually discharges from those
17 aquifers. Some discharge location could be a creek or river.
18 It could ultimately be an area near the ocean.

19 Q. With regard to substantially all of the water in the State
20 of Mississippi in the confined aquifer, when it enters -- does
21 the water under natural conditions -- strike that. Let's start
22 over.

23 Under natural conditions, when we talk about
24 equilibrium, what are you talking about?

25 A. Oh, an interesting concept of a balance in the groundwater

1 system. Geologists would say that when a groundwater system is
2 in steady state, that the amount of water entering the
3 groundwater system is balanced by the amount of water exiting
4 the groundwater system. So the equipotential surface remains
5 relatively constant through time.

6 So that doesn't mean that you can't have an increase
7 in wet periods and a decrease in dry periods. But effectively,
8 a nonpump groundwater system, disregarding any major changes in
9 precipitation from time, will be in balance, and we say that
10 the recharge is balanced by the discharge, so the equipotential
11 surface of the water table would remain relatively constant
12 through time.

13 Q. So absent, in the State of Mississippi, or absent pumping,
14 the groundwater in the confined aquifers in the State of
15 Mississippi and Northwest Mississippi would remain as an
16 essentially constant amount of groundwater, varying with, as
17 you said, the weather and all; but if you looked at the
18 pressures in the confined aquifer, they would not be changing
19 material over time. Is that correct?

20 MR. BRANSON: Your Honor, objection. We've tried to
21 be very spare with our objections today, but he's leading the
22 witness with these types of questions, and we'd ask for a more
23 open-ended question.

24 THE COURT: (Inaudible)

25 (Reporter interruption)

1 MR. ELLINGBURG: The judge instructed me not to lead
2 him; is that right?

3 THE COURT: We of course know we're not before a jury,
4 so it's not so bad. But when that objection is made, let's try
5 to obey it.

6 MR. ELLINGBURG: I understand. And thank you.

7 BY MR. ELLINGBURG:

8 Q. I'm trying to understand what you see below the surface in
9 the groundwater system before any pumping was taking place
10 within the State of Mississippi. And could you try to make
11 that clear for me, because I'm not -- obviously not learned in
12 all this.

13 A. If you had a -- an aquifer, and it was at equilibrium, so
14 that the amount of water entering the aquifer is about the
15 amount of water leaving the aquifer, and on any given day that
16 aquifer had a billion gallons of water in its pore spaces, you
17 would say that enough water would have to enter the aquifer and
18 exit the aquifer on a daily, monthly, yearly basis to maintain
19 that constant volume of water within the aquifer.

20 Q. And with regard to the specific confined aquifer system in
21 North Mississippi, would you expect over the last several
22 hundred years for that volume or that level of potentiometric
23 surface to change materially, absent pumping?

24 A. Absent pumping? No.

25 Q. And why is that?

1 A. Well, absent pumping, a groundwater system would -- in the
2 absence of significant climate change, like changes in
3 precipitation -- be in a balance, where the amount of water
4 entering the aquifer is balanced by the amount of water exiting
5 the aquifer. We would say discharge is balanced by recharge,
6 and we would have a relatively constant volume of water in the
7 aquifer as the water slowly moves from the recharge areas
8 through the confined aquifer to the discharge areas.

9 Q. And again, you're defining "slowly" in terms of what?

10 A. I'm always defining "slowly" in terms of groundwater
11 velocities, which are measured in inches or fractions of a
12 foot --

13 Q. Which converts to thousands?

14 A. -- a day.

15 Thousands of years of travel time.

16 Q. Okay.

17 A. Right.

18 Q. But the water -- but the system is, unless someone
19 intercepts that water that would otherwise be discharged; then
20 that water is going to remain in that system?

21 A. Right.

22 Q. Thank you.

23 Or at least that volume of water, because the specific
24 molecules are turning over in this process?

25 A. That's the point. It's not the same molecules of water;

1 it's the same number of molecules of water.

2 Q. Thank you.

3 Now, before pumping, is there another groundwater
4 formation in Mississippi to which the confined aquifer would
5 discharge water?

6 A. I'm sorry, I didn't understand that question.

7 Q. I said is there another aquifer system that a -- above the
8 confined aquifer involved in this case to which that natural
9 discharge would go before it was ever pumped?

10 A. If we're talking about the Memphis Aquifer and the Sparta
11 Aquifer of the Middle Claiborne hydrologic unit --

12 Q. Yes.

13 A. -- it's overlain by confining layers and other potential
14 aquifers that would receive water by upward movement in
15 discharge areas in response to those head gradients, so water
16 can flow out of the confined aquifer upward, across confining
17 layers and other aquifers, before it's ultimately discharged.

18 Q. Okay. What aquifers overlie the area near the Mississippi
19 River in the State of Mississippi that would ultimately receive
20 groundwater that was being discharged, if it were not
21 intercepted, and that are commonly used?

22 A. In Tennessee or Mississippi?

23 Q. In Mississippi.

24 A. In Mississippi, on top of the Sparta Sand Aquifer, there is
25 the Middle Claiborne confining unit, and its geological

1 formation is the Cook Mountain Formation, and it's considered
2 to be a confining unit. Above that in Mississippi is a
3 relatively thin aquifer called the Upper Claiborne Aquifer.
4 And its geological formation is called a Cockfield Formation.
5 And then there's the Jackson Formation and the Vicksburg
6 Formation, both of which are considered confining layers.

7 And on top of that, in some places there is a
8 relatively young sedimentary sequence called alluvium, that's
9 really related to more recent geological times and association
10 with deposition relative to Mississippi -- the Mississippi
11 River system and its changing position through time.

12 Q. Is that the Mississippi Alluvial Aquifer?

13 A. It's called the Mississippi River Valley Alluvial Aquifer,
14 in terms of the hydrogeologic unit. And the geological
15 formation would be called alluvium terrace and deposits.

16 Q. Thank you. So before pumping this water we're talking
17 about, that had moved through the thousands of years and was
18 ultimately discharged, was some of it going into that alluvial
19 aquifer?

20 A. I believe that it is.

21 Q. Okay.

22 A. The geological reports that I've seen show some discharge
23 upward across confining layers and into the Mississippi
24 Alluvial Aquifer and in tributaries and into Mississippi.

25 Q. Thank you.

1 Now I'm going to move back to the cone of depression.
2 And my question here is whether the -- the radial extent away
3 from the well and the cone, can that radial extent be
4 reasonably estimated or calculated?

5 A. Yes. It can be kind of generalized. For example, at a
6 given pumping rate, the cone of depression in an unconfined
7 aquifer will generally be not as large radially as that in a
8 confined aquifer, and you can sort of generalize depths of the
9 cone of depression in that way. But the best way to determine
10 the configuration, size, and shape of the cone of depression is
11 from either determining directly, by having an adequate number
12 of observation wells near a production well, and/or calculate
13 it using modern equations.

14 Q. Okay. And the calculations are dependent on the -- on the
15 amount of information you have, and they are a kind of a
16 homogenization of everything within the cone, I would think?

17 A. I'm not sure what you mean, but you can't calculate the
18 size and shape of the cone of depression unless you know the
19 hydraulic properties of the aquifer in the vicinity of the well
20 that you're talking about, or the aquifer that you're talking
21 about.

22 Q. But if you know those hydraulic properties and that cone of
23 depression and the size of it, the reach, if you will, from the
24 well out are you able -- could that be reasonably calculated?

25 A. Oh, yes.

1 Q. Now, how do you do that?

2 A. I'm not sure what your question is. Do you mean how do you
3 get the answer to the question of what are the hydraulic
4 properties, or how do you calculate it once you know them? The
5 hydraulic properties.

6 Q. I think you said you have to determine the hydraulic
7 properties, so I guess, how do you determine the hydraulic
8 properties?

9 A. Okay. My opinion is that you can look at a geological
10 material and estimate its hydraulic property, at least one of
11 them; that's called permeability. But the way that hydraulic
12 properties of aquifers are determined are from modern tests
13 that we call aquifer tests. Aquifer tests involve putting in a
14 production well and removing water from that well at constant
15 rate, and measuring the rate of decline of water level in that
16 well, and knowing the rate of decline and the pumping rate.

17 You can calculate one of the important hydraulic
18 properties, called transmissivity, in the aquifer. But
19 transmissivity of an aquifer can be calculated directly and
20 determined directly from a test in a single well, single
21 production well; but if you really want to determine the nature
22 and extent of the cone of depression, you also have to
23 determine something called storage coefficient.

24 Storage coefficient cannot be determined from a single
25 well test. In other words, you can't put in a production well

1 like the one I'm pointing to, of this diagram on page 44, and
2 test it at constant rate and determine storage coefficient.
3 Instead, you have to have that well, and another one that will
4 be in the cone of depression, that's used to monitor the rate
5 of decline of water level in that well in response to a
6 constant rate withdrawal of water from that production well.

7 So we need a production well, and a monitoring well
8 nearby. And from those data we can calculate storage
9 coefficients. Armed with transmissivity and storage
10 coefficient, we can calculate the theoretical limit of the cone
11 of depression, and you can tell me how long you want to pump
12 that water; in other words, if you want to pump it for one day
13 or one year, I need to know that before I can calculate how big
14 the cone of depression is.

15 Q. What is permeability?

16 A. Permeability is a term that geologists use generally, but
17 prefer a better term, called hydraulic conductivity. But I'll
18 just use the word "permeability."

19 Permeability, or hydraulic conductivity, is the -- is
20 a measure of the ability of a naturally occurring material in
21 this case to transmit water. It's a measure of the ease with
22 which that material transmits water.

23 Q. Do different materials have different permeabilities?

24 A. One of the things that fascinates me most about hydraulics
25 is that permeability of naturally occurring materials varies

1 over 12 orders of magnitude. I find nothing else in nature
2 that has that much variability as a single concept.

3 Hydraulic conductivity, as shown in this slide.

4 Q. Now, you just put a slide that's titled "Igneous and
5 Metamorphic Rocks"?

6 A. No, that's not the title. That's a category within the
7 body of the feature. This is a figure from --

8 Q. No surprise: Ralph?

9 A. And it shows different rock types and different sediment
10 types as a function of a quantified permeability, a measure of
11 permeability.

