No. 143, Original

IN THE
Supreme Court of the United States

STATE OF MISSISSIPPI,
Plaintiff,
v.

STATE OF TENNESSEE, CITY OF MEMPHIS, TENNESSEE,
AND MEMPHIS LIGHT, GAS & WATER DIVISION,
Defendants.

On Bill of Complaint
Before the Special Master, Hon. Eugene E. Siler, Jr.

EXHIBITS IN SUPPORT OF DEFENDANTS' JOINT MOTIONS IN LIMINE

DAVID C. FREDERICK
JOSHUA D. BRANSON
T. DIETRICH HILL
GRACE W. KNOFCZYNSKI
KELLOGG, HANSEN, TODD,
FIGEL & FREDERICK, P.L.L.C.
1615 M Street, N.W.
Suite 400
Washington, D.C. 20036
(202) 326-7900

Special Counsel to Defendant State of Tennessee

November 1, 2018

LEO M. BEARMAN
Counsel of Record
DAVID L. BEARMAN
KRISTINE L. ROBERTS
BAKER, DONELSON, BEARMAN,
CALDWELL & BERKOWITZ, PC
165 Madison Avenue, Suite 2000
Memphis, Tennessee 38103
(901) 526-2000
(lbearman@bakerdonelson.com)

Counsel for Defendants City of Memphis, Tennessee, and Memphis Light, Gas & Water Division

(Additional Counsel Listed On Next Page)

HERBERT H. SLATERY III
Attorney General
ANDRÉE SOPHIA BLUMSTEIN
Solicitor General
BARRY TURNER
Deputy Attorney General
Counsel of Record
SOHNIA W. HONG
Senior Counsel
P.O. Box 20207
Nashville, Tennessee 37202-0207
(615) 741-3491
(barry.turner@ag.tn.gov)

Counsel for Defendant
State of Tennessee

CHERYL W. PATTERSON
CHARLOTTE KNIGHT GRIFFIN
MEMPHIS LIGHT, GAS & WATER
DIVISION
220 South Main Street
Memphis, Tennessee 38103

Counsel for Defendant
Memphis Light, Gas & Water
Division

BRUCE A. MCMULLEN
City Attorney
CITY OF MEMPHIS, TENNESSEE
125 North Main Street, Room 336
Memphis, Tennessee 38103

Counsel for Defendants
City of Memphis, Tennessee, and
Memphis Light, Gas & Water
Division

TABLE OF EXHIBITS

Exhibit	Description
1	Excerpts from Expert Report of Richard K. Spruill, Ph.D., P.G. (June 30, 2017)
2	Excerpts from Expert Report Addendum #1 of Richard K. Spruill, Ph.D., P.G. (July 31, 2017)
3	Excerpts from Deposition of Richard Spruill (Sept. 28, 2017)
4	Excerpts from Preliminary Report on Diversion of Ground-Water from DeSoto and Marshall Counties Mississippi Due to Memphis Area Pumpage (Expert Report of David Wiley) (December 31, 2006)
5	Excerpts from Report on Diversion of Ground Water from Northern Mississippi Due to Memphis Area Well Fields (Expert Report of David Wiley) (May 2007)
6	Excerpts from Update Report on Diversion and Withdrawal of Groundwater from Northern Mississippi into the State of Tennessee (Expert Report of David Wiley) (April 14, 2014)
7	Excerpts from Update Report on Diversion and Withdrawal of Groundwater from Northern Mississippi into the State of Tennessee (Expert Report of David Wiley) (June 30, 2017)
8	Excerpts from Update Report on Diversion and Withdrawal of Groundwater from Northern Mississippi into the State of Tennessee Addendum #1 (Expert Report of David Wiley) (July 31, 2017)
9	Excerpts from Deposition of David Wiley (September 26, 2017)
10	Excerpts from Expert Report of Brian Waldron, Ph.D. (August 30, 2017)
11	Excerpts from Deposition of John Van Brahana (November 5, 2007)
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14	Excerpts from the State of Mississippi's Responses to City of Memphis, Tennessee, and Memphis Light, Gas & Water Division's First Set of Request for Admissions (Jan. 20, 2017)
15	State of Mississippi's Response to Defendants' Proposed Statement of Facts (January 29, 2018)
16	Excerpts from Defendants' Joint Deposition Designations (Sept. 14, 2018)
17	Excerpts from Mississippi's Deposition Counter-Designations (Oct. 5, 2018)
18	Mississippi's Exhibit List (Sept. 14, 2018)

Exhibit 1

Excerpts from Expert Report of Richard K. Spruill, Ph.D., P.G

(June 30, 2017)

EXPERT REPORT

Hydrogeologic Evaluation and Opinions for
State of Mississippi versus
State of Tennessee, City of Memphis,
and Memphis Light, Gas & Water Division

PREPARED FOR:
Daniel Coker Horton & Bell, P.A.
265 North Lamar Boulevard, Suite R
Oxford, Mississippi 38655
Telephone: (662) 232-8979

PREPARED BY:
Groundwater Management Associates, Inc.
4300 Sapphire Court, Suite 100
Greenville, North Carolina 27834
Telephone: (252) 758-3310

GMA

June 30, 2017

Richard K. Spruill, Ph.D., P.G.
Principal Hydrogeologist

I. Introduction

Groundwater Management Associates (GMA) was retained by the firm of Daniel Coker Horton & Bell, P.A. (DCH&B) to provide expert geologic and hydrogeologic consulting regarding the origin and distribution of groundwater, interactions between surface water and groundwater, natural and man-induced migration patterns of groundwater, and specific topics regarding the geology and hydrogeology of predominantly sandy sediments comprising the Eocene-age Middle Claiborne Group that host the Sparta-Memphis Sand aquifer system in northwestern Mississippi and southwestern Tennessee. GMA's services included producing this expert report, which is focused on known or likely impacts on groundwater distribution and migration patterns within the Sparta-Memphis Sand (aka, the Sparta Sand, Memphis Sand, Memphis Aquifer, and other variations) in response to historic and ongoing pumping in Shelby County, Tennessee.

This expert report was produced for DCH&B using information available from publicly-available maps and reports from a variety of sources, including federal agencies such as the United States Geological Survey (USGS). This information was used in combination with the professional training and experience of the report's author, Dr. Richard K. Spruill, to develop opinions about the geologic and hydrogeologic setting of the study area. A partial list of resources and documents that were reviewed or employed to prepare the expert report is provided as Appendix A.

II. Qualifications

Richard K. Spruill, Ph.D, is GMA's Principal Hydrogeologist, president, and co-owner of the firm. Dr. Spruill's professional practice is focused on the hydrogeological exploration, evaluation, development, sustainable management, and protection of groundwater resources. He has been a geologist for over 40 years, and he is licensed in North Carolina as a professional geologist. Since 1979, Dr. Spruill has been a faculty member in the Department of Geological Sciences at East Carolina University (ECU), Greenville, North Carolina. He teaches hydrogeology, mineralogy, petrology, field geology, and physical geology at ECU. Dr. Spruill has provided litigation support and testified previously regarding geology, hydrogeology, water resources, and environmental contamination. His *curriculum vitae* is provided as Appendix B.

I, Dr. Richard K. Spruill, am the author of this expert report. My descriptions, interpretations, conclusions, and professional opinions described within this expert report are subject to revision, expansion, and/or retraction as additional information becomes available.

III Summary of General Opinions

The following is a summary of my opinions provided within this expert report. The opinions itemized below are based on (1) my education, training, experience, (2) detailed study of the geology and hydrogeology of the Mississippi Embayment, (3) evaluation of the specific geological and hydrological characteristics of the pertinent geological formations in north Mississippi and west Tennessee, and, (4) specific resources and materials referred to and identified with this report.

- The Sparta-Memphis Sand, also known as the Middle Claiborne Aquifer or the Memphis Aquifer, is an important source of potable groundwater within northwestern Mississippi and southwestern Tennessee. Most of the Sparta-Memphis Sand is a hydraulically-confined aquifer that consists of geologic deposits that accumulated within the Mississippi Embayment approximately 40 million years ago. The Sparta-Memphis Sand is inclined (dips) toward the west from areas where the unit crop out in both Mississippi and Tennessee. These sandy deposits thicken toward the center of the Embayment, which generally coincides with the present trace of the Mississippi River.
- The Middle Claiborne formation contains several lithologic constituents, including the Sparta Sand, that comprise an aquifer that has accumulated groundwater over many thousands of years. Historically, most of that groundwater originated as surface precipitation that infiltrated the formation where exposed at or near

the surface, and that groundwater migrated generally westward in both states to create a source of high-quality groundwater that did not naturally flow to any significant extent in a northerly direction out of Mississippi and into Tennessee.

- The Sparta-Aquifer Sand is the most productive source of high-quality groundwater available in the states of Mississippi and Tennessee.
- Massive withdrawal of groundwater by pumping wells operated by Memphis Light, Gas and Water (MLGW) in southwestern Tennessee has reduced substantially the natural hydraulic pressures existing in the Sparta-Memphis Sand in both Tennessee and Mississippi, thus artificially changing the natural flow path of Mississippi's groundwater in this aquifer from westward to northward toward MLGW's pumping wells. This groundwater withdrawal has dramatically reduced the natural discharge of Mississippi's groundwater in the Sparta-Memphis Sand to the Mississippi River's alluvial aquifer system within the state of Mississippi.
- The taking of Mississippi's groundwater by MLGW's pumping has decreased the total amount of available groundwater in the Sparta-Memphis Sand available for development in Mississippi, thus increasing the cost of recovering the remaining available groundwater from the aquifer within the broad area of depressurization (aka, cone of depression) created by MLGW's pumping.
- The intensity of pumping that has been, and continues to be, conducted by MLGW is not consistent with good groundwater management practices, and denies Mississippi the ability to fully manage and utilize its own groundwater natural resource.
- The best management strategy for sustainability of groundwater resources involves withdrawing groundwater at a rate that is equal to or less than the recharge rate of the aquifer being developed.

Richard K Spruill

Richard K. Spruill, Ph.D., P.G.
Principal Hydrogeologist

IV. Principles of Groundwater Hydrogeology

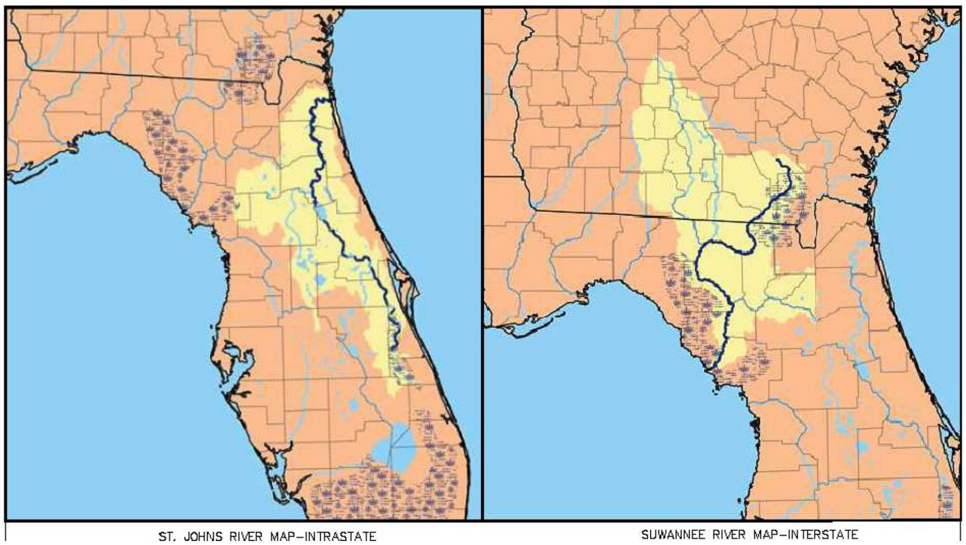
This section of the expert report provides an overview of key aspects of groundwater hydrogeology, especially as it pertains to the Sparta-Memphis Sand (aka, Memphis Aquifer or Middle Claiborne Aquifer) in northwestern Mississippi and southwestern Tennessee. Geologic and hydrogeologic details of the Sparta-Memphis Sand (SMS) are described elsewhere in the report.

Because groundwater availability depends on specific aspects of the local and regional geologic setting, it is not found in 'usable' quantities everywhere in the subsurface. The location, age, quality, movement, and availability of groundwater for human exploitation are determined by the actual geologic materials (i.e., aquifer) that host the water (e.g., sand) and the geologic and hydraulic characteristics of the aquifer system. This introduction to the basic principles of groundwater hydrology is generally tailored to be applicable to the groundwater system of the Middle Claiborne Group in northwest Mississippi and southwest Tennessee, and an analysis of the natural characteristics of the groundwater that is in legal dispute.

Groundwater originates as precipitation at the land surface, and some of that precipitation infiltrates the surface and enters the subsurface. In some places, groundwater originates as seepage through the bottoms and sides of surface water channels or basins, as well as by migration from other groundwater-bearing materials (e.g., 'confining units' that enclose some aquifers). Groundwater is located in the subsurface within small pore spaces located between rock and mineral particles and/or within fractures or other types of secondary porosity (e.g., voids in limestone from dissolved shell fragments).

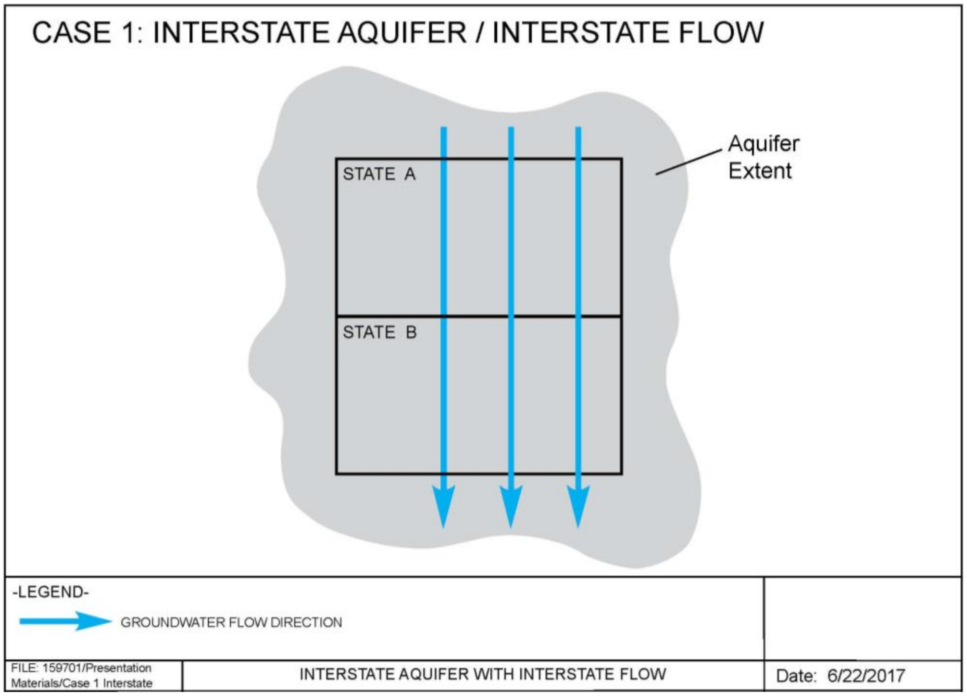
Because groundwater typically moves through the subsurface at a rate of only a few feet or tens of feet per year, the water at a particular location and depth may have been in the subsurface for many years, decades, or millennia. By way of comparison, groundwater flowing at 1 foot per day is generally considered to be fast, while the velocity of water flowing in a stream is typically more than 1 foot per second (more than based on the locations of the respective watersheds (drainage basins) from which the water is derived and the flow paths of the rivers.

Figure 13: Drainage Basin and Channel location of an Intrastate River (left) and an Interstate River (right) in Florida (modified from Wikipedia)

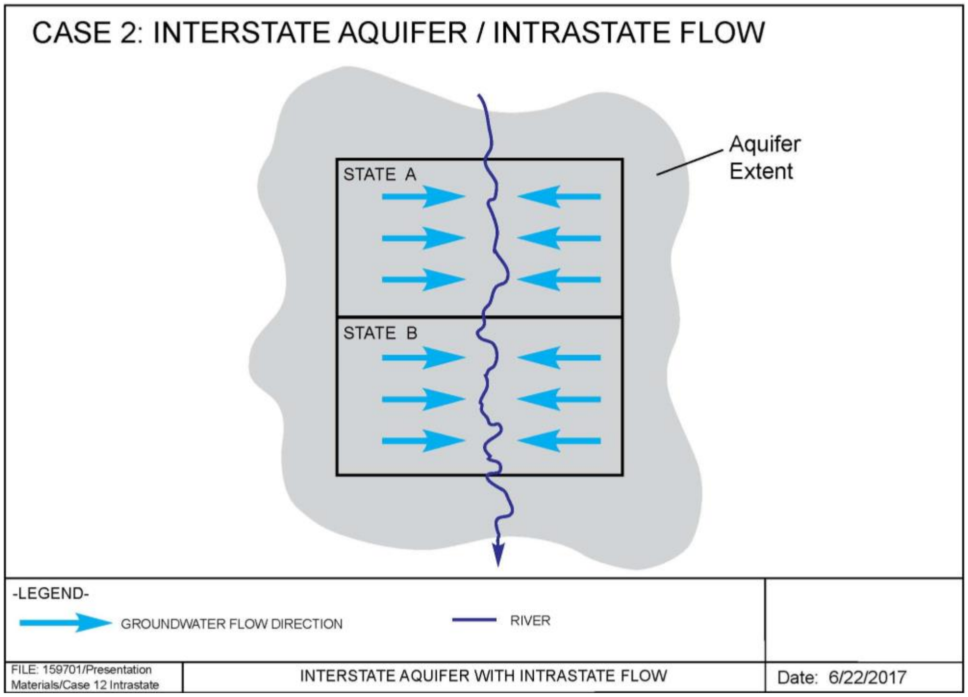


The natural territorial accumulation and flow of surface water along the lowest path created by geological processes is visible to the entire world. While it is not as visible, thus making it inherently more complicated, the natural territorial accumulation and flow of groundwater within a confined aquifer is also determined by geological forces and identifiable by application of the concepts described in this expert report. Using my analysis of the Sparta-Memphis Sand Aquifer, I present two hypothetical cases to illustrate how the groundwater within a confined aquifer may or may not be a shared natural resource like the two rivers in Florida illustrated above, and I draw a distinction between Intrastate and Interstate groundwater.

- **Case 1**. Figure 14 is a map of a regionally extensive aquifer, and two states sharing an east-west border lie entirely within the extent of the aquifer. Because of the regional geology, the natural groundwater flow within the aquifer is directed from north to south, and the groundwater flow lines clearly cross the east-west border between the two states. In this case, the groundwater accumulates within, and flows through, both states under natural conditions, thus the groundwater is a shared natural resource under natural conditions analogous to an interstate river.



- **Case 2**. Figure 15 is a map of a regionally extensive aquifer, and two states sharing an east-west border lie entirely within the extent of the aquifer. In this case, a river running southward bisects both states. Because of the geologic conditions, the natural groundwater flow within this aquifer is directed toward the river from both the east and the west. In this case, the groundwater accumulation and flow is confined to each state, as shown by flow lines parallel to the boundary separating the two states. In this example, the groundwater accumulates and flows (for millennia) through one state under natural conditions to its discharge area located within that state. Therefore, the groundwater is that state's natural resource under natural conditions, and the groundwater is analogous to the water in an intrastate river.



Although these hypothetical examples are simple, they are applicable to this litigation. The fundamental question in the specific case of groundwater flow in the northern part of the Mississippian Embayment, and specifically in the Wilcox and Claiborne Aquifer Systems, is: What is the nature of groundwater flow within an aquifer system that is laterally extensive, and what did a groundwater flow net (flow lines and equipotential contours) look like during the pre-development time frame? The only viable way to answer this question is to carefully examine the flow patterns in the confined portions of these aquifer systems prior to any significant development of the groundwater system (i.e., the construction and operation of groundwater production well fields).

Several researchers have produced analyses of the pre-development flow patterns for the Wilcox and/or Claiborne Aquifer Systems for the border region of northwestern Mississippi and southwestern Tennessee, including (1) numerous studies by the United States Geological Survey and (2) investigations by private and academic scientists and engineers. Examples for each group of researchers are described below.

Studies by the United States Geological Survey include the work by Cushing et al. (1964), which provides a good summary of stratigraphy of the Mississippi Embayment.

Exhibit 10

Excerpts from Expert Report of
Brian Waldron, Ph.D.

(August 30, 2017)

Sur-Rebuttal Expert Report of Brian Waldron, Ph.D.

Prepared on Behalf of the State of Tennessee

In the Matter of *Mississippi v. Tennessee et al.*, No. 143, Original (U.S.)

August 30, 2017

Signed: ____________________

Brian Waldron, Ph.D.

surface elevations to both ends of the vertical error range to measure whether contour placement or flow direction changed, i.e., whether vertical error might affect the water level map. Accounting for the vertical error at each well, the range of flow quantities moving from Mississippi into Tennessee expands, but the contour placement and flow direction do not change significantly. In particular, flow direction does not materially change to a direct east-west direction.

Combining Confined and Unconfined Water Levels

13. Spruill expresses the view that using groundwater levels or drawing contours from both the confined and unconfined portions of the Middle Claiborne invalidates the representation of actual conditions and flow. He states (at 22) that mixing water level contours between confined and unconfined is improper: "Data for the unconfined aquifer system should never be used to define groundwater flow patterns in the confined portions of the aquifer system which reflect regional flow patterns." (emphasis by Spruill) Spruill further states that Reed (1972) and Criner and Parks (1976) do not include water levels in the unconfined section of the Middle Claiborne, and he relies extensively on these two publications for his arguments. In fact, however, it is standard practice to measure levels and draw contours from both confined and unconfined portions of the aquifer, as demonstrated by USGS hydrologists, including the very authors on which Spruill relies.

14. To see clearly that USGS hydrologists analyze both the confined and unconfined areas together, it is important to determine where those regions are. Parks (1990) identifies thickness of the Upper Claiborne confining clay for the Shelby County area (Figure 1), and shows the limit of the Upper Claiborne pinching out before reaching Fayette County, Tennessee, to the east. Therefore, west of the dotted line the Middle Claiborne is considered confined and to the east unconfined.