12 So I can give you a couple of examples.

13 Q. Okay.

14 A. On this axis, there are different ways that geologists deal
15 with these units. They're units of metric meters per day,
16 they're units of standard unit speed per day, and they're old
17 units by the US Geologic Survey, gallons per day per foot
18 squared.

19 I'm just going to focus on units of feet per day --
20 and by the way, it's not velocity; it looks like it, but it's
21 not.

22 The ability or the ease with which water flows through
23 naturally occurring materials is defined with a number, and
24 that number has units of feet per day; but it's really a volume
25 of water that can be transmitted through this material under

1 certain conditions. And they give you an indication of that, a
2 material that we call clay, and we all remember is less than
3 $1/256$ of a millimeter, has a permeability on average of 10 to
4 the -6 and 10 to the -7 cubic feet of water that can pass
5 through --

6 (Reporter interruption)

7 A. I'm a simple guy; it's a measure of the volume of water
8 that can be transmitted through the material. One times 10 to
9 the -7 cubic feet of water is a thimbleful of water. It's not
10 much water at all; you can hold it in the palm of your hand.

11 So that's one times 10 to the -7 cubic feet of water
12 would be transmitted by a clay. If you take the same amount of
13 earth material and make it a lean sand, or coarse sand, meaning
14 all the particles are about the same size, 10 -squared cubic
15 feet of water would pass through that same area of the
16 material.

17 So sand has a permeability one, two, three, four,
18 five, six, seven, eight -- nine orders of magnitude higher; it
19 has nine orders of magnitude greater ease of transmission of
20 water than clay. Clay, then, doesn't easily allow water to be
21 transmitted through it. But it's not impermeable; it's just
22 very restrictive.

23 And so this is the concept of permeability, the
24 ability of a naturally occurring material in this case to
25 transmit water.

1 Q. So what is storage coefficient? You mentioned that
2 earlier.

3 A. Storage coefficient is the thing that separates
4 hydrogeologists from wannabes. Storage coefficient is the most
5 difficult concept that you can possibly imagine, because in
6 confined -- can we go back one slide?

7 In confined aquifers, when we take water out of these
8 pore spaces and the water flows to the well, the pore spaces
9 are still completely filled with water. When we take water out
10 of a confined aquifer, the pore spaces are still completely
11 filled with water. Which is absolutely fascinating to me.

12 And so what we've learned is that the water in these
13 confined aquifers is under pressure; and in a given volume,
14 then, in the aquifers, in a given volume there's more molecules
15 of water, because the water is slightly compressible; just like
16 air is compressible, water is slightly compressible.

17 So in the pore spaces down there, we can put a bunch
18 of extra molecules. And when we lower the pressure, the water
19 expands. We can take a few of those extra molecules out.

20 I would give the analogy of a car tire, a car tire
21 that has 15 pounds per square inch of air in it, thus its
22 pressure is filled with air. You can put some more air in that
23 car tire, and it's still filled with air, and you can jack the
24 pressure up to 30PSI. How do you do that? You just compress
25 the molecules a little bit. But if you'll recall, when you put

1 more molecules in a tire, the tire gets a little bit bigger.

2 So in an aquifer --

3 Q. A confined aquifer?

4 A. In a confined aquifer, the water is under pressure. And
5 that pressure allows more water molecules to be in a given
6 volume, but it also pushes the grains a little bit apart, and
7 now there's more space for those water molecules.

8 So it wasn't recognized until the 19- -- late '20s and
9 1930s in this country that aquifers are elastic and that water
10 is slightly compressible, and that you can put more into an
11 aquifer and take water out of a confined aquifer and it will
12 still be filled with water. You can put some molecules of
13 water already in a confined aquifer. It's full of water; just
14 put some more in it. You can do that by compressing the water
15 and moving the grains apart just a little bit.

16 So in answer to your question, I'm sorry, we have come
17 to understand that storage coefficients for an aquifer is a
18 number. It is the volume of water that you can put into the
19 pore spaces or take out of the pore spaces for a given volume
20 of the aquifer per foot of head change. If you want to take
21 water out of the pore spaces, lower the head. If you want to
22 put water in the pore spaces, increase the head.

23 We put water in the confined aquifers all the time
24 that are already filled with water, and we just pack them full
25 of molecules of water.

1 Q. Okay. So was that the area of the cone of depression, even
2 though if you looked at it, it's still filled with water, there
3 is in fact less water than there was before? Is that correct?

4 A. Absolutely true. There's less water within the cone of
5 depression and those pore spaces than there was before the cone
6 of depression generated, but the pore spaces are still filled
7 with water.

8 Q. Right. And is that why the total available drawdown you
9 described earlier is less; you can produce less water than you
10 could have outside the cone of depression within the cone of
11 depression?

12 A. In effect, yes.

13 Q. Okay. Sir, can you -- to determine the size of the cone of
14 depression, do you need a storage coefficient?

15 A. My opinion is that if you want to determine the size of the
16 cone of depression at a specified time, you have to have the
17 storage coefficient. There are older equations that say, "I
18 can tell you what the size of the cone of depression is going
19 to be way out in the future, when everything is stabilized."
20 But if you ask me, how big is the cone of depression after one
21 day or ten days or a year, you have to have the storage
22 coefficient.

23 Q. Okay. And do you need actual pumping information?

24 A. You need information from aquifer tests that accurately
25 give that storage coefficient for the region in the vicinity of

1 the well.

2 Q. Thank you.

3 Okay. I'm going to show you another document which,
4 on the bottom, indicates that it is taken from --

5 A. This one up here? Oh.

6 Q. At the bottom it says "Distance from center of pumping in
7 Lichterman wellfield in feet."

8 No, that's not the next one? Going back. I missed
9 one. Okay.

10 This one says "Wellfield design." Could you explain
11 this to me, and how you use it, and what it's used for.

12 A. Yes, sir. This is another figure from Heath, and -- who
13 would have thunk it? Living with this figure, because this is
14 the basic tool that you use to design wellfields; that is, the
15 areas composed of one or more wells.

16 And so what you would do in this case is actually use
17 the value of transmissivity for an aquifer and storage
18 coefficient for an aquifer. And if I said to you, "Well, I'm
19 going to tell you the size of the cone of depression after a
20 time of 365 days," I could calculate, using a real simple
21 equation, this number.

22 And this number, which I've called R-subzero, or
23 radical R-subzero, is 90,600 feet. And so if I pump an aquifer
24 whose hydraulic properties are 5,000 feet square per day for
25 transmissivity, and 5 times 10 to the -4 per storage

1 coefficient, for one continuous year, the cone of depression
2 would extend outward at a homogeneous and isotropic acclimate
3 to 90,600 feet.

4 And so that's the first aspect of this design, is that
5 the calculation is done to get that number, which I then apply
6 here at 90,000 feet.

7 Q. Okay. And so --

8 A. 90,000 feet is about 19 or -- 19 to 20 miles.

9 Q. So that shows the distance of the cone from the well or the
10 wellfields?

11 A. Yeah, so -- yes. It would say if I put a well at this
12 location, or at any location, the distance to the place where
13 there would be no impact, theoretically, would be 90,600 feet,
14 equal to R_{subzero} .

15 Q. And that's under stated specific properties?

16 A. Yeah, you change these numbers and change this time, you
17 change that value.

18 Q. So all those things -- so it all depends on the specific
19 geology within the area of the cone?

20 A. Depends on the hydraulic properties in the vicinity of the
21 cone.

22 Q. And how did you say you can determine those?

23 A. You put in a production well with an observation well. You
24 have to have that observation well. Pump that well probably
25 for 24 hours, and the presence of that observation well,

1 measure the rate of decline. Use the Tatis -- T-A-T-I-S --
2 nonequilibrium procedures developed in the 1930s to calculate T
3 and S for any time -- sorry, to calculate T and S, and then you
4 use modifications of that equation to calculate R-subzero.

5 Q. Okay. Thank you.

6 Now I'll ask you to go to the next slide. So could
7 you explain to the Court what this slide shows.

8 A. This is another of those plots, and I'm sorry, on the
9 previous plot I failed to point out that this scale is a
10 logarithmic scale.

11 So here is a graph showing distance from the center of
12 a pumping well -- this happens to be in the Lichterman
13 wellfield -- in feet. So it says, okay, if you're 1,000 feet
14 away from a pumping well, or 10,000 feet or 100,000 feet away
15 from a well, and that well is pumping, how big would the cone
16 of depression be?

17 And so we've said so far that the theoretical size of
18 the cone of depression, its radius or diameter is a function of
19 transmissivity, storage coefficient, and time. But the cone of
20 depression has another dimension, and that's its depth. How
21 much drawdown do you have in the well, or in the aquifer next
22 to the well? And that is a function of the pumping rate in
23 gallons per minute.

24 And so here's an example from the literature report
25 back from the 1960s on the well that was pumped that

1 Lichterman -- or some theory about it, that says that if you
2 pump a well at 6,000 gallons a minute, which is a really high
3 pumping rate, the cone of depression, the drawdown will extend
4 outward to about 100,000 feet. And at a distance of about --
5 1,000, 2,000 -- at a distance of 3,000 feet, you'd have about
6 22 feet of drawdown.

7 The cone of depression would extend outward to
8 100,000 feet, and this is the amount of drawdown you would have
9 at the 2,000 feet; but if you increase the pumping rate to
10 14,000 gallons per minute from 6,000 gallons per minute, it
11 doesn't influence the theoretical limit of the cone of
12 depression. It causes more drawdown at the well and
13 immediately adjacent to the well.

14 So at 1,000, 2,000, 3,000 feet, instead of having
15 22 feet of drawdown at 6,000 gallons a minute, at the same
16 distance, 2,000 feet, you would have 55 feet of drawdown.

17 So the cone of depression size is independent of the
18 pumping rate. The depth is a function of the pumping rate.

19 Q. Now, I think earlier you testified what transmissivity was;
20 is that correct?

21 A. We didn't say much about it. I used the term but didn't
22 talk about it very much, so I talked about the term
23 "permeability" or "hydraulic conductivity."

24 And that's a really great term, but it indicates how
25 much water would flow through a small cross-sectional area of

1 an aquifer. So hydrologists found it more convenient to say,
2 "Well, let's just multiply the permeability." That's that
3 thing that varies over 12 orders of magnitude by the thickness
4 of the aquifer.