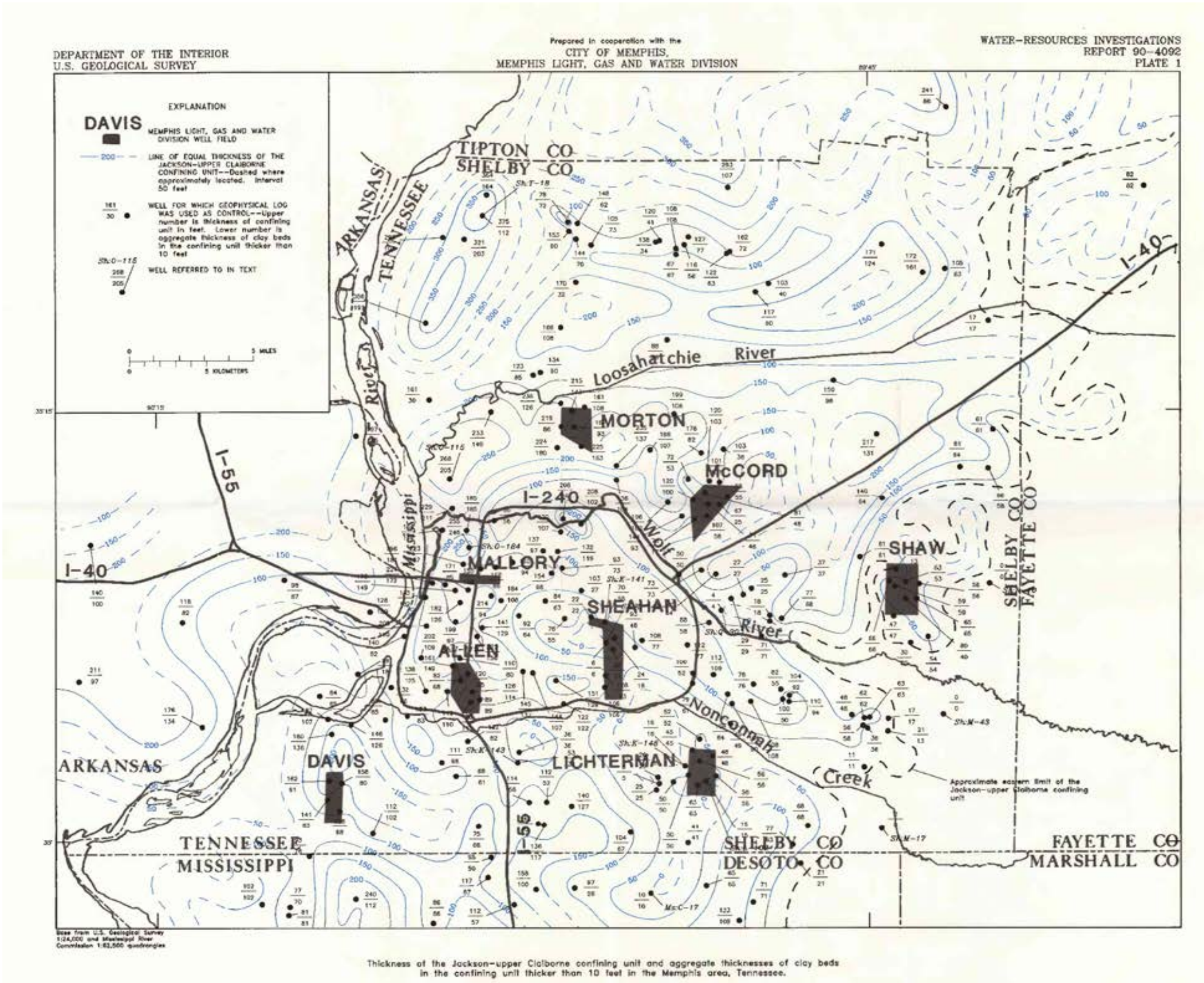


Figure 1. Thickness of Upper Claiborne confining clay with outcrop region of Middle Claiborne shown occurring along eastern Shelby County and into Fayette, Desoto, and Marshall Counties.

15. Lloyd and Lyke (1995) similarly provide in their USGS publication an illustration of the outcrop of section of the Middle Claiborne, and thus show the unconfined region (Figure 2) (Lloyd and Lyke, Figure 126, p. K27). They depict the unconfined region of the Middle Claiborne in West Tennessee passing through Fayette, Haywood, Crockett, Gibson, and Weakley counties, then continuing into Graves, Carlisle, and a small portion of Hickman counties in Kentucky.

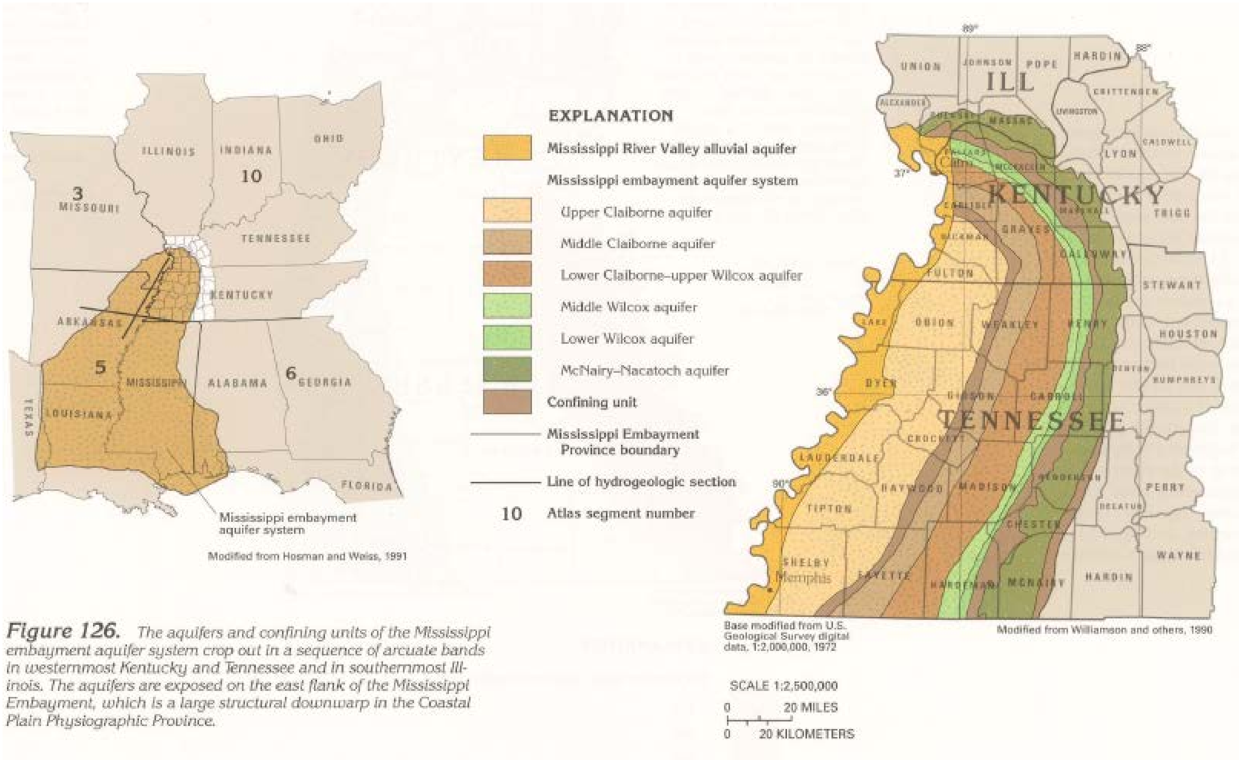


Figure 2. Depiction of extent and outcrop of Middle Claiborne in West Tennessee.

16. Spruill states (at 18) that "maps produced by Criner and Parks (1976) and Reed (1972) only consider groundwater-flow conditions in the confined portions of the aquifer" (emphasis by Spruill). Spruill also states: "It is significant that Criner and Parks only employed data from confined portions of the SMS aquifer system. Problems introduced by mixing water level data for confined and unconfined portions of an aquifer were discussed in my expert report" (p. 11) and "[d]ata for the unconfined aquifer system should never be used to define groundwater flow patterns in the confined portions of the aquifer system which reflect regional flow patterns" (p. 22) (emphasis by Spruill). Based on that view, Spruill states, "Examination of the data sources cited by W&L 2015, and the locations assigned for many of their 'well' data points used to create their Figure 4, reveals that they elected to combine indiscriminately data from confined and unconfined portions of the Sparta-Memphis Sand aquifer. Waldron and Larson's decision to combine these disparate data, in addition to the fundamentally flawed nature of the data itself, render the interpretation of the SMS' pre-development equipotential surface in W&L 2015 meaningless, and also explains why their interpretation is considerably different from that of USGS researchers (e.g., Reed, 1972; Criner and Parks, 1976)." (p. 15) Spruill relies heavily on Reed (1972) and Criner and Parks (1976) for his arguments.

17. Contrary to Spruill's assessment and argument regarding mapping confined and unconfined water levels together, Reed (1972) does in fact map water levels for the Middle Claiborne in the confined and unconfined sections (Figure 3). As shown in the red box, Reed (1972) maps water levels for the Middle Claiborne in Fayette County, Tennessee – shown by Parks (1990) and Lloyd and Lyke (1995) to be unconfined – while also mapping water levels in the confined portion of the Middle Claiborne in Shelby County. Reed (1972) further maps water levels in the Middle Claiborne

throughout West Tennessee and into southwest Kentucky in the same counties listed above minus Graves County, Kentucky (Figure 3, green box). As can be seen, Reed depicts (with the grayed area) the approximate area of the outcrop of the Middle Claiborne and maps a 400 ft water level in this area (Figure 3, blue box).