5 So transmissivity is equal to hydraulic conductivity
6 or permeability times aquifer thickness. In hydrology, we
7 say -- and I think my students memorized -- TKB, T is
8 transmissivity, K --

9 (Reporter interruption)

10 A. K, hydraulic conductivity, times B, aquifer thickness.

11 So you imagine how much water would flow through a
12 little cross-sectional area by how many cross-sectional areas
13 there are. That's the thickness of the aquifer. It's a better
14 measure of the ability of the aquifer to transmit water than is
15 just permeability.

16 Q. Based on that, is the Sparta Sand in Mississippi either
17 more or less transmissive than Memphis Sand is?

18 A. If you assume equal permeability in the Memphis Sand and
19 the Sparta Sand, because the Sparta Sand is thinner, it by
20 definition has a lower transmissivity. My studies show that
21 from the literature, that there's also a difference in
22 permeability in some parts of the Sparta and Memphis Sands. So
23 the Memphis Sand generally has a higher trans -- sorry, higher
24 permeability than does the Sparta Sand.

25 So if you combine those two factors for the Sparta

1 Sand -- reduced thickness, reduced permeability -- it has a
2 lower transmissivity than the Memphis Sand.

3 Q. Thank you.

4 And I think you said that as you increased pumping
5 rates, the -- what happens isn't so much the extent of the cone
6 as it is the amount of total available drawdown reduction; is
7 that correct?

8 A. The theoretical limit of the cone of depression, its
9 diameter, independent of the pumping rate. It's a function of
10 transmissivity, storage coefficient, and how long you've been
11 pumping.

12 Q. And it's 19 or 20 miles, generally?

13 A. For a lot of confined aquifers, that's a good starting
14 number, yeah, 90,000 at the end of a year of pumping.

15 Q. Okay. Thank you.

16 So what is a wellfield?

17 A. A wellfield is one or more wells drilled for the purpose of
18 supplying water demands of some organization -- individuals or
19 organization. So it is in effect one or more wells.

20 Q. So what is wellfield design?

21 A. Well, wellfield design, as I envisioned it, is a -- is a
22 process of learning everything you can about an aquifer: Its
23 depth, its thickness, its permeability, its storage
24 coefficient; all those properties. Its water chemistry.

25 And armed with that information about its hydraulic

1 properties, it's designing one or more wells that will
2 collectively produce the volume of water needed by the client,
3 while minimizing the impact to the groundwater system or the
4 impact to adjacent property owners.

5 Q. Okay. Are those impacts something that you always factor
6 into your wellfield designs?

7 A. I certainly -- I certainly try. It's a fundamental part of
8 wellfield design, as I learned from Ralph Heath.

9 Q. Is the creation of the cone of depression something you
10 take into account when you are engaged in wellfield design?

11 A. You have to understand the size and depth of the cone of
12 depression to do an adequate job of wellfield design. And
13 that's because when you drill one or more wells, if one well
14 happens to be within the cone of depression of the other, you
15 have to factor in well interference.

16 Q. So we've put up another slide. Does this slide address the
17 issue of cone -- or well interference?

18 A. Yes, it does.

19 Q. And could you tell us what it shows.

20 A. This slide from Ralph Heath is designed to illustrate the
21 concept of well interference in its simplest form. So this
22 upper slide, the slide is divided into two parts: An upper
23 sequence and a lower sequence. And in the upper sequence,
24 we're showing a confined aquifer in blue, with arrows in it.
25 And the arrows in the confined aquifer are pointing towards

1 Well A, indicated here, and a little bit of water shown coming
2 out of it, so it's pumping.

3 Q. And this slide is titled "Well Interference"?

4 A. "Well Interference."

5 And so the concept here is that if you pump Well A at
6 some rate, it will generate a cone of depression illustrated by
7 the words "Cone of Depression with Well A Pumping." And so it
8 will generate a cone of depression that looks like this, and
9 the cone of depression will extend out to here. I'm showing
10 out to the right, under the words "Static Potentiometric
11 Surface."

12 And water will flow in the aquifer rate leading by the
13 water standing and the aquifer materials contracting. And
14 we're taking the water out of the aquifer, but the pore spaces
15 are filled.

16 And so imagine that you turn on Well B, Well B, and
17 Well A was not on. Well B, if this aquifer is the same across
18 this area, Well B would create a cone of depression that is
19 identical, if you use the same pumping rate and pump it the
20 same amount of time. And so the cone of depression, if Well B
21 were pumping and Well A were idle, is the dash line.

22 What's critical about wellfield design is this: If
23 you go to put two wells, one within the cone of depression of
24 the other, you have to know how much drawdown is going to occur
25 at each of these wells caused by each of the other wells.

1 I can illustrate that in this real simple way: Well A
2 pumping causes that much drawdown -- I'm indicating the
3 distance between the potentiometric surface and the
4 potentiometric surface for Well A.

5 Well B pumping causes the same amount of drawdown as
6 Well A. Halfway between the two wells, Well A causes a
7 substantial amount of drawdown; Well B causes the same amount
8 of drawdown. And so the resultant -- we call it the resultant,
9 the combination of those drawdowns, is shown in the second
10 diagram.

11 And so instead of just having this pumping water level
12 in this well, I've got to add the additional drawdown in Well A
13 caused by pumping at Well B. And so the drawdown will be
14 lower. And it's designed to show that in this second or bottom
15 sketch, that Well A, the drawdown is lower in that well --
16 greater in that well than it is in Well A pumping alone.

17 Q. Go ahead. Is there anything you can do to minimize the
18 radial extent and the depth of a well's cone of depression?

19 A. As a factor in wellfield designs, or --

20 Q. Yes, we're still on wellfield design.

21 A. Okay. So the closer you put these wells together, the
22 closer the spacing of these two wells in this theoretical
23 wellfield design, the greater the drawdown that is caused at
24 each well.

25 So if you want to minimize the depth of the cone of

1 depression, one of the things you can do is move the wells
2 further apart. By moving the wells further apart, you minimize
3 the amount of drawdown in each well. That doesn't minimize the
4 size of the cone of depression; it minimizes the depth of the
5 cone of depression.

6 So that's one thing you can do. So you're asking,
7 what can you do to minimize the cone of depression?

8 Q. The extent and the depth.

9 A. Okay. Minimizing the extent of the cone of depression is
10 different from minimizing the depth of the cone of depression.
11 So if you'll allow, I'll just take them one at a time.

12 If you want to minimize the extent of the cone of
13 depression -- that is, R_{subzero} ; how far it extends out from
14 the well -- pump the well for a shorter time period. You can't
15 change the transmissivity or storage coefficient of the
16 aquifer, but you can reduce the pumping time. How big the cone
17 of depression is is a function of T and S of the aquifer and
18 how long you pump it. The longer you pump it, the bigger it
19 gets. Reduce the pumping time, you reduce dramatically the
20 theoretical limit of the cone of depression, or its radius.

21 If you want to reduce the depth of the cone of
22 depression, or the drawdown that you have in these individual
23 wells and the aquifer in the vicinity of the wells, then there
24 are lots of things that you can do. You can move the wells
25 further apart. You can pump the wells at a lower pumping rate,

1 measured in gallons per minute. You can alternate the wells,
2 so that one's pumping for a while, and then you turn it off and
3 let the other one pump.

4 Those are some of the key things that you can do to
5 minimize the nature and extent, the size and the depth of the
6 cone of depression.

7 Q. In an aquifer system, or a hydrogeologic system, where you
8 have multiple formations, can you do anything to reduce the
9 size or the depth of the cone of depression?

10 A. I'm not sure what you're asking. But if you have at your
11 disposal more than one aquifer, or more than one permeable zone
12 in an aquifer, you can minimize the size and the shape of the
13 cone of depression by developing some of your wells in
14 different parts of that aquifer, or wells in different
15 aquifers. And that would certainly minimize the cone of
16 depression, compared to putting two wells, one inside the cone
17 of depression of the other.

18 Q. Now, once the cone of depression has been created, is it
19 possible to shrink it?

20 A. Yes, it is.

21 Q. Why is that?

22 A. Because of the natural recharge of aquifers. So if the
23 operation of a well is such that a cone of depression has been
24 generated, and the aquifer hasn't been harmed -- that is, it
25 hasn't been pumped so hard that the grains of sand, for

1 example, can't -- can't be pushed apart again; that is, if it's
2 compressed by too much pumping over a long period of time --
3 unless that's happened, when you stop pumping, the rate of
4 water level recovery, the rate at which the pressure will
5 return, is a sort of reversed image of the rate at which it
6 declined, associated with the onset of pumping.

7 And so the cone of depression will recover itself in
8 an amount of time more or less equal to the amount of time it
9 took to develop that cone by pumping.

10 Q. Do you have any specific examples where this has been done
11 that you were directly involved in?

12 A. The best example I would give, and the one I'm most proud
13 of is the Central Coastal Plain of North Carolina, where they
14 produced literally hundreds of feet of drawdown in a really
15 large cone, and as a result of the efforts -- mainly I could
16 credit Ralph Heath; I was the spokesperson, but he was the
17 brains -- we convinced the State that that wasn't a tolerable
18 situation. And so the State stepped in and said, "Okay, in
19 this multicounty area, you got to stop pumping so much water
20 from the aquifer."

21 So we said -- so the State said, "How much do we need
22 to stop pumping?"

23 And we said, "75 percent reduction in the volume that
24 you're taking."

25 And the water purveyor said, "Unfunded mandate,

1 unreasonable expectations."

2 So we said, "Okay, let's do it over a 16-year period.
3 Let's start reducing 25 percent, another 25 percent, another
4 25 percent, until we got to 75 percent."

5 And as we reduced our reliance on that aquifer, under
6 State mandate, the water levels recovered, and are continuing
7 to recover today, some 20 years after implementation, or
8 17 years after implementation, I think, of that program.

9 So, yes, we got a lot of recovery early, and we're
10 still continuing to recover. But what that required is that
11 people who were using that particular aquifer -- and it was all
12 of us in the Central Coastal Plain -- had to find alternative
13 sources of water.

14 Q. Using another aquifer or surface water?

15 A. We went to surface water in some cities, other aquifers in
16 other cities, and developed alternative sources of water,
17 because of the requirement that you can no longer pump that
18 volume of water from that aquifer or those aquifers.

19 Q. In your work in this case, have you been become familiar
20 with the groundwater production activities of Mississippi
21 Light, Gas & Water?

22 A. I've studied it as much as I can.

23 Q. Could you give us -- could you provide us kind of a brief
24 overview, then -- I think you put some slides together on this?

25 A. A brief overview.

1 Q. Tell us what's the first slide -- go ahead. Give the brief
2 overview.

3 MR. BRANSON: Sorry, your Honor. Before we get into
4 this, we wanted to restate our relevance objection to this. In
5 reliance on your ruling in this case, we have not focused our
6 discovery on MLGW's pumping activity. So we think it's
7 prejudicial to allow it in. It's not relevant. If it is going
8 to come in, we'd ask for a continuing objection and have the
9 ability to move to strike it.

10 THE COURT: And I'm sure what the -- go ahead.
11 Anyway ...

12 MR. ELLINGBURG: This is clearly relevant, because
13 Memphis and Tennessee, and Memphis Light, Gas & Water, have all
14 taken the position that if you pump anything in Tennessee, it
15 necessarily takes water out of Mississippi. And it is
16 fundamental -- that's fundamentally scientifically
17 unsupportable.

18 And that's one of the things we've been building up
19 to, is this point. So the pumping that was done by MLGW, and
20 the way that pumping was increased, and the way it located its
21 wellfields, shows that that was an -- and the rest of the
22 testimony I believe will show that that was an avoidable -- and
23 I think that you can't -- they can pump the water. It doesn't
24 necessarily have the impact.

25 And this case is not about the sand; it's about the

1 water. And our position is that they have taken Mississippi
2 water. They say, "Well, it's not Mississippi water, because if
3 anybody pumps, Mississippi loses water."

4 That's just not so. So it is relevant.

5 MR. L. BEARMAN: I want to join in with the objection,
6 your Honor, and point out an additional point. This is well
7 beyond the scope of the pleadings and beyond the scope of the
8 lawsuit.

9 THE COURT: So I agree -- I'm going to overrule the
10 objection that you make, put it in subject to it being
11 stricken.

12 MR. ELLINGBURG: Yes, your Honor.

13 And I will point out one thing at this juncture in
14 response to Mr. Bearman's statement. The order entered of
15 Court, which has been characterized by defendants with some
16 liberality, specifically says that evidence which you would
17 envision could be relevant would have to be with historical
18 flows of the water.

19 Now, the historical flows of the water, as we have
20 been showing, laying the foundation to show, is directly
21 impacted by the pumping. And so it falls within this category
22 of the historical flows between states, which is one of the
23 comments in your order, as long as -- as well as the geology
24 and the hydrogeology, which is what we've been focusing on.

25 THE COURT: All right. You may proceed.

1 MR. ELLINGBURG: Thank you.

2 BY MR. ELLINGBURG:

3 Q. So, Dr. Spruill, you've prepared some slides which show a
4 progression -- okay. You were about to give a brief overview
5 of the pumping by MLGW --

6 A. Okay.

7 Q. -- in Shelby County, Tennessee?

8 A. Okay. MLGW, according to my research, operates one of the
9 largest artesian wellfields in the country. They withdraw
10 water from approximately 160 wells and 10 different wellfields
11 in the county -- that's Shelby County -- and they have produced
12 over the years variable amounts of water, starting back into
13 the 1800s -- I don't remember the exact dates, but the
14 mid-1800s -- producing water from a series of wells and
15 wellfields, progressing up to as high as 150 million or so. I
16 think the current withdrawals from the ten wellfields is
17 probably in the vicinity of 120, 24, 23 million gallons of
18 water a day.

19 So they -- they are a large purveyor of water,
20 extracting water from the Memphis Aquifer, from ten different
21 wellfields. They provide that water for the use of the people
22 in the region.

23 Q. And does that cone of depression extend beyond the City of
24 Memphis?

25 A. Today?

1 Q. Yes.

2 A. Clearly. The cone of depression of a single well, pumping
3 this aquifer for a long period of time, would extend outward --

4 Q. Okay. So let's --

5 A. -- 15 to 20 miles, and extend beyond the City of Memphis.

6 Q. Now you've provided some slides that show the progression
7 to how we got where we are today in terms of wellfields?

8 A. Okay.

9 Q. What does this first slide show?

10 A. Just prepared a slide that shows that Memphis Light &
11 Gas -- Memphis Light, Gas & Water wellfield comprised of -- a
12 well system comprised of one, two, three, four -- four
13 wellfields: The Mallory, Allen, Sheehan, and McCord
14 wellfields, up to the year 1958.

15 Q. And did you track the additional wellfields?

16 A. I did. I thought it was very interesting to see the
17 historical development of additional wellfields.

18 And so the next slide, from 1965, shows that in
19 addition to those initial four wells that -- whose names I
20 mentioned, the Lichterman wellfield was brought online, and
21 according to my records the first pumping was probably in 1965.

22 Q. And what is the next progression -- now, the Lichterman
23 field is -- I think we've already moved to the next one, but
24 the Lichterman field is -- or you can see on the map, it's
25 located closer to the Mississippi border; is that correct?

1 A. Yeah, it's -- most of the wells are between, say, two and
2 four miles from the border between Tennessee and Mississippi.

3 Q. Now, is that the wellfield from which you obtained the
4 information of the projected pumping, in terms of the size of
5 the cone of depression, from Lichterman?

6 A. Yes.

7 Q. Okay. And so you said the cone of depression would extend
8 about 20 miles; is that correct?

9 A. Right. Right. At the increased -- at the pumping rate
10 projected by the USGS geologists that did that work, they
11 projected a cone of depression extending outward to
12 approximately 20 miles.

13 Q. Thank you.

14 Now, what's the next wellfield?

15 A. The next field -- wellfield that comes online, according to
16 my data, is the Davis wellfield, in about 1970.

17 Q. And is that the one that's been added to the lower
18 left-hand corner?

19 A. Yes, it is.

20 Q. And then were there any other wellfields added?

21 A. Yeah, at this -- about the same time, the LMG facility --
22 and that would be up in the northeast corner of that facility,
23 right underneath the bar scale -- LMG, I think, facility came
24 online, started pumping around 1970.

25 Q. And were any other wellfields constructed after Lichterman,

1 in addition to Davis, close to the Mississippi/Tennessee
2 border?

3 A. Yeah, this slide shows the development of a Palmer
4 wellfield, somewhere around '71 or '2.

5 Q. Now, that bright line -- the dark line across there,
6 underneath the Palmer wellfield, it says
7 "Tennessee/Mississippi"; is that the Tennessee/Mississippi
8 State line?

9 A. Yes, it is.

10 Q. And I think earlier Mr. Bearman put a map up that showed
11 that -- this is Shelby County, Tennessee, and immediately below
12 it, where you can see the eastern boundary of Shelby County on
13 that slide, and then immediately below that is DeSoto County,
14 Mississippi, is that correct?

15 A. Correct.

16 Q. Now, do all these wellfields pump from the Memphis Sand?

17 A. As far as I can determine, yes, they do.

18 Q. Do they all have the same number of wells?

19 A. They do not.

20 Q. They don't?

21 A. Some have a small number of wells; some have as many I
22 think as 20 wells or so.

23 Q. Do they all produce the same volume of water?

24 A. No. No.

25 Q. Let's go to the next slide, because I think I focused on

1 these close to Mississippi, but I think there's some more
2 wellfields there.

3 What's the next slide? Does that show the addition of
4 another wellfield?

5 A. I'm sorry, I'm confused. Yeah, this would show, I think,
6 the 1973 addition of the Morton wellfield.

7 Q. Which is to the north of Memphis?

8 A. That would be correct.

9 Q. Or at least to the north of the existing wellfields.

10 A. Except -- with the exception of LMG.

11 Q. Right.

12 And would you go one more slide.

13 Okay. And so does this show the addition of the Shaw
14 wellfield?

15 A. Yes, it shows the addition of the Shaw wellfield in 1990.

16 Q. And so those are the wellfields you referred to a little
17 bit earlier, when you were talking about the total number now?

18 A. Yes. Shows the ten wellfields that I mentioned earlier.

19 Q. Now, do you know how far those three southernmost
20 wellfields are from the Mississippi/Tennessee border?

21 A. Yeah. I mean, I'd -- I took the time to calculate those
22 distances. I don't have that chart with me, but I know
23 generally how far those wells -- wellfields are.

24 Q. Okay. And I think the parties have agreed they're
25 generally within two to three miles; is that correct?

1 MR. ELLINGBURG: Is that not the stipulation, David?
2 What is the stipulation?

3 MR. D. BEARMAN: I don't have it. I don't have it.

4 MR. ELLINGBURG: We can move on.

5 Q. Do you have a slide, or would you give a slide that shows
6 the actual Palmer wellfield?

7 A. The Palmer wellfield is shown as Slide 55.

8 Q. So how many wells did it have?

9 A. I count five wells in the Palmer wellfield. And by my
10 calculation, these wells are about three-quarters of a mile
11 from the Tennessee/Mississippi border.

12 Q. Now, do you have a slide showing the Davis wellfield?

13 A. This is a slide of the Davis wellfield.

14 Q. How many wells does it have?

15 A. I'm convinced that it has eleven wells. And these wells
16 are approximately two miles from the border. I don't remember
17 the exact numbers, but about two miles from the border.

18 Q. Okay. Did you provide us with a slide of the Lichterman
19 well?

20 A. Yes. And this is that figure, and it shows approximately
21 20 wells. About 20 wells, and by my calculation, these wells
22 range from about two to about four miles from the
23 Tennessee/Mississippi border.

24 Q. Now, did you -- did you add a scale to Slide -- the slide
25 of the Lichterman wellfield?

1 A. I did, because maps without scales drive me up the wall.

2 Q. And so where did you get the information to add a scale to
3 it?

4 A. I went to the USDS, found latitude and longitude values for
5 the individual wells, and had my GS specialist in my company
6 take those coordinates and then do our GIS magic and calculate
7 the distance from those wells to the border.