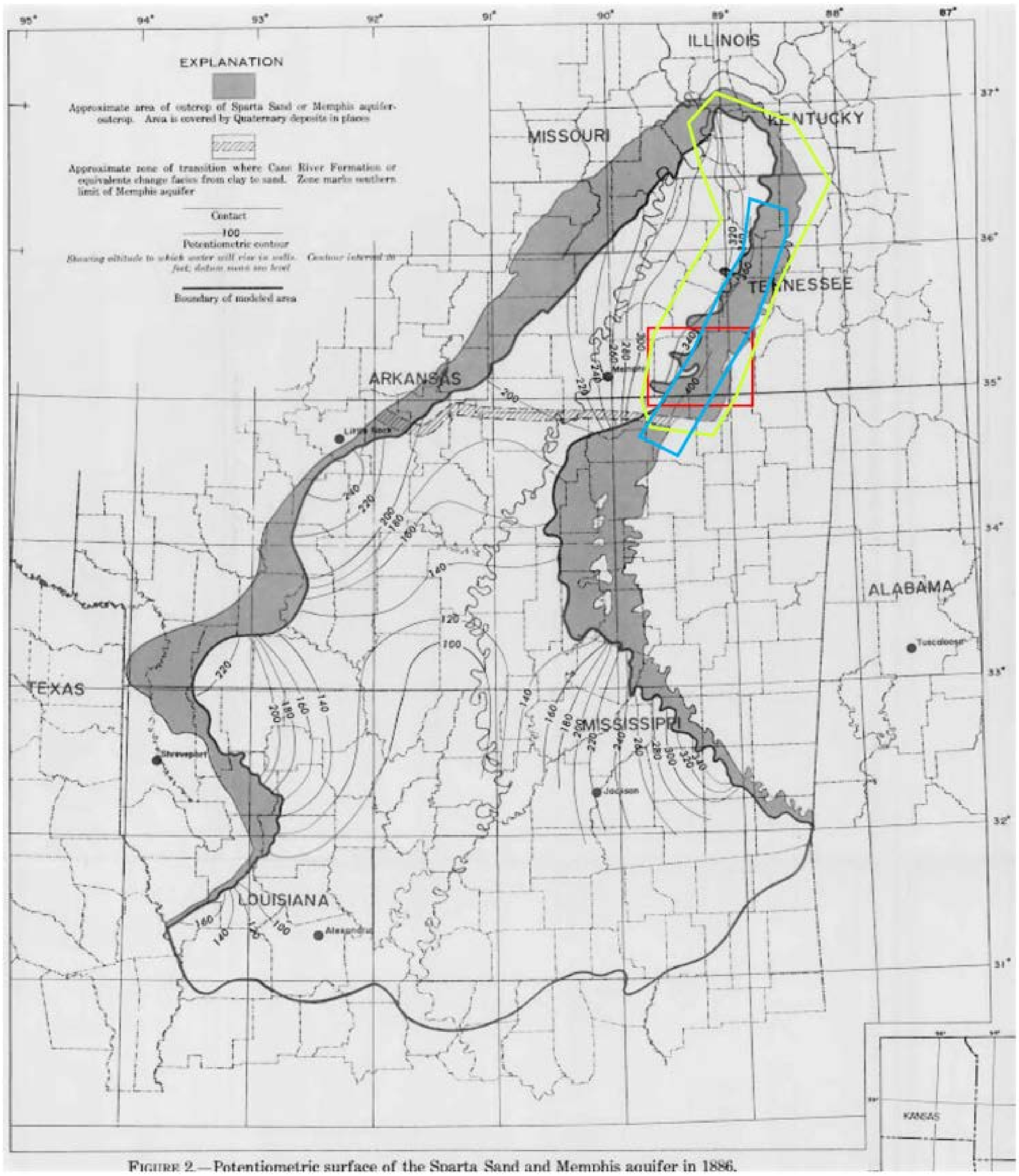


Figure 3. Predevelopment potentiometric surface contours of the Middle Claiborne suggested by Reed (1972), including outcrop (unconfined) region of the Middle Claiborne in West Tennessee.

18. Similarly, Criner and Parks (1976) can be seen mapping water levels in both the confined and unconfined regions. Criner and Parks use a well in Fayette County, Tennessee, with the USGS label Fa:R-002. According to Parks (1990),* this well is in the *unconfined* section of the Middle Claiborne residing within a remnant Upper Claiborne clay lens. This well is used in subsequent water level maps of the Middle Claiborne. Further, according to Parks (1990)'s new rendition of the outcrop section of the Middle Claiborne, the eastern water level contours of Criner and Parks (1976) reside in the unconfined section of the Middle Claiborne.

19. Additionally, Parks and Carmichael (1990) mapped the thickness of the Middle Claiborne throughout West Tennessee and depicted on their *Figure 2* (Figure 4) the outcrop (i.e., unconfined section) of the Middle Claiborne residing between two thick black lines. Parks and Carmichael (1990) produce in their subsequent *Figure 3* (Figure 5) the "potentiometric surface" of the Middle Claiborne in 1983. Clearly, water levels are mapped in the confined and unconfined sections of the Memphis aquifer.

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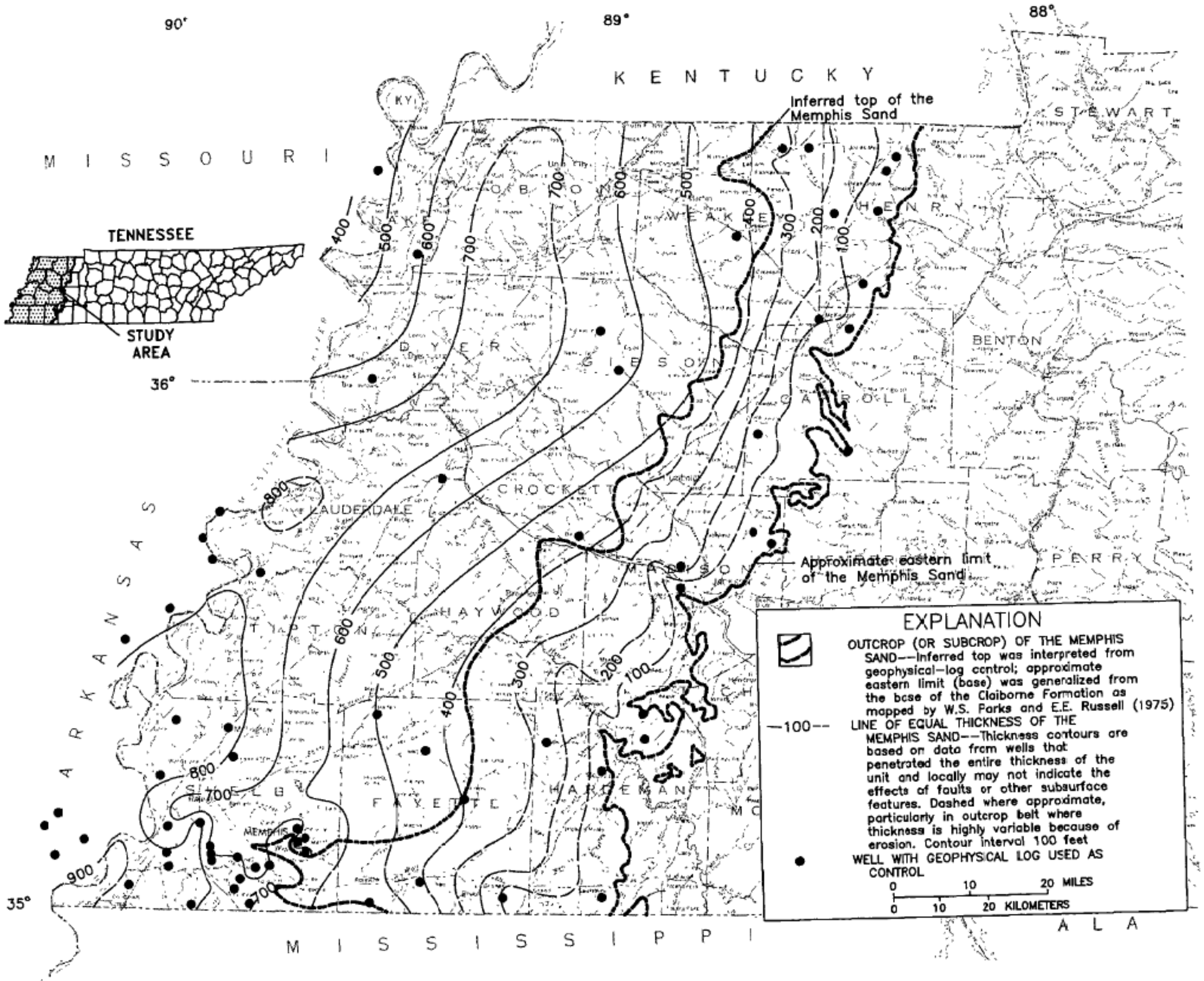
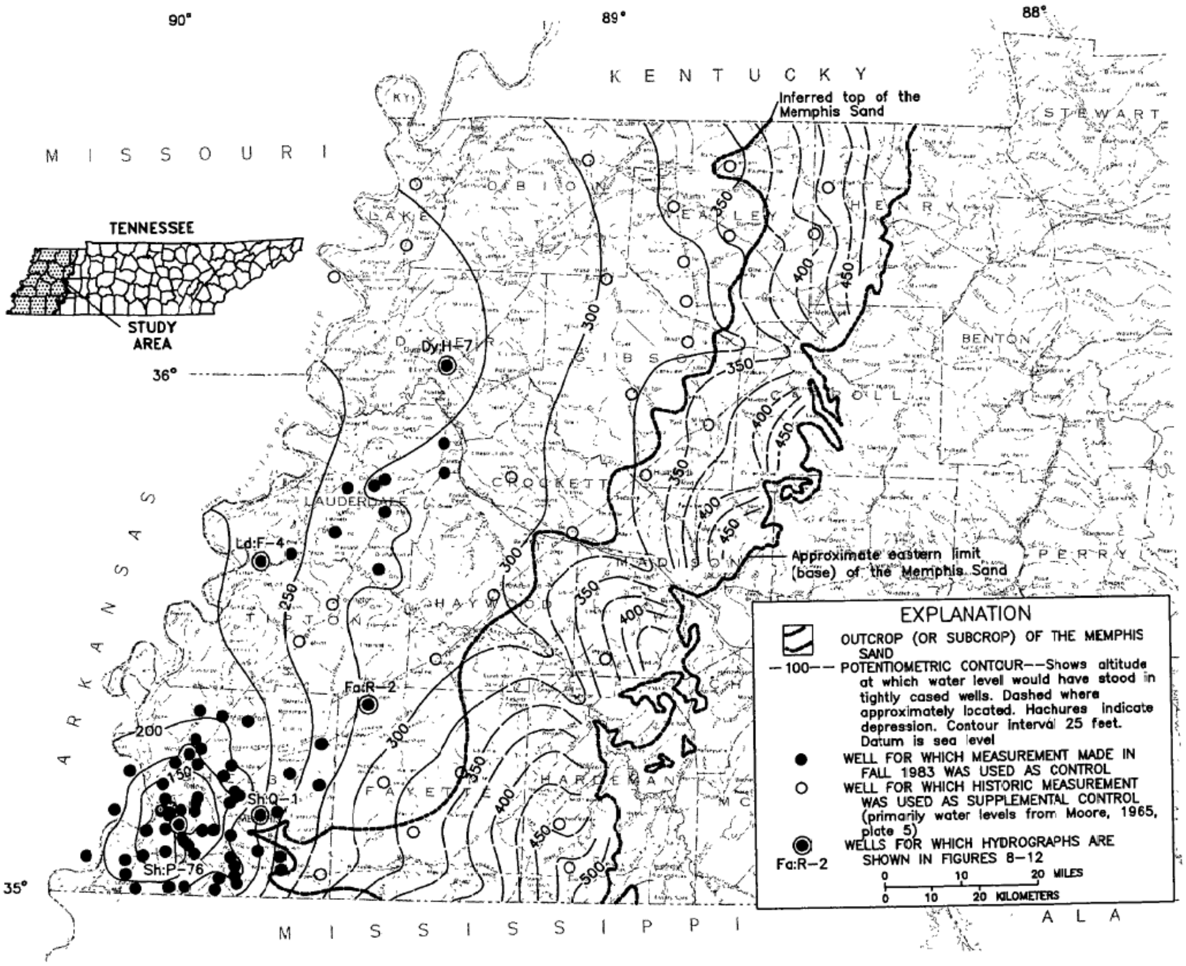
*Each reference to "Parks" among these papers refers to the same W.S. Parks.



Base from U.S. Geological Survey, State base map, 1:500,000, 1973

Figure 2.--Generalized thickness of the Memphis Sand.

Figure 4. Extent of the Middle Claiborne in West Tennessee, including depiction of the outcrop (unconfined) region of the Middle Claiborne.



Base from U.S. Geological Survey, State base map, 1:500,000, 1973

Figure 3.——Generalized potentiometric surface in the Memphis aquifer, fall 1983.