8 MR. BRANSON: Your Honor, I'd have to object to this
9 as well. None of this information he's cited was in his expert
10 reports. We haven't deposed him on this. We haven't taken
11 discovery on it. It sounds like he's done this after the
12 depositions.

13 MR. L. BEARMAN: Same objection.

14 MR. ELLINGBURG: Your Honor, there's been continuing
15 work on this case. This is a matter of great importance, and I
16 don't -- we're not in a case where somebody is saying they're
17 bringing in a new doctor on the eve of the trial. This
18 information is all relevant to these inquiries.

19 MR. BRANSON: Your Honor, I have no idea if this is
20 accurate or not. We haven't had a chance to test it. The
21 whole point of discovery and a scheduling order is so that
22 we're all on the same page and we're prepared for the hearing.
23 If it's done after discovery closed, I don't think it should be
24 allowed here.

25 THE COURT: I'm not sure I see that, but I'm going to

1 let it come in.

2 Overruled. Overrule the objection, and you may
3 proceed.

4 MR. ELLINGBURG: We'd also like to offer at this time
5 Exhibit P57, which is not a joint exhibit, but which has an
6 explanation of the scale and how it was added, using USGS data.

7 THE COURT: Okay. Any objection?

8 MR. ELLINGBURG: I'll provide it to the parties.

9 THE COURT: I'll let it be introduced at this time,
10 subject to later change.

11 MR. BRANSON: Your Honor, can I just note a continuing
12 objection to these, so I don't have to keep saying that.

13 THE COURT: Yes. You'll have a chance to strike it.

14 MR. L. BEARMAN: Same thing.

15 THE COURT: Okay.

16 We'll take a short break at this time. Ten minutes.

17 (Recess)

18 THE COURT: The witness may take the stand.

19 MR. L. BEARMAN: Your Honor, can I add to the
20 objection: No proper foundation has been laid for this
21 testimony.

22 I know I heard your Honor rule; I just want to make
23 clear --

24 THE COURT: Okay. Yes. Your objection is well taken.
25 It's overruled.

1 Go ahead.

2 BY MR. ELLINGBURG:

3 Q. Dr. Spruill, in your notebook, you have Exhibit P57.

4 Correct?

5 A. 157?

6 Q. P57.

7 A. Oh, 57. Yes. Yes, I see it.

8 Q. Okay. And can you explain to us what is shown in

9 Exhibit P57.

10 A. That --

11 Q. This one. The one in your notebook has more than one page.

12 A. Oh. Okay. So are you asking me about this figure? I'm

13 sorry.

14 Q. No, excuse me. No. On P57 relates to --

15 A. I think it's Number 58.

16 Q. Look at P57 in your notebook.

17 Are you looking at it?

18 A. Yes.

19 Q. Does it have more than one page? If it does, it's good.

20 A. Well, I just have something called P57, page one of four.

21 Q. Right. Do you have four pages as part of P57?

22 A. No. Well, hold on.

23 Q. Let me hand this to you.

24 A. Okay.

25 Q. Because it is a four-page document, and I think that was an

1 error.

2 MR. ELLINGBURG: Did you all get four pages?

3 MS. KNOFCZYNSKI: Yes.

4 A. Oh, I see what you're talking about. That's further along
5 than I thought. Sorry.

6 Q. Okay. So now do you see Exhibit P57?

7 A. I do.

8 Q. And can you tell me what's on the three pages after the
9 slide we've shown that you discussed.

10 A. Oh, those are -- those are some latitude and longitude
11 values for wells, by number. In the different wellfields,
12 Palmer, Davis, and Lichterman wellfields.

13 Q. Now, was that used to prepare the images and to give the
14 testimony you gave with regard to the location of those wells?

15 A. It was only used to prepare a figure called P57, that has a
16 scale on it. So I used those data --

17 Q. Okay.

18 A. -- with the GIS specialists in my company to pinpoint the
19 location of those wells, and just do the simple calculation of
20 how far is it to the border?

21 And then we said, "Well, we love maps with scales on
22 them, and the maps don't have scales on them; that's not good.
23 So let's put a bar scale on it."

24 So we generated that bar scale that you see in the
25 lower right-hand corner.

1 Q. Okay.

2 MR. ELLINGBURG: So that -- for P57, Plaintiff's
3 Exhibit, which we'd like to offer along with -- we'd like to
4 offer the full copy of P57 into the record to show the basis,
5 the dermination of the scale.

6 THE COURT: It's been tendered to the other side
7 before this trial?

8 MR. ELLINGBURG: Yes, your Honor.

9 MR. BRANSON: We have the same objection. You've
10 already heard it, your Honor.

11 THE COURT: I'll overrule the objection. But it may
12 be placed in evidence at this time.

13 (Plaintiff's Exhibit 57 received in evidence)

14 BY MR. ELLINGBURG:

15 Q. I just want to make sure, is that the information used to
16 apply that scale?

17 A. Yes.

18 Q. Pull up the next slide. No, wait a minute, I've got my --
19 all right.

20 Before we move on, did you use P57 in any way to
21 calculate the scale added to this map?

22 A. I used the latitude and longitude numbers for the
23 individual wells that we recovered from the USGS -- some USGS
24 website; I don't remember which one.

25 And the position of the Mississippi/Tennessee line,

1 which you can also get from websites, to not only calculate the
2 distance from the border to the individual wells, but to
3 generate a map scale, to simply say on this map one inch equals
4 about half a mile.

5 Q. Okay. And did you determine the distance between the
6 map -- the wells using that scale?

7 A. I'm sorry, did I determine what?

8 Q. Did you determine the distance between the wells in the
9 wellfield using the scale?

10 A. Just generally, I mean, you can look at the -- now the --
11 you can look at the bar scale at the bottom, and you can
12 determine that a lot of the wells there in Lichterman, relative
13 to each other, might be a quarter of a mile, 13 -- 1,300 or so
14 feet.

15 Other wells, from the northwest to the southeast --
16 there seem to be kind of two clusters here; one on the
17 northwest, one on the southeast. Those wells would be further
18 apart by a distance easily measured with a reasonable bar
19 scale.

20 Q. Thank you.

21 Earlier we talked about the shrinking of the cone of
22 depression, and I think you discussed the possibility of
23 limiting the amount of time that wells in the wellfield were
24 pumped; is that correct?

25 A. I did. I did say that.

1 Q. What if you just turned all the wells off? Would that have
2 any impact on the well -- on the cone?

3 A. It will eliminate the cone, the cone -- eliminate it in
4 large part relatively rapidly, and the final recovery of the --
5 of the artesian pressure would occur over a period of -- of
6 years after that, but it would recover, in my opinion.

7 Q. So you could recover the original predevelopment pumping
8 pressures if you turned off all the wells?

9 A. All the wells.

10 Q. Yeah?

11 A. Yeah. Yes.

12 Q. Thank you.

13 A. I'll add something to that. I said before, the withdrawal
14 of water from confined aquifers can result in nonelastic
15 behavior of an aquifer. I don't think that's the case for the
16 Memphis Sand. I don't think the sand -- I think the Memphis
17 Sand behaves elastically, and that is, if you -- so there's no
18 damage, no substantial damage or subsidence that I can see so
19 far.

20 So I just want to qualify that.

21 Q. Thank you.

22 Have you had and used some information relating to the
23 volume of groundwater being pumped from these wells and others
24 in wellfields?

25 A. I'm aware of the numbers, of millions of gallons per day

1 withdrawn from the wellfields, and I've looked at those
2 numbers.

3 Q. So do you have before you Exhibit P157? That's in your
4 notebook; it's the last, I believe.

5 A. Yes, I do.

6 Q. If you would turn back to -- or let's -- we're going to go
7 back -- we'll give it to you -- to slide -- the slide showing
8 the wellfields. Slide 54. It's up there? Okay.

9 Can you summarize the groundwater production from the
10 Davis field, using the --

11 A. Through time, or just the most recent number?

12 Q. No, not...

13 A. So Davis -- according to this P157 chart, the Davis
14 wellfield, there in the southwestern portion of Shelby County,
15 came online in about 1970. And the early production figures
16 show about 3.2 million gallons of water per day. And it began
17 to increase through time, achieving -- I would say a maximum,
18 in the 2005/2006 time frame, of about 20.8 million gallons of
19 water per day from that wellfield. And the 2016 total for
20 Davis suggests 14.98 million gallons of water per day from that
21 wellfield.

22 Q. Thank you. Can you do the same for Palmer?

23 A. Palmer, I think, came online around 1972, and it has
24 consistently produced between about 2.8 and 4 million gallons
25 of water a day. So the first year of record that I find

1 suggests about 2.8 million gallons of water, and the highest
2 that I think I remember seeing was a little over 5 million
3 gallons of water a day from that wellfield. And the 2016 --
4 yeah, 2016 wellfield production is recorded as 3.68, roughly,
5 million gallons per day.

6 Q. And finally, what about Lichterman?

7 A. Lichterman I believe came online in 1965, and it -- it
8 started off in around 4.2 million gallons per water --
9 4.2 million gallons of water per day. And probably the highest
10 production from it occurred in the late 1980s, around
11 25 million gallons of water per day. And in 2016, the reported
12 value is 18.5 million gallons of water per day production from
13 the total wellfield.

14 Q. What about MLGW's overall pumping volumes?

15 A. These records indicated on this chart started 1965, and
16 they indicated at that time total MLGW pumping was about
17 71.96 million gallons of water per day. And it increased, and
18 sort of seemed to cap out in the 162 million gallon-per-day
19 range around year 2000. And today -- and 2016, the value is
20 123 -- 123. I think it's -- I think it's 123.9, roughly,
21 million gallons of water per day.

22 Q. So which of the MLGW wellfields have been the largest
23 groundwater producers in recent years?

24 A. "Recent years" meaning last --

25 Q. Last time you remember them.

1 A. Okay. So in 2016, the largest producers were Allen at 14,
2 Lichterman at 18, McCord at 14, Davis at almost 15, Morton at
3 almost 16, and Shaw at almost 20.

4 Q. Thank you.

5 MR. ELLINGBURG: Before I move on, may I approach the
6 witness, your Honor?

7 THE COURT: Yes, you may.

8 BY MR. ELLINGBURG:

9 Q. Doctor, you should take a few minutes, and all I'd like you
10 to do is authenticate, verify, that the series of slides which
11 I'll identify are slides that came out of your report; they're
12 figures within your report.

13 The first one is Figure 1. Is that a figure that came
14 out of your report?

15 A. Yes.

16 Q. Figure 2?

17 A. Yes.

18 Q. Is that a -- which is marked as P192; Figure 1 was marked
19 as P191.

20 Figure 3, which is marked as P193, is that a --

21 A. Yes.

22 Q. Okay. Figure 4, which is marked as P194 --

23 A. Yes.

24 Q. -- is that one of yours?

25 A. Yes.

1 Q. Figure 5 is marked as P195; is that one of yours?

2 A. Yes.

3 Q. Figure 8, which is marked as P198: Is that one of your
4 figures?

5 A. Yes.

6 Q. Figure 9, which is marked as P199: Is that one of your
7 figures?

8 A. Yes.

9 Q. Figure 10, marked as P200: Is that one of your figures?

10 A. Yes.

11 Q. Figure 11, marked as P201: Is that one of your figures?

12 A. Yes.

13 Q. Figure --

14 MR. BRANSON: We're just -- for the record, we're
15 happy to stipulate; you don't have to keep --

16 MR. ELLINGBURG: There was an authenticity objection
17 to these.

18 MR. BRANSON: I think, if all you're doing is saying
19 that these figures on the exhibit list are actually in his
20 expert report, we will stipulate to that.

21 MR. ELLINGBURG: Okay.

22 MR. BRANSON: I don't --

23 MR. D. BEARMAN: We agree.

24 MR. ELLINGBURG: Thank you.

25 THE COURT: This is what he's been testifying to,

1 mostly? All these exhibits are what we saw?

2 MR. ELLINGBURG: These are figures that came from his
3 original report back in 2000.

4 THE COURT: If there's no objection, they may be
5 admitted.

6 MR. ELLINGBURG: And so they go from P191 to P208.

7 MR. BRANSON: And, your Honor, to be clear, we have
8 our evidentiary objections we submitted to you on these, but
9 I'm just stipulating to the fact that they actually are in his
10 expert report.

11 THE COURT: No authenticity, but you don't give up
12 your objection on relevancy.

13 MR. BRANSON: Thank you, your Honor.

14 MR. D. BEARMAN: Thank you, your Honor.

15 THE COURT: They will be admitted.

16 (Plaintiff's Exhibits P191 to P208 received in
17 evidence)

18 MR. ELLINGBURG: Your Honor, for the purposes of
19 preserving the sketch and making the transcript somewhat more
20 understandable, based upon the testimony, we had someone take a
21 color picture of what he drew on the whiteboard. And this goes
22 to his testimony, and we wanted to submit that for the record,
23 for clarification.

24 MR. FREDERICK: Can we put an exhibit number or
25 something on that, counsel, so that we can at least know what

1 we're talking about?

2 MR. ELLINGBURG: Sure. We also took a better picture.

3 THE COURT: No objection, that will be filed, subject
4 to the relevancy.

5 MR. ELLINGBURG: And the other thing that we'd like to
6 do is to put some exhibit numbers on the slides, so that they
7 can -- again, so the record can be followed.

8 MR. BRANSON: Which slides are you talking about?

9 MR. ELLINGBURG: The ones used with Dr. Spruill's
10 testimony.

11 MR. BRANSON: The ones that were not on the exhibit
12 list before the hearing, that we didn't get until Friday, I
13 think we would have an objection to them being submitted as
14 exhibits.

15 MR. D. BEARMAN: Absolutely agree, your Honor.

16 MR. ELLINGBURG: Can we mark them for identification,
17 your Honor?

18 THE COURT: Sure, they may be.

19 MR. ELLINGBURG: Thank you. And so we'll put stickers
20 on those after we finish today --

21 THE COURT: All right.

22 MR. ELLINGBURG: -- and submit them to the Court.

23 BY MR. ELLINGBURG:

24 Q. Dr. Spruill, do you have any opinions on the impact of --
25 if any -- on the pumping in Shelby County, Tennessee, and

1 including the MLGW pumping operations on the Middle Claiborne
2 Hydrologic Unit within the State of Mississippi?

3 A. The creation of a cone of depression associated with
4 pumping 120-plus million gallons of water a day, to me, is
5 undeniable. The cone of depression would be large, and it
6 would be relatively deep, depending on the hydraulic properties
7 of the aquifer.

8 And so my general statement would be I would
9 anticipate the development of a large, a really extensive and
10 reasonably deep cone of depression, based on what I understand
11 about hydraulic properties of the aquifer, and what I've read
12 from the literature and from reports that I've read that deal
13 with estimation or calculation on the size of the cone of
14 depression associated with pumping that much water from an
15 aquifer from ten wellfields located in their current positions.

16 Q. Thank you.

17 Do you have an estimate of about how far that cone of
18 depression extends into, or could have been determined to
19 extend into the State of Mississippi?

20 A. Makes sense to me that for wells located within a couple
21 miles of the Mississippi/Tennessee line, that a cone of
22 depression of 20 miles, theoretical limit of the cone of
23 depression of 20 miles would be very reasonable.

24 And so that would put an impact south of the
25 Tennessee/Mississippi border of on the order of 15 to 18 miles,

1 and that's with respect to the theoretical limit of the cone of
2 depression, with respect to the depth of the cone. I can only
3 rely on the reports that are related to modeling to estimate
4 the amount of well-level change or reduction in pressure you
5 would have down in Mississippi.

6 Q. Based on the modeling which you've seen -- which would
7 include USGS models, right?

8 A. Right.

9 Q. Do you have an estimate of what the drawdown impact could
10 have been anticipated to be in one in the cone of depression
11 created by the MLGW wells?

12 A. I can only rely -- since I didn't do the modeling, I can
13 only rely on what I see in terms of model results or model
14 outputs from models like those done by Dave Wiley at LBG, and
15 earlier models that were done by the USGS that attempted to
16 predict or to show the cone of depression at different times
17 against different pumping rates.

18 And so a generality is that there's a 20-foot cone --
19 20-foot drawdown area that extends over -- appreciably over
20 large parts of DeSoto County, and that drawdowns of 20, 40,
21 maybe even 60 feet up near the border of Tennessee and
22 Mississippi are shown on some of those -- those maps, both
23 as -- taking the different surface maps, and then subtracting
24 the equipotential surface map from the calculated cone of
25 depression, you get a drawdown map. So I've seen both of those

1 that indicate that general size.

2 Q. In addition to what you've seen from -- I think you said
3 LB -- what --

4 A. LBG is the -- I'm sorry, is the old name for Dave Wiley's
5 company, Leggette Broshears Graham, a Florida-based
6 hydrogeology firm.

7 Q. I think in addition to those models, have you looked at
8 model results from -- published by USGS?

9 A. Yes.

10 Q. Are those part of the basis of your opinion?

11 A. Yes.

12 Q. And so how long have you actually been planning wellfields?

13 A. I designed my first wellfield in 1989 -- sorry, late in
14 1988, into '89 and 1990, at the city of Washington in North
15 Carolina. The original Washington.

16 Q. Have you designed any wellfields specifically for the
17 purpose of limiting the amount of the -- or limiting the depth
18 of the cone of depression for a public utility or other entity?

19 A. I would like to think I've never designed a wellfield
20 without that information. That would be my hope.

21 Q. And how many wellfields would you say you've designed, an
22 estimate?

23 A. I've designed and worked on over -- well, hundreds of wells
24 in my career. I don't have an exact number. But wellfields,
25 20, 30, or more.

1 Q. Thank you.

2 What are the remaining known or obvious impacts in
3 Mississippi that have been reported in the USGS documents that
4 you've seen?

5 A. I'm not sure what you're asking me.

6 Q. I'm asking if USGS for modeling has indicated that the
7 pumping would be coming out of Mississippi if MLGW proceeded as
8 they planned?

9 A. I guess two -- yes. The answer would be yes. I've seen
10 reports, examples.

11 Q. Right.

12 A. I recall the 1965, I think, report by Moore from the US
13 Geological Survey, who indicated that continued development
14 of -- development of supplies, development of wellfields, and
15 especially in that area closest to the border, could cause
16 water to flow from other states and could be problematic.

17 I specifically recall -- and I just focused on,
18 because I love the report -- the work done by a USGS gentleman,
19 whose name escapes me, on the Lichterman wellfield about the
20 same time, about 1965, in which he did calculations indicating
21 the nature and the extent of the cone of depression, and where
22 he predicted cones extending outward in the 20-mile range.

23 Q. What are the specific changes to the groundwater system in
24 the Middle Claiborne and Mississippi, within the cone of
25 depression that you discussed, created the Memphis wellfields?

1 A. Generally speaking, the development of a cone of depression
2 of this magnitude will change groundwater and flow patterns.
3 It will affect pressures within the cone of depression. It can
4 and generally does cause changes in direction of groundwater
5 flow that can be significant.

6 It has always the result of decreasing the pressure,
7 and hence reducing the total available drawdown within the cone
8 of depression. And so if the cone of depression extends
9 outward for a reasonable distance, or for any distance within
10 that cone of depression, there is a -- an absolute reduction in
11 the amount of total available drawdown.

12 And I'm speaking just generally now, so in the
13 vicinity -- within the cone of depression, or as a result of
14 the cone of depression, you have to anticipate potential water
15 quality issues that result when you create a pressure gradient
16 between different parts of the system, so that if you lower the
17 water level in an aquifer by a cone of depression, the
18 overlying and underlying aquifers that have their own pressure
19 regimes can begin to respond by pushing water in the direction
20 of reduced pressure, which is in the cone of depression.

21 And so water quality changes are something we always
22 think about when we think about developing a developed cone of
23 depression by leakage across, say, windows or breaches in the
24 confining layer by faulting, and things of that nature.

25 Q. Now, in your answer you said something can happen. Based

1 on the work you've done, do you know whether the total
2 available drawdown has been reduced within the state of
3 Mississippi as a result of the pumping in Shelby County,
4 particularly MLGW?

5 A. Based on the drawdown map and the equipotential surface
6 maps that I've seen, the total available drawdown in
7 Mississippi has been reduced by pumping from across the border.