Figure 5. Potentiometric surface of the Middle Claiborne in West Tennessee depicted in the confined and unconfined regions of the Middle Claiborne.

20. Spruill (at 20-22) cites Schrader (2008) in his argument over changes in water levels between 1886 levels as analyzed by W&L and 2007 levels as analyzed by Schrader (2008). Spruill's own argument involves a well in the unconfined portion of the Memphis aquifer (according to Parks, 1990) using a study by Schrader (2008) that, like others, maps water levels in both the confined and unconfined sections of the Middle Claiborne (Figure 6, see grayed areas) in Tennessee and Mississippi. (W&L also use Schrader (2008) in their analysis of comparing groundwater quantities passing from Mississippi into Tennessee.)

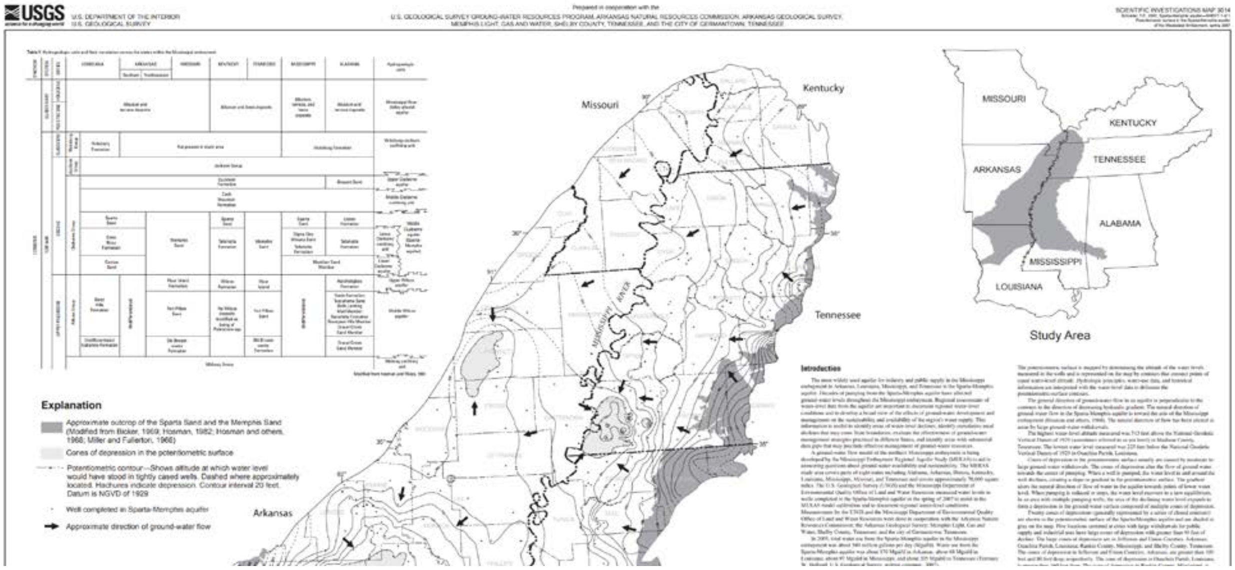


Figure 6. Potentiometric contours of the Middle Claiborne in 2007 mapped within the confined and unconfined regions (lower half of original figure has been cut off).

21. Mapping water levels in the Middle Claiborne confined and unconfined regions is a common practice followed by many of the very USGS authors Spruill cites. W&L followed this ordinary practice in mapping both confined and unconfined regions together.

22. The same practice is followed for other aquifers, as well. For example, Lloyd and Lyke (1995) map water levels in the Lower Wilcox aquifer confined and unconfined portions in West Tennessee in their *Figure 137* (Figure 7), again illustrating the commonality of mapping confined and unconfined water levels together.

Wells Used by Waldron and Larsen Were Recorded in USGS Publications

23. Spruill remarks on the lack of well construction data, arguing that it reduces the reliability of the water level data used by W&L. Although construction techniques were not as well-documented as they would be today, the USGS reported the water levels nonetheless. If the water levels were questionable because of unusual construction in particular wells, it seems unlikely that USGS authors (Fuller, 1903; Crider and Johnson, 1906; Glenn, 1906) would have recorded water levels for scientific purposes, as the USGS is a scientific research and data collection body. Spruill goes on to say (at 18): "Historic records used in W&L 2015 to obtain water level data do not provide any information about well construction and grouting." (emphases by Spruill). [In fact, an early publication by Brown (1947) as part of a Mississippi State Geological Survey lists numerous wells in each county in Mississippi that includes water levels but not a single mention of well construction information (Figure 12).]

The earliest, continuous, automatically-recorded water-level data collected in the Memphis area began in 1927 on Sh:O-124. This well is near the site of the first well completed to the Memphis Sand in 1886, and for this reason, its hydrograph was projected backward in time to illustrate the probable original water level with respect to the land surface (fig. 3). This projection to an estimated water level

Figure 9. Excerpt from Criner and Parks (1976) regarding back-projection of only Sh:O-124.

28. As noted, Spruill suggests (at 17) that "[m]any 'wells' cited W&L 2015 *are <u>not</u> actually wells*" (emphasis by Spruill). Though this statement is incorrect (as discussed), Spruill argues (at 17) that water level data derived from what he thinks are not wells in W&L renders our analysis invalid. Yet, in fact, the single well Criner and Parks (1976) project backwards in time to define actual predevelopment water level conditions for the region (i.e., Sh:O-124) is not a well, but a water collection shaft (see Figure 10).

It should be noted that well Sh:O-124 is an inspection shaft to an underground tunnel used in an early water-supply system as a collector for water which flowed from several wells screened in the Memphis Sand. Little is known about the tunnel, but it is reported to have been

Figure 10. Excerpt from Criner and Parks (1976, p. 13) on Sh:O-124, the single and only well used to project probable predevelopment conditions.

29. Spruill also questions the reliability of the data used by W&L by stating (at 16): "In addition to their use of ambiguous, uncertain, or clearly defective historic data from wells of unknown construction to develop a map based on those completely unreliable data." Again, however, Criner and Parks (1976), on which Spruill heavily relies, expressly state that Sh:O-124 is of questionable reliability, noting that: (1) Sh:O-124 is not a well but a tunnel (Figure 10); (2) "[l]ittle is known about the tunnel" (Figure 10); and (3) water levels in the tunnel were "anomalously high" and influenced by recharge (Figure 11).

The hydrograph (fig. 3) and potentiometric-surface maps indicate that the water level in Sh:O-124 is anomalously high and that the tunnel may have become a line of recharge to the Memphis Sand in about 1955.

Figure 11. Excerpt from Criner and Parks (1976, p. 13) on Sh:O-124 and observed anomalously high water levels.

TABLE 13—RECORD OF WATER WELLS IN DESOTO COUNTY

No.	Location	Owner or name	Driller	Completed	Diameter well (In.)	Depth well (feet)	Depth cased (feet)	Depth to screen (feet)	Length of screen (feet)	Principal water-bearing bed: Thick. (feet)	Material	Geologic form.
1.	SW.1/4, NE.1/4, Sec.24, T.1 S., R. 10 W.	R. P. Harris	Mr. Seay	1921	3	1532	1532	...	60	...	Sand	Lower Wilcox
2.	NW.1/4, NE.1/4, Sec.23, T.1 S., R. 10 W.	T. P. Howard	T. B. Minyard	1926	3(?)	1580	...	...	...	...	Sand	Lower Wilcox
3.	NW.1/4, NE.1/4, Sec.32, T.1 S., R. 9 W.	H. P. Sullivan	C. M. Journey	1935	2	1525	...	...	...	57	Sand	Lower Wilcox
4.	NE.1/4, SW.1/4, Sec.35, T.1 S., R. 10 W.	O. L. Cox		1922	3(?)	1580	...	...	...	...	Sand	Lower Wilcox
4a.	NE.1/4, SW.1/4, Sec.35, T.1 S., R. 10 W.	O. L. Cox	C. M. Journey	1940	3	1541	1541	1499	42	80	Sand	Lower Wilcox
5.	NW.1/4, NE.1/4, Sec.24, T.2 S., R. 10 W.	Mrs. J. C. Brantley	E. S. Archer	...	2½	1460	...	...	20	...	Sand	Lower Wilcox
6.	NW.1/4, NE.1/4, Sec.24, T.2 S., R. 10 W.	Mrs. J. C. Brantley		...	4½	2120	...	...	...	...	...	Lower Wilcox
7.	NW.1/4, NW.1/4, Sec.24, T.2 S., R. 10 W.	W. W. Blythe & others	J. A. Pollard	...	3	1560	...	...	...	...	Sand	Lower Wilcox
8.	SW.1/4, SE.1/4, Sec.32, T.2 S., R 10 W.	I. A. Clement		...	3	1800	...	...	...	...	Sand	Lower Wilcox
9.	NE.1/4, NW.1/4, Sec.15, T.3 S., R. 9 W.	S. B. Dean	C. M. Journey	1938	4	324	324	310	16	29	Sand	Cockfield
10.	NW.1/4, SE.1/4, Sec.13, T.3 S., R. 8 W.	Town of Hernando	Layne-Central Co.	1934	8	250	...	...	...	50+	Sand	Kosciusko
11.	NW.1/4, SE.1/4, Sec.13, T.3 S., R. 8 W.	Town of Hernando	Layne-Central Co.	1940	8	250	...	...	...	50+	Sand	Kosciusko
12.	SW.1/4, NE.1/4, Sec.2, T.4 S., R. 9 W.	Arkabutla K III bore hole		1940	...	365	...	...	...	...	...	Kosciusko(?)

TABLE 13—RECORD OF WATER WELLS IN DESOTO COUNTY—(Continued)

No.	Water Level: + or − meas. pt. (feet)	Date measured	Measuring point: Feet above m.s.l.	+ or − ground (feet)	Description	Yield Flow	(g.p.m.) Pump	Temp. °F.	Use of water	Other records and general information
1.	7.0	July 15	213	1	Top of well tee	70	10(app.)	...	Dom.	Reported yield when drilled
2.	16.3	July 15	210	0	Top of well tee	...	...	...	Dom.	Reported decline of static head
3.	16.25	July 15	205	0	Top of well tee	...	...	...	Dom.	Static head of 18 feet reported when drilled
4.	18.75	July 15	207	1	Top of 1¼ in. lower tee	...	...	74	Dom.	4½ in. casing land at 1139 feet 8 in.
4a.	+	May 22	206	0	Level of land at well head	120	...	...	Dom.	Reported by driller
5.	16.0	July 15	210	3	Top of well tee	140	...	...	Dom.	Reported yield when drilled
6.	+	...	...	...	...	1	...	...	Aban.	
7.	−18.9	July 15	206	2	Top of well tee	...	...	77	P. S.	
8.	21.85	July 15	205	1.5	Top of well tee	...	...	...	Dom.	
9.	−80.0(app.)	Feb. 22, 1940	301	0	Concrete pump base	25	...	...	Saw Mill	
10.	...	...	...	...	...	250	...	...	P. S.	
11.	...	...	...	...	...	250	...	...	P. S.	
12.	...	...	197.5	...	...	...	...	...	...	

Figure 12. Table 13 for groundwater wells in DeSoto County, Mississippi (Brown, 1947).