8 Q. Has the cone of depression created by the pumping in Shelby
9 County and by MLGW caused any change in the natural flow path
10 of groundwater within the confined aquifer unit within
11 Mississippi?

12 A. Again, if you look at equipotential surface maps, based on
13 actual data, and then say for predevelopment conditions, or
14 within the cone of depression as model, for example, it's clear
15 that groundwater flow patterns have changed such that water
16 that naturally resided in Mississippi is moving towards -- has
17 moved towards or is continuing to move towards the State of
18 Tennessee, unless the cone of depression is eliminated or
19 lessened.

20 Q. Okay. Within a confined aquifer, what was the
21 predevelopment direction?

22 A. In Mississippi?

23 Q. Yes.

24 A. Generally to the west.

25 Q. And how has that direction been changed as it shows up on a

1 map?

2 A. Maps that I see -- and obviously not all maps show the same
3 thing, but there is a shift towards a more northerly flow
4 pattern in the vicinity of the Tennessee and Mississippi
5 border.

6 Q. Based on your testimony earlier with regard to total
7 available drawdown, has the amount of water that can be
8 produced from the Middle Claiborne hydrologic unit in the state
9 of Mississippi been reduced by the pumping in Shelby County and
10 by MLGW?

11 A. I would have to base my answer to that on the drawdown map
12 that I have observed from the Wiley study that shows, say, by
13 way of example, 40 feet of drawdown in the northern part of
14 DeSoto County and south of the border. 40 feet of reduction
15 and total available drawdown would be then implied by the
16 drawdown map showing a 40-foot drawdown.

17 Putting that in perspective, if you have a well at
18 that location that's capable of producing 10 gallons a minute
19 for every foot that you lower the water level, then reducing
20 the total amount available drawdown by 40 feet would reduce the
21 ability -- would reduce the capacity of that well, maximum
22 capacity, by 400 gallons a minute.

23 Q. And is that because of this movement of some of the
24 molecules of water out of the pore spaces?

25 A. It means that the amount of water in storage in these

1 completely filled pore spaces has been reduced materially by
 2 the reduction it had within the cone of depression up -- at
 3 that value. I gave a value of I think 40 feet, so 40 feet of
 4 pressure reduction would result in a loss of 400 gallons a
 5 minute maximum capacity of a well --

6 Q. Within your example?

7 A. Within my example.

8 Q. Okay. Are there any other impacts that relate to -- on the
 9 production of groundwater in Mississippi that arise from the
 10 reduction in total available drawdown?

11 A. I would have concerns, based on my experience, that if you
 12 had a well within the cone of depression that I've stipulated,
 13 this cone of depression that has maybe 20, 40, 60 feet of
 14 drawdown, if somebody else had a well within that cone and they
 15 were producing a given amount of water, it's entirely
 16 conceivable that the cost of pumping that water to the surface,
 17 it is reasonable to assume that the cost of pumping that water
 18 to the surface increases, because now, instead of pumping
 19 against the high water level, they're pumping against a lower
 20 water level.

21 As we all know, the definition of work is moving an
 22 object over a distance. So that pump has to move the water
 23 over a greater distance; it has to do more work, so it caused
 24 that water purveyor more money.

25 Throughout my career, I've been involved in situations

1 like this, where the pump that was installed was perfectly
2 capable of producing a given amount of water against that head,
3 that pressure; but when the pressure was lost, that pump could
4 no longer produce the same amount of water, so the pump had to
5 be replaced.

6 Q. So that's a possible example. But in the case of actually
7 pumping --

8 THE COURT: Just a minute.

9 MR. L. BEARMAN: We're now talking about what's
10 possible, which is inadmissible, in my judgment. We are also
11 speculating, if the Court please. And while I understand your
12 Honor's ruling, I think this has gone beyond the pale.

13 MR. ELLINGBURG: Which is the reason I was about to
14 ask him to clarify that further, without talking about --

15 THE COURT: The point is well taken. But I'll let you
16 proceed, and overrule the objection. But don't get into
17 possibilities; do probabilities, if you can.

18 BY MR. ELLINGBURG:

19 Q. Dr. Spruill?

20 A. Yes, sir.

21 Q. Is there any impact on the cost of producing water from
22 a -- within a cone of depression, where you have to pump out of
23 that cone, as distinguished from pumping at conditions outside
24 the cone?

25 A. Absolutely.

1 Q. And what is the cost?

2 A. Increased cost of lifting water to the surface against --
3 against a reduced water level in a well at that same rate.

4 Q. And what amount -- the actual well itself, did it have to
5 go deeper?

6 A. It's possible that the --

7 Q. Not possible?

8 A. It's probable -- well, okay. Depending on the pump
9 setting, depending on the pump setting, you may have to lower
10 the pump to achieve the same flow of water, gallons per minute.

11 Q. Okay. So that was "may," and again, that's speculative.
12 But if you have to pump from the deeper depth because of all
13 the circumstances, does that cost any more money?

14 A. Certainly. Yes.

15 Q. And how about -- do you have any idea how much more it
16 costs?

17 A. Under the calculation years ago that shows if you lift a --
18 I don't want to give this example.

19 Q. Then don't.

20 A. It costs more money to lift water over a greater distance.

21 Q. Okay.

22 Also, I want to make sure I understand that earlier in
23 your answer -- I'm not sure how you phrased it, but is it your
24 opinion that the pumping -- do you have an opinion as to
25 whether the pumping in Shelby County and by MLGW has withdrawn

1 any groundwater through Mississippi?

2 A. The modeling results and reports that I see, that show the
3 cone of depression and changing flow lines, say to me that
4 groundwater that originally was residing in Mississippi has
5 changed directions, in some locations moving towards the
6 Mississippi and by -- some of that water has moved across the
7 border.

8 Q. And do you -- when you say "the model results," are you
9 talking about the USGS models included in that?

10 A. Both the USGS model and recent modeling efforts.

11 Q. Thank you.

12 Now, you mentioned earlier some water quality issues
13 resulting from the lowering of the pressures within the Middle
14 Claiborne Hydrological Unit; is that correct?

15 A. Yes.

16 Q. Have you seen evidence of that?

17 A. I've read lots of papers outlining the migration of water
18 in response to the development of the cone of depression
19 downward from overlying units and through confining beds and
20 breaches in confining beds, through things that are variably
21 referred to as paleo channels, windows, thinning -- areas of
22 thin confining beds, etc.

23 Q. And when you say you've read papers, do you have an opinion
24 based on the information, scientific information available, as
25 to whether that has taken place?

1 A. Yeah, I think it's a lot of really nice work that involves
2 the use of isotopes and looking at the introduction of human
3 contaminants, human-related contaminants, into the groundwater
4 system.

5 Q. Dr. Spruill, you said, I think it's nice work. My question
6 is, do you have an opinion, based on the scientific information
7 you reviewed?

8 A. Yeah, I have an opinion.

9 Q. Yes?

10 A. Contaminants have moved downward through these features
11 that I described.

12 Q. Or younger water?

13 A. Or younger, uncontaminated water, into the aquifers within
14 the cone of depression.

15 Q. Yes.

16 MR. L. BEARMAN: Do I understand, your Honor, that we
17 have a continuing speculation objection as well?

18 THE COURT: I understand that. I'll let it be
19 introduced. You may reserve your right to strike it.

20 BY MR. ELLINGBURG:

21 Q. I think you said yes; is that right?

22 A. I said yes.

23 Q. And what is the opinion?

24 A. The opinion is clear. There's lots of scientific evidence,
25 based on constituents that show up at production wells that are

1 not part of the confined aquifer system, that have come from
2 demonstrably younger water making its way down through these
3 special areas within the overlying materials that are making
4 their way into the groundwater system.

5 It is well documented. It's not speculation. It's
6 well documented that there are windows that allow or facilitate
7 the migration of younger water that may be anthropogenically --
8 may be contaminated with human-related constituents; for
9 example, gasoline. Constituent of gasoline, benzene, or
10 something else that might come up --

11 Q. We don't need to talk about what may happen.

12 A. Okay.

13 Q. But has there been downward migration?

14 A. Yes.

15 Q. And is it your opinion that that's the...

16 A. Yes.

17 Q. And that is -- and why is that as it relates to the cone of
18 depression?

19 A. The establishment of a cone of depression changes the
20 pressure environment and increases the rate of downward
21 migration of water from overlying units within the cone of
22 depression.

23 Q. Thank you.

24 Would you put the last slide up there.

25 This is a document taken from hydrogeology of the

1 principal aquifers in relation to faults to interaquifer
2 leakage in the Memphis area. Have you seen this before?

3 A. Yes.

4 Q. And what is it that is significant on this slide that you'd
5 like to talk about, and how does it relate to your opinion?

6 A. This figure, from a report by the USGS, shows the position
7 of the ten wellfields. There's Davis. I'm pointing to Allen,
8 Sheahan, Lichterman; can't see Palmer because of the timing.

9 But it shows the area where the confining unit is thin
10 or absent. And it shows the areas where the confining unit is
11 thin or absent most conspicuously, and most understandably, in
12 the confining -- in the unconfined portions of the aquifer,
13 where it's expected to be absent.

14 But it shows the position of areas in some cases
15 closely related to the position of the wellfields, where there
16 is thinning of the confining unit or the confining unit is
17 absent. And so those would be places where the confined
18 aquifer would be -- is less protected from downward migration
19 of water than areas where these windows or thin areas don't
20 exist.

21 Q. Okay. So those are the windows you were talking about;
22 would that also -- does that have any relation to the paleo
23 channels?

24 A. I don't know whether these are paleo channels, ancient
25 channels that form when sea level fell, rivers cut deeper, sea

1 level rose, the channels were filled with gravel and sand. I
2 don't know whether they are paleo channels or whether they are
3 areas where simply there's a thinning of the confining bed on
4 top of the aquifer. But they are recognized as areas -- and
5 these are the ones that were recognized, I guess, up to this
6 point in time.

7 Q. Thank you.

8 Would you put Slide 23 back up.

9 We discussed this slide earlier on, did we,
10 Dr. Spruill?

11 A. Yes.

12 Q. Do you have an opinion as to whether there is available
13 groundwater that can be produced within the State of Tennessee
14 far enough from the border of the State of Mississippi that
15 would have no significant impact on channels?