30. Spruill states (at 18) that W&L mentioned Well #3 (Forrest City, Arkansas), but did not use it in their analysis; he further suggests that, if W&L had done so, it would reorient the Middle Claiborne predevelopment gradient to be more east-to-west. In fact, however, W&L did incorporate this well into their analysis. The well is on the extreme outskirts of the data area, and there are not enough other data near that well to draw a 2D contour for a single point (following the logic that two points define a line). Figure 13 shows the Forrest City well, which is present in the analysis though not shown on W&L's *Figure 4*.

40. Reed (1972) does not show any well locations used to derive his predevelopment groundwater level map of the Middle Claiborne, so no determination can be made about the wells' quality or validity. Reviewing the three references listed by Reed (1972) does not reveal any well locations.

41. Criner and Parks (1976) use water levels from six wells (though, as noted, Sh:O-124 is a tunnel) to show water level changes in the Middle Claiborne between 1886 and 1975. (See Figure 8, upper graph.) These wells are labeled Sh:O-1274, Sh:U-002, Sh:Q-001, Sh:P-076, Sh:K-066, and Fa:R-002.

42. The University of Memphis' Center for Applied Earth Science and Engineering Research has well information as follows:

a. Sh:K-066: screen length of 61 ft (Figure 18) and no construction record

b. Sh:Q-001: screen length of 9 ft (Figure 18) and no construction record (Figure 19)

c. Sh:P-076: screen length of 60 ft (Figure 18) and no construction record (Figure 20)

d. Sh:U-002: screen length of 80 ft (Figure 18) and no construction record (Figure 21)

e. Sh:O-124: no screen (not a well; see Figure 10) and no construction record

f. Fa:R-002: screen length of 20 ft (Figure 18) and no construction record

TN157R000414PR

OBSERVATION WELL DATA

MEMPHIS SAND

MLGW/USGS WELLS

MLGW NUMBER	USGS NUMBER	WELL LOCATION	WELL ADDRESS	TOP SCREEN	WELL DEPTH	LENGTH SCREEN
0M1	SH:O-212	WELL LOT 13	1245 N. PARKWAY	733	743	10
0M2	SH:P-97	WELL LOT 36	721 IDLEWOOD	815	825	10
0M3	SH:O-179	WELL LOT 34	566 LEATH	462	472	10
0M51	SH:K-66	WELL LOT 73	3926 CENTRAL	438	499	61
1M1	SH:J-126	WELL LOT 135	961 ALCY	255	265	10
2M1	SH:Q-59	WELL LOT 219	6138 ELMORE	830	840	10
2M2	SH:P-85	TEST HOLE #1	5571 RALEIGH LA GRANGE	312	319	7
3M1	SH:L-39	WELL LOT 307	6304 KINGCREST	341	349	8
4M1	SH:J-140	DAVIS STA.	1800 W.SHELBY DR.	543	553	10
5M1	AR:O-1	ST.CLAIRE ARK	FOGELMAN FARM	477	497	20
5M2	AR:H-2	MILLERS ARK.	REMBERT FARM	480	500	20
5M3	AR:C-1	LEHI ARK.	CARLSON FARM	602	622	20
5M4	SH:P-76	PEABODY PARK	CENTRAL AVE.	428	488	60
5M5	SH:O-1	FRAYSER	O.K. ROBERSON RD.	424	434	10
5M6	SH:P-1	RALEIGH	4858 SCHIBLER RD.	332	342	10
5M7	SH:Q-1	CORDOVA	8179 MACON RD.	375	384	9
5M8	SH:J-1	GOODMAN	5420 WEAVER RD.	327	334	7
6M1	SH:P-113	WELL LOT 617	3225 RIDGEMONT	519	529	10
7M1	SH:R-31	WELL LOT 700	10320 KENTWOOD EST.	500	540	40

TOTAL WELLS 19

USGS WELLS NOT OWNED BY MLGW

WELL OWNER	USGS NUMBER	WELL LOCATION	WELL ADDRESS	TOP SCREEN	WELL DEPTH	LENGTH SCREEN
USGS	FA:R-2	BRADEN	HWY 59	345	365	20
ERVIN	SH:U-2	SLOANVILLE	SHAKE RAG RD.	360	440	80

TOTAL WELLS 2

Figure 18. Screen lengths of wells, including those used by Criner and Parks (1976).

TN157G000537ML

Mr. Fred H. Klear Jr.

OBSERVATION WELL NO. 3
Log of Well

LOCATION OF WELL   TN157-000537 ✓

On Macon road 5 miles East of Highway NO. 70

LOG

0	To	15	Feet	----- Clay
15	"	45	"	----- Sand & Gravel
45	"	120	"	----- Clay
120	"	185	"	9---- Sand
185	"	210	"	----- Clay
210	"	258	"	----- Sand
258	"	348	"	----- Clay
348	"	400	"	----- Sand
400	"	440	"	----- Mucky sand
440	"	460	"	----- Muddy sand
460	"	492	"	----- Brown clay
492	"	493	"	----- Rock
493	"	507	"	----- Clay
507	"	580	"	----- Sand

OBSERVATION WELL NO. 4
Log of Well

LOCATION OF WELL

On Winchester Pipe 4 miles East of Highway No. 78, South of City.

LOG

0	To	18	Feet	------ Clay
18	"	65	"	------ Sand & Gravel
65	"	178	"	------ Clay
178	"	320	"	------ Sand
320	"	465	"	------ Clay
465	"	480	"	------ Sand
480	"	550	"	------ Clay
550	"	580	"	------ Sand

Figure 19. Only available information for Sh:Q-001, which is a driller's log (above) and a geophysical log, available at CAESER or USGS.

TN157D000268ML

LITHOLOGIC LOG

Owner: Memphis Light, Gas & Water | WELL No: ~~79:5-135~~ Sh:P-76
Driller: Date: | County: Shelby State: Tenn.
Logged by: Date: | Location:
Datum | Location No. In Peabody Park E of pump house north of Central Ave.
Depth, hole: dia:
Depth, casing: dia:
Depth, screen: dia: | Alt. datum Ca. 305'? Alt. LSD
E. log: gamma: caliper: temp: conductivity flow meter

AGE	FORMATION	LITHOLOGY	Thick-ness (ft)	Depth (feet)
		Clay, surface	10.0	10.0
		Clay, yellow	14.0	24.0
		Sand, yellow; and graved	56.0	80.0
		Rock	1.5	81.5
		Sand, fine, white	1.5	83.0
		Clay, blue, hard	43.0	126.0
		Clay, brown	4.0	130.0
		Lignite	4.0	134.0
		Clay, blue, hard	12.0	146.0
		Sand; rock	1.5	147.5
		Clay, blue	38.5	186.0
		Rock, hard	1.0	187.0
		Clay, blue	33.0	220.0
		Rock, hard	.6	220.6
		Clay, blue	14.4	235.0
		Sand, fine, white	30.0	265.0
		Sand, fine and clay streaks	65.0	330.0
		Sand, fine	40.0	370.0
		Sand, good	20.0	390.
		Sandstone	4.0	[illegible]

Figure 20. Only available information for Sh:P-076, which is a driller's log (above) and a geophysical log, available at CAESER or USGS.

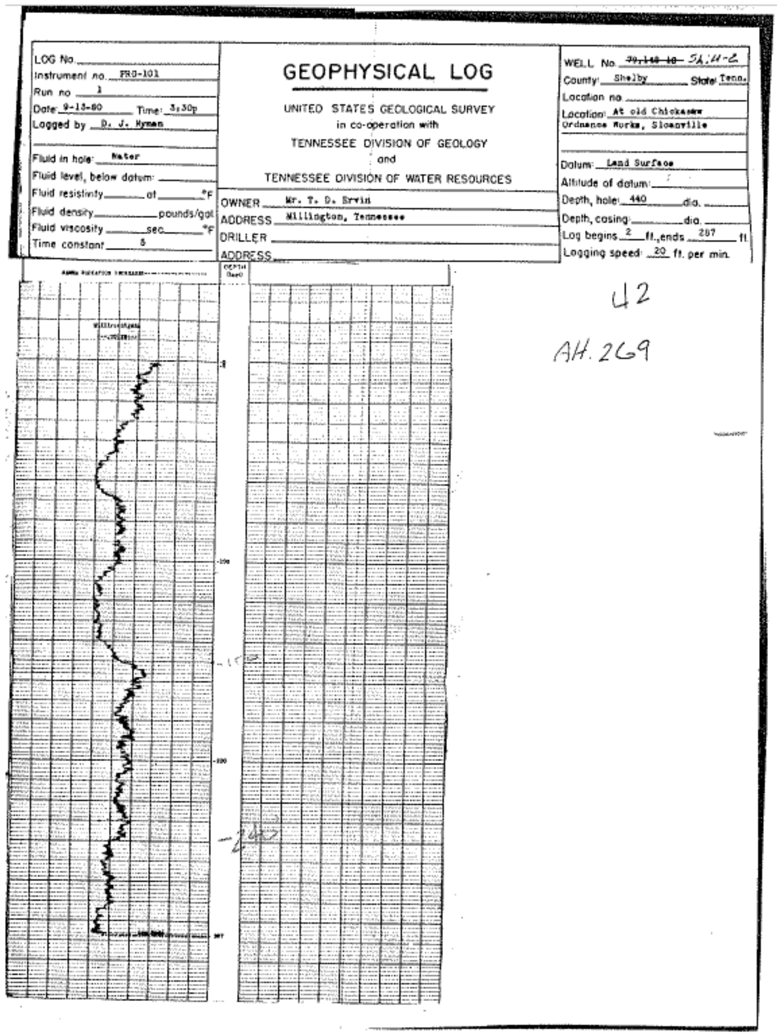


Figure 21. Only available information for Sh:U-002 (geophysical log).

43. An example of a construction log is shown in Figure 22 for Sh:L-010, used by Criner and Parks (1976) in developing their potentiometric surfaces of the Middle Claiborne for the years 1960, 1970, and 1975 (not predevelopment). Note that the 6-inch screen (Layne with #8 opening) has a length of 50 ft, a length Spruill expresses he believes to be invalid for developing water level maps.

Exhibit 11

Excerpts from Deposition of
John Van Brahana

(November 5, 2007)

IN THE UNITED STATES DISTRICT COURT
FOR THE NORTHERN DISTRICT OF Mississippi
DELTA DIVISION

JIM HOOD, Attorney General, ex rel,
THE STATE OF MISSISSIPPI, Acting
for itself and Parens Patriae for
and on behalf of the People of the
State of Mississsippi,

Plaintiff,

Vs. Case No. CIVIL ACTION 2:05CV32D-B
(And Related Cases)

THE CITY OF MEMPHIS, TENNESSEE and
MEMPHIS LIGHT, GAS & WATER DIVISION,

Defendants.

THE DEPOSITION OF JOHN VAN BRAHANA

November 5th, 2007

BRIAN F. DOMINSKI, RPR, RMR
ALPHA REPORTING CORP.
COURT REPORTERS
LOBBY LEVEL, 100 NORTH MAIN BUILDING
Memphis, Tennessee 38103
(901) 523-9874

suit, the lawsuit, was filed, February of 2005, somewhere -- March, 2005.
Q. By whom were you retained?
A. By the lawfirm.
Q. By --
A. Baker, Donelson, Bearman.
Q. What was the scope of or your charge in connection with your duties as a consulting expert? In other words, what services were you asked to provide by the Baker-Donelson Lawfirm?
A. Assessment of technical work that I had done previously, groundwater geology, in the area.
Q. What do you mean "assessment of prior work or previous work"?
A. I had worked in the Memphis area from approximately 1977 on with the US Geological Survey, and in that collaboration I had been involved with groundwater modeling and practical problems that related to movement of water underground in the shallow aquifers, the Memphis Sand and the deeper aquifer.
Q. So from 1977 until 2005, when you

They wanted to minimize impact on it as much as possible. They found that the groundwater modeling tool was one model that they could do so.

Q. When you say "minimize impact," what do you mean?

A. I mean spread out areas of pumping so that they would have the least deleterious effect on the general area, on the region, and minimize drawdown. If you take all of the water from one source, then you are going to create a much deeper drawdown cone. If it is spread out, then it is minimized.

Q. What would happen if you create this larger, deeper cone? What would be the deleterious effect? You referred to a deleterious effect that needed to be minimized.

A. They would have to spend a lot more money pumping because the water-level declines would be greater in the main portion of the well field.

Q. So it would result in greater cost to MLG&W and its customers?

A. That is one. Yeah, that's one impact. If you had any -- depending on where that source was, if you were drawing water, when you create a greater difference, you can impact the amount of water that you would draw from those shallower aquifers, and the shallower aquifers would be dried up, and if there were bad water quality in those, that could quite possibly be drawn into the system.

Q. Was that more of a qualitative issue? I mean, in other words, this was more of a contamination issue?

A. That portion, but it didn't start -- the water quality wasn't the main issue when we started. It became so later because they found Tritium, which is a radionuclear-active hydrogen. It is radioactive and gets it from the atmosphere. It has got a short half-life of point three years. If you've got Tritium in the system, that means you are recharging the area with young water. They found some Tritium in several of their wells, I think at the Alamo Field.

Q. Where does that come from, the Tritium?
A. Tritium comes from the -- the United States did some -- there is some natural production of Tritium in the atmosphere, but it is in the precipitation. We did some bomb-testing in the atmosphere back in the 1960's, 1950's and 1960's.
Q. Nuclear?
A. Nuclear testing. It generated a variety of tracers of substances, chemical substances, which if we see that in the water, it is usually an indication that the water has recharged fairly recently.
Q. When you started, what was the real focused issue? What was the sort of jugular issue, if you will, that you were called upon to assess? I'm referring to the 1970's when you began working on the Memphis Sand Aquifer.
A. It was on --
MR. DAVID BEARMAN: If there was one.
Q. (BY MR. CAMERON) You said

contamination was not a main issue. So what was the main issue?
A. It was probably water quantity, how much, and just understanding the system. MLG&W has always sought to understand the system. If we needed -- if we had a data gap to understand the model, what a model does is it allows you to test hypotheses about how things work, and MLG&W in my opinion always came forward with -- I mean, if we're missing data, they came forward and volunteered putting wells in at places we needed.
Q. So USGS worked cooperatively on this with MLG&W?
A. Yes.
Q. Did MLG&W fund any of the work that was done by USGS?
A. They did. They funded it all.
Q. They fund the all of the --
A. Excuse me, it was a cooperative, but, yes, they were a major player in that.
Q. When you became involved in the assessment of water quantity in the mid-1970's, did you have to start from

You've put no time frame on the question. And I think that that moves over into Rule 26, consulting expert, and what we talked about earlier.

Q. (BY MR. CAMERON) To your knowledge, Dr. Brahana, has MLG&W ever taken any steps whatsoever to reduce the cone of depression so that it would not extend into the State of Mississippi?

A. I don't know the answer to that. I do not know of any.

Q. If MLG&W shut in pumpage of the Davis or Lichterman or ceased pumpage from the southern well fields, would that pull the cone of depression or reduce it so it wouldn't extend into the State of Mississippi?

MR. DAVID BEARMAN: Same objection.

I'm going to ask you not to answer that question for the same reason as stated before.

Q. (BY MR. CAMERON) To your knowledge, were the deleterious effects you referred to earlier in relation to the aquifer, did those include quantity issues that may arise as between the State of Mississippi and the City of Memphis?

MR. DAVID BEARMAN: I'm going to object to that question because that's not what he said, number one, and, number two --

MR. CAMERON: No, no, I'm asking they were among the deleterious effects.

MR. DAVID BEARMAN: He hasn't testified to any deleterious effects.

MR. CAMERON: His opinion was, as I recall, and he stated an opinion, that Memphis was a good steward and that it had taken steps to minimize the deleterious effects of pumpage on the aquifer.

I'm asking do those deleterious effects include steps taken to reduce the cone of depression so it does not extend into the State of Mississippi.

MR. DAVID BEARMAN: Based on his knowledge from when he was working with the USGS, is that your question? That's fine.

Q. (BY MR. CAMERON) Let me ask this, then: From whose perspective were you talking when you said MLG&W was a good steward and had taken steps to minimize the deleterious effects of pumpage?

A. Historically from what I've seen as a hydrogeologist, that overall opinion was mine based on news articles, based on publications, based on things that I have seen recounting of -- looking at the data, how much drawdown had occurred over long periods of time.

Q. Can you identify any specific action taken by MLG&W to mitigate the cone of depression?

MR. DAVID BEARMAN: I'm going to object to the form.

You can answer.

A. Oh, okay. I didn't know that term. I thought -- I cannot name specific cases other than the fact that they -- it is apparent they have spread out the well field, the pumping. So no.

Q. (BY MR. CAMERON) Is it your

understanding that MLG&W moved well fields out or spaced them so as to mitigate the cone of depression?

A. They looked at their new well fields to distribute pumping from -- I have forgotten. I think Morton is a new well field. I think -- let me look. I can't remember the names of all the well fields now. It is more redistribution of existing pumping. Shaw, for example, Shaw was shifted out, Morton was accommodated, features up in the north.

Q. Do you have any documents in your file or have you reviewed any documents in connection with your preparation of Exhibit 10 that would support the notion that MLG&W has spread out well fields so as to mitigate the cone of depression?

A. The way you asked that question, no, I don't.

MR. CAMERON: If we could take just a moment. We may be done.

THE VIDEOGRAPHER: The time is now 2:36. We're going off the record.

Exhibit 12

Excerpts from Deposition of
Charles Thomas Branch

(October 1, 2007)

UNITED STATES DISTRICT COURT
FOR THE NORTHERN DISTRICT OF MISSISSIPPI
DELTA DIVISION

JIM HOOD, Attorney General, ex rel.,
THE STATE OF MISSISSIPPI PLAINTIFF

VS. CIVIL ACTION NO: 2:05CV32-D-B
CONSOLIDATED FOR DISCOVERY

THE CITY OF MEMPHIS, TENNESSEE and
MEMPHIS LIGHT, GAS & WATER DIVISION DEFENDANTS

DESOTO COUNTY, MISSISSIPPI PLAINTIFF

VS. CIVIL ACTION NO: 2:05CV085-D-B

THE CITY OF MEMPHIS, TENNESSEE and
MEMPHIS LIGHT, GAS & WATER DIVISION DEFENDANTS

NESBIT WATER ASSOCIATION, INC., et al. PLAINTIFFS

VS. CIVIL ACTION NO: 2:05CV108-D-B

THE CITY OF MEMPHIS, TENNESSEE and
MEMPHIS LIGHT, GAS & WATER DIVISION DEFENDANTS

THE VIDEOTAPED DEPOSITION OF
CHARLES THOMAS BRANCH

Taken on behalf of the Defendants on October 1, 2007, at the Barrett Law Office, 404 Court Square North, Lexington, Mississippi 39095, beginning at approximately 9:36 a.m.

Reported By: Marilyn C. Rea, CSR 1059, RPR 036208

4656721a-c7c3-4f47-87c3-8a2583d49212

Alan, have we designated Charles as an expert?

MR. BEARMAN: No.

MR. CAMERON: No.

MR. McMULLAN: Okay. All right. That's fine. No, just a fact witness.

MR. BEARMAN: Well, during a break --

MR. McMULLAN: Yeah.

MR. BEARMAN: -- we would like to check, because we may want to make some of that exhibits.

MR. BEARMAN:

Q Can you tell me your work history, Mr. Branch. Let's start -- well, you can either start when your retired and go back or go forward, either way.

A Let me go back and try to come forward.

Q Okay. That's fine. That's fine with me.

A After receiving the BS in engineering, I went to work for International Paper Company for a short period of time; left International Paper Company and went back to school, received a master's degree in 1969; went back to work with International Paper Company in Mobile, Alabama in engineering

relative to other large users of that
aquifer system.

BY MR. BEARMAN:

Q You don't know if they are occurring in Southhaven; is that what you are saying?

A That is what I am saying right here today.

Q Look at this next sentence. In fact, during my tenure at OLWR -- that's the Office of Land and Water Resources, correct?

A Yeah.

Q -- it was determined that the City of Memphis was the user of groundwater for municipal purposes in the State of Mississippi. Do you see that sentence?

A Yes.

Q What was determined?

A It was determined, based on my conversations with Mr. Boswell and the technical staff, of the amount of water that was flowing across the state line into the Memphis pumping centers and their assessments of the range of the volumes that daily were crossing that state line.

Q Did your office do a study?

A Did my office do the study?

Exhibit 13

Excerpts from Deposition of
Randall W. Gentry, Ph.D., P.E.

(August 7, 2006)

DEPOSITION OF RANDALL W. GENTRY, PH.D., P.E.

August 7, 2006

IN THE UNITED STATES DISTRICT COURT
FOR THE NORTHERN DISTRICT OF MISSISSIPPI
DELTA DIVISION

JIM HOOD, ATTORNEY GENERAL, EX REL., THE STATE OF MISSISSIPPI, ACTING FOR ITSELF AND PARENS PATRIAE FOR AND ON BEHALF OF THE PEOPLE OF THE STATE OF MISSISSIPPI Plaintiff, vs. THE CITY OF MEMPHIS, TENNESSEE, AND MEMPHIS LIGHT, GAS & WATER DIVISION, Defendants.	CIVIL ACTION NO. 2:05CV32-D-B Consolidated
DESOTO COUNTY, MISSISSIPPI, Plaintiff, vs. THE CITY OF MEMPHIS, TENNESSEE, AND MEMPHIS LIGHT, GAS & WATER DIVISION, Defendants.	CIVIL ACTION NO. 2:05CV85-D-B
NESBIT WATER ASSOCIATION, INC., NORTH MISSISSIPPI UTILITY COMPANY, INC., AND BILL J. ROBERSON, ON BEHALF OF THEMSELVES AND ALL OTHER ENTITIES AND PERSONS SIMILARLY SITUATED, Plaintiffs, vs.	CIVIL ACTION NO. 2:05CV108-D-B

Q. What is your position with the University of Tennessee?

A. I'm an associate professor of civil and environmental engineering.

Q. What are your duties and responsibilities as an associate professor?

A. Most of the duties are related to teaching and research. I teach several courses in civil and environmental engineering at the undergraduate and graduate level, and also perform research in my area of competency, which is water resources, generally ground-water hydrology.

Q. Is there a water resources program with which you are associated?

A. Well, we do have a water resources program. It's more interdisciplinary. We have two faculty members in the civil and environmental engineering and several faculty members across campus, some in earth and planetary sciences and some on the ag campus.