16 MR. BRANSON: Your Honor, I just note a foundation
17 objection to that question. There's been no evidence that
18 Dr. Spruill has studied that question.

19 THE COURT: I'll overrule it, but you may put it in.

20 BY MR. ELLINGBURG:

21 Q. Before we do that, do you recall being asked questions in
22 the deposition by Mr. Branson in which he asked how the cone
23 could be mitigated?

24 A. Yes.

25 Q. And you stated that wells could be placed further to the

1 north?

2 A. Yes.

3 Q. Okay. That said, do you have an opinion as to whether
4 there is an adequate supply of water, based upon the US
5 Geological Survey's mapping, north of Memphis to meet the needs
6 in Tennessee without any significant impact on channels?

7 A. Yes, I have an opinion. This map shows the thickness of
8 the Middle Claiborne Aquifer. North of the transition zone,
9 the Middle Claiborne Aquifer unit is composed of the Memphis
10 Sand Aquifer.

11 North of the facies line, I think that it's called,
12 the facies transition that's shown on this map, there's an
13 indication that the Memphis Sand, well north in Tennessee and
14 east of the Mississippi River, contains a thickness of 600 feet
15 or higher, which is an appreciable sand thickness. And so the
16 transmissivity of that aquifer would be an important question,
17 because transmissivity is not just aquifer thickness, but it's
18 also permeability times aquifer thickness.

19 And so I base my opinion on a report prepared in the
20 1960s by Moore, in which he presented a map of zones of
21 transmissivity for this particular area that we're describing;
22 that is, the area north of Memphis, east of the Mississippi
23 River, and well to the west of the -- of the unconfined
24 portions of the system.

25 I cannot tell you what individual yields from wells

1 would be, but my opinion is that that's a zone capable of
2 sustaining significant quantities of water from wells or
3 wellfields.

4 Q. And based on the Moore --

5 A. Based on the Moore study.

6 Q. And on channels?

7 A. And on this, it shows a significant thickness.

8 Q. Give me a moment.

9 MR. ELLINGBURG: Excuse me just a moment.

10 THE COURT: Yes.

11 MR. ELLINGBURG: Trying to find our copy of the joint
12 exhibits.

13 THE COURT: All right.

14 MR. BRANSON: Mike, do you have a particular one
15 you're looking for?

16 MR. ELLINGBURG: Yes. I'd like to see Joint
17 Exhibits 58 and 59.

18 THE COURT: Why don't we just recess until tomorrow,
19 and you can see if you can find that and answer anything else,
20 or ask any questions, and then have cross-examination tomorrow.
21 Yes.

22 MR. BRANSON: Your Honor, I have something I'd like to
23 raise briefly before we recess. Dr. Spruill has not addressed
24 today -- and I understand he's probably not going to on
25 direct -- the predevelopment of flow map generated by Dr. Brian

1 Waldron, who we're planning to call. And this was an extensive
2 subject of discovery; 70, 80 pages of expert reports were
3 devoted to it. Both experts were deposed on it.

4 I don't know if they're planning to do Dr. Spruill's
5 criticisms of Dr. Waldron on rebuttal or not, but I would ask
6 that if they are, that we -- that you instruct them to do it on
7 direct, so that we can only have Dr. Waldron testify once. I
8 don't want to have him testify, then get critiqued, and then
9 have to come testify again.

10 So I just wanted to raise that issue.

11 THE COURT: Okay.

12 MR. ELLINGBURG: Your Honor, this issue was first
13 raised today, and we have planned to direct -- to present our
14 evidence in that fashion. We will follow the typical rule,
15 that you have direct and that the other side has a response,
16 and then if you need it, you have rebuttal. And so we'd like
17 to hear what he has to say first, before we know whether we
18 have to put any testimony on.

19 MR. BRANSON: Judge, there's no mystery about what our
20 expert is going to say. He published an academic paper that
21 all five experts in this case have talked about. There are
22 literally 70 pages of expert reports exchanged on it. It goes
23 to a core thing that I understood your Honor wanted evidence
24 on, which is the historical flows in the aquifer between the
25 states.

1 We think that it needs to be part of the case in
2 chief. There's no good reason to have both witnesses testify
3 twice about it when we could just do it once.

4 MR. ELLINGBURG: Well, there's no reason for it to be
5 testified to twice. I mean, we don't know what Dr. Waldron is
6 going to say about it and how that examination is going to go.
7 We can't make a decision as to whether we want to put
8 Dr. Spruill on to respond any of it; he may say something about
9 Dr. Spruill.

10 There's a reason that this has always been done this
11 way, which is that you put on your witnesses, they put on
12 theirs, and then if you need to, you put on rebuttal.

13 And so we object to having to ask him questions about
14 something that we may not even need to ask him questions about.

15 THE COURT: Well, what we'll do, we won't decide that
16 issue today, but we'll decide it in the morning. And it may be
17 that if you don't cover -- make their expert go, if they want
18 to, or if you expect to put Dr. -- what's his name, Moore?

19 MR. BRANSON: No, our expert is Dr. Waldron, your
20 Honor.

21 Just to be clear, he's testifying -- Mr. Frederick
22 presented his map of the aquifer in his opening statement, and
23 he's going to testify based on an academic paper that all five
24 experts have discussed about the predevelopment cross-border
25 flows in the aquifer.

1 So we're not letting him go. My point is that
2 Dr. Spruill submitted essentially this entire expert report
3 criticizing Dr. Waldron's map. Both of them were deposed about
4 it. There's just no good reason to do this piecemeal and force
5 both of these gentlemen to testify twice. It just makes sense.

6 THE COURT: Well, put it in tomorrow; then you can
7 hold your witness over, or you can put it in later, if it's a
8 proper report. But if it doesn't come in, I don't see any
9 reason for you to have your expert here.

10 MR. BRANSON: Your Honor, this is -- to be clear, our
11 expert is independent of Dr. Spruill. Our expert has published
12 a map about predevelopment flows in the aquifer, which I
13 understood your Honor wanted evidence on in this hearing, the
14 extent of historical flows between states. And so it's an
15 affirmative part of our case.

16 THE COURT: So you want to use him anyway?

17 MR. BRANSON: We're going to use him anyway.

18 MR. ELLINGBURG: As he said, it's an affirmative part
19 of their case.

20 THE COURT: Well, we'll try to figure that out. I
21 never had that come up before. But we'll see about it now, and
22 we'll talk about it tomorrow.

23 MR. FREDERICK: Your Honor, the main point is that if
24 we could finish this week, by having efficiency with the
25 witnesses --

1 THE COURT: That's correct.

2 MR. FREDERICK: -- that's a net good for everybody.

3 THE COURT: Sure.

4 MR. FREDERICK: And so having Dr. Spruill address all
5 the issues that he opined about in his expert report once, and
6 then we just have one cross-examination of him, I'm sure he
7 would appreciate that. And then having Dr. Waldron talk about
8 his information and then not have to come back two days later
9 to address any issues that Dr. Spruill might testify about
10 specifically to Dr. Waldron.

11 We're just trying to make the hearing more efficient.

12 THE COURT: I understand that. I'm not sure that I
13 can look at it in a vacuum, frankly, because you're going to
14 put your man on, and if he doesn't testify about it, you may
15 not have any problem whether it's done. We'll just have to be
16 as flexible as we can about it.

17 MR. BRANSON: Your Honor, the other -- the only other
18 thing I had is my experience in these -- in trials has been
19 that when a witness is still live on the stand when we break
20 for the day, such as Dr. Spruill is now, that attorneys should
21 not be talking to the witness about the substance of their
22 testimony, and that would apply to both sides. I just wanted
23 to see if that was your understanding as well.

24 THE COURT: What do you say?

25 MR. ELLINGBURG: We have no objection to that.

1 THE COURT: All right. That's my direction, then.
2 Don't talk to your witness until we get back tomorrow and put
3 him on the stand.

4 Is there anything else to take up?

5 MR. ELLINGBURG: The only thing I can say about that
6 is that we have not planned on putting on testimony by him
7 directly about Dr. Waldron. And so if the Court were to
8 require us to put testimony on for him before we've heard
9 Dr. Waldron testify, we'd have to do some more work.

10 That's part of the reason we're objecting to this
11 being brought up today. They've brought up almost every
12 imaginable thing they wanted to during the pretrial, and so
13 it's hard for me to see how they can justify today telling us
14 that one is going to change the historic rule of the progress
15 of trial with regard to our witness, and then not let us -- you
16 know, not even let us talk to him if we're going to have to do
17 that.

18 You know, I just think that -- we don't mind not
19 talking to him, but we would have to talk to him if we were
20 going to have him testify with regard to --

21 THE COURT: Well, if you don't plan to do it, don't
22 change it, and we'll just wait to see what he testifies about,
23 and we'll -- I'll rule after that.

24 MR. BRANSON: And your Honor, just to be clear, if
25 there ends up being rebuttal testimony criticizing our expert,

1 we would move for leave to have a surrebuttal and have our
2 expert respond to the criticisms.

3 THE COURT: I'm not sure whether rebuttal will pass,
4 or surrebuttal, but we'll pass that also.

5 MR. ELLINGBURG: Thank you, your Honor.

6 MR. BRANSON: Thank you, your Honor.

7 THE COURT: If there's nothing else, this Court will
8 be in recess until 9:00 a.m.

9 (Adjourned until May 21, 2019, at 9:00 a.m.)

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STATE OF TENNESSEE:

COURT REPORTER'S CERTIFICATE

I, PATRICIA A. NILSEN, Licensed
Reporter for the State of Tennessee, CERTIFY:

1. The foregoing deposition was
taken before me at the time and place stated in the foregoing
styled cause with the appearances as noted;

2. Being a Court Reporter, I then
reported the deposition in Stenotype to the best of my skill
and ability, and the foregoing pages contain a full, true and
correct transcript of my said Stenotype notes then and there
taken;

3. I am not in the employ of and am
not related to any of the parties or their counsel, and I have
no interest in the matter involved.

WITNESS MY SIGNATURE, this,
the _____ day of _____, 2019.



PATRICIA A. NILSEN, RMR, CRR, CRC
TN Licensed Court Reporter
LCR Number: 717
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