Q. What is your relationship to the program? What is your position?

A. Well, there is the academic program, and then the research program which is the -- a newly-formed institute on campus. It's the Institute

Exhibit 14

Excerpts from the State of Mississippi's Responses to City of Memphis, Tennessee, and Memphis Light, Gas & Water Division's First Set of Request for Admissions

(January 20, 2017)

No. 143, Original

IN THE SUPREME COURT OF THE UNITED STATES

STATE OF MISSISSIPPI,
Plaintiff,

v.

STATE OF TENNESSEE, CITY OF MEMPHIS, TENNESSEE,
AND MEMPHIS LIGHT, GAS & WATER DIVISION,
Defendants.

THE STATE OF MISSISSIPPI'S RESPONSES TO CITY OF MEMPHIS, TENNESSEE, AND MEMPHIS LIGHT, GAS & WATER DIVISION'S FIRST SET OF REQUEST FOR ADMISSIONS

COMES NOW, the State of Mississippi, by and through counsel, and Responds to City of Memphis, Tennessee, and Memphis Light, Gas & Water Division's First Set of Request for Admissions, as follows:

REQUEST NO. 1: The Aquifer underlies several states including Mississippi, Tennessee, and Arkansas.

RESPONSE: Mississippi objects to Request No. 1 because it improperly defines the "Aquifer" as "the underground hydrogeologic units identified in paragraphs 15 and 41 of the Complaint," and conflates the natural groundwater movement and storage in a deep confined geological formation within each state's borders with generalized geology to erase state boundaries and sovereignty to natural resources residing within their territory under natural conditions. (See

Defendants' "Definitions and Instructions," at paragraph 14.) Mississippi's claims relate solely to groundwater collected and stored in the Sparta Sand within Mississippi and its specific hydrogeology, not in multiple "hydrogeologic units." Further, the proposed definition and Request No. 1 are built on a false premise, as they fail to distinguish between (1) the sandstone geological formation known as the "Sparta Sand within Mississippi territory," and (2) the water naturally collected and stored in Mississippi in the Sparta Sand formation. Mississippi, therefore, denies Request No. 1.

Without waiving its objection, Mississippi states that the general geologic formation known as the Sparta Sand underlies several states, including Mississippi, Tennessee, and Arkansas; and avers that the groundwater at issue in this case underlies and is confined in Mississippi only under natural conditions, and is an intrastate natural resource.

REQUEST NO. 2: Groundwater from the Aquifer is being pumped and has been pumped from wells located in Mississippi and from wells located in Tennessee.

RESPONSE: Mississippi objects to Request No. 2 because it improperly defines the "Aquifer" as "the underground hydrogeologic units identified in paragraphs 15 and 41 of the Complaint," and conflates the natural groundwater movement and storage in a deep confined geological formation within each state's

Exhibit 15

State of Mississippi's Response to
Defendants' Proposed Statement of Facts

(January 29, 2018)

No. 143, Original

IN THE
Supreme Court of the United States

STATE OF MISSISSIPPI,
Plaintiff,

v.

STATE OF TENNESSEE, CITY OF MEMPHIS, TENNESSEE,
AND MEMPHIS LIGHT, GAS & WATER DIVISION,
Defendants.

Before the Special Master, Hon. Eugene E. Siler, Jr.

STATE OF MISSISSIPPI'S RESPONSE TO DEFENDANTS' PROPOSED STATEMENT OF FACTS

COMES NOW the State of Mississippi, by and through undersigned counsel, and submits its response to Defendants' Statement of Undisputed Material Facts pursuant to the Case Management Plan entered in this matter on November 1, 2017 (Dkt No. 61), as amended on December 13, 2017 (Dkt. No. 62):

GENERAL RESPONSE

1. Mississippi objects to Defendants' Proposed Statements of Fact 1, 2, 3, 4, 5, 8, 10, 13, 14, 15, 16, 17, 18. 19, 21, 22, 24-62, 64, as overly broad, confusing, inaccurate, misleading, and failing to clarify and narrow the real issues raised in this case because they lack necessary narrowing context, and/or they omit relevant information necessary to accomplish these objectives.

2. Mississippi objects to Defendants' Proposed Statements of Fact using the shorthand designation of "Memphis-Sparta Aquifer" and "the Aquifer" as defined by Defendants and appearing in Proposed Statements of Fact 8, 13, 15, 19, 20, 25-32, 34-52, 54-57, 59-62, and 65-81 as overly broad and confusing rather than clarifying the issues and relevant facts in this dispute.

As shown in Table 1 of the Mississippi Embayment Regional Aquifer Study, Scientific Investigations Report 2009-5172, nine geological units of the Claiborne Group (created during the Eocene Epoch) act as aquifers and confining layers in the eight states which Defendants sweep into their "Memphis-Sparta Aquifer" moniker. These nine formations are the Sparta Sand, Cane River, Carrizo Sand, Zilpha Clay, Meridian Sand, Winona Sand, Tallahatta, Memphis Sand, and Lisbon. The Memphis Sand only appears in Tennessee, extreme northwestern Mississippi, Missouri, and Arkansas; and the Sparta Sand only appears in Mississippi, Louisiana, and Kentucky.

While these water-bearing geologic formations have hydrologic connections, those connections are complex, and the local sediment composition and disposition varies significantly over short distances, both between and within the separate formations, making the natural groundwater hydrology within any local area very complex. The effects of the massive MLGW and Shelby County municipal and industrial groundwater pumping at issue in this case are relatively localized, and Defendants have provided no scientific data to even suggest that the pumping has affected or materially diverted confined groundwater throughout the "Memphis-Sparta Aquifer" as defined by Defendants (or could ever do so).

The most recent USGS groundwater investigation which focuses on the impacts of municipal and industrial pumping in northwest Mississippi and west Tennessee from the Memphis Sand in Tennessee, and the Sparta Sand in Mississippi, is the USGS Water-Resources Investigations Report 89-4131 by J.V. Brahana and R.E. Broshears published in 2001. Nothing in this USGS Report, or any other subsequent USGS report relating to the pumping in DeSoto County, Mississippi, even suggests a material impact on naturally available high quality groundwater production outside Mississippi. The only material facts relating to the Original Action brought by Mississippi against Defendants are material facts concerning the natural pre-development availability of groundwater within this local border between Mississippi and Tennessee, and the impact of municipal and industrial groundwater pumping from the Sparta Sand and the Memphis Sand aquifers in the local area surrounding Memphis. Confined to this geographic area, the shorthand description "North Mississippi Border Sparta and Memphis Sand Aquifer" is a more accurate summary of the aquifers involved.

Exhibit 16

Excerpts from Defendants'
Joint Deposition Designations

(September 14, 2018)

DEPOSITION OF RANDALL W. GENTRY, PH.D., P.E.

August 7, 2006

IN THE UNITED STATES DISTRICT COURT
FOR THE NORTHERN DISTRICT OF MISSISSIPPI
DELTA DIVISION

JIM HOOD, ATTORNEY GENERAL, EX REL., THE STATE OF MISSISSIPPI, ACTING FOR ITSELF AND PARENS PATRIAE FOR AND ON BEHALF OF THE PEOPLE OF THE STATE OF MISSISSIPPI Plaintiff, vs. THE CITY OF MEMPHIS, TENNESSEE, AND MEMPHIS LIGHT, GAS & WATER DIVISION, Defendants.	CIVIL ACTION NO. 2:05CV32-D-B Consolidated
DESOTO COUNTY, MISSISSIPPI, Plaintiff, vs. THE CITY OF MEMPHIS, TENNESSEE, AND MEMPHIS LIGHT, GAS & WATER DIVISION, Defendants.	CIVIL ACTION NO. 2:05CV85-D-B
NESBIT WATER ASSOCIATION, INC., NORTH MISSISSIPPI UTILITY COMPANY, INC., AND BILL J. ROBERSON, ON BEHALF OF THEMSELVES AND ALL OTHER ENTITIES AND PERSONS SIMILARLY SITUATED, Plaintiffs, vs.	CIVIL ACTION NO. 2:05CV108-D-B

Mississippi into Tennessee before there was any pumping at all; right?

A. If there was water flowing, it would include that, yes.

Q. And you have already stated that based on the models that you have worked with and seen, that there was a northwest flow of the water in the DeSoto County, Marshall County, Shelby County area, before there was any pumping?

A. There was a component that was definitely moving from the southeast to the northwest.

Q. And what that means is that before anybody was pumping any water out of the Memphis Sands aquifer, there was water moving from Mississippi into the Memphis area in Tennessee?

A. That's reasonable.

Q. This cone of depression that you have talked about earlier, you mentioned, I think, that it was centered in the downtown Memphis area; is that right?

A. That's correct.

Q. And you would agree that to the extent this cone of depression may even affect Mississippi, that that effect would be limited to the extreme northwest part of Mississippi?

Exhibit 17

Excerpts from Mississippi's Deposition
Counter-Designations

(October 5, 2018)

DEPOSITION OF RANDALL W. GENTRY, PH.D., P.E.

August 7, 2006

IN THE UNITED STATES DISTRICT COURT
FOR THE NORTHERN DISTRICT OF MISSISSIPPI
DELTA DIVISION

JIM HOOD, ATTORNEY GENERAL, EX REL., THE STATE OF MISSISSIPPI, ACTING FOR ITSELF AND PARENS PATRIAE FOR AND ON BEHALF OF THE PEOPLE OF THE STATE OF MISSISSIPPI Plaintiff, vs. THE CITY OF MEMPHIS, TENNESSEE, AND MEMPHIS LIGHT, GAS & WATER DIVISION, Defendants.	) CIVIL ACTION NO. 2:05CV32-D-B Consolidated
DESOTO COUNTY, MISSISSIPPI, Plaintiff, vs. THE CITY OF MEMPHIS, TENNESSEE, AND MEMPHIS LIGHT, GAS & WATER DIVISION, Defendants.	) CIVIL ACTION NO. 2:05CV85-D-B
NESBIT WATER ASSOCIATION, INC., NORTH MISSISSIPPI UTILITY COMPANY, INC., AND BILL J. ROBERSON, ON BEHALF OF THEMSELVES AND ALL OTHER ENTITIES AND PERSONS SIMILARLY SITUATED, Plaintiffs, vs.	) CIVIL ACTION NO. 2:05CV108-D-B

possibly also storativity.

Q. I don't know if we have talked about storativity. Please tell the jury what storativity refers to.

A. When you stress an aquifer, and we have been describing these cones of depression, as the head begins to change laterally outward, that's flow coming into the cone of depression. There is also another source of water called aquifer storage. And aquifer storage is defined based upon the compressibility of water which is extremely small, but also the compressibility of the mineral structure in the aquifer.

So, if I had a series of spheres, and I stack them, and I have a small box I put them in, I can actually rearrange those spheres and change the amount of open space in that box. So when you begin pumping on an aquifer, think of sand grains as those small spheres, sometimes they will reorient themselves and produce where I had a higher porosity, it may be a lower porosity and generate a water flux. That's called water from storage. And its effect is to keep the head in the aquifer or the cone of depression from moving out at any faster rate.

Q. What potentially may happen if the cone of depression is through pumping-induced stresses moved outward?

A. Most of the water from storage has probably been captured at that point, and it's beginning to go outward and try and capture water from outlying areas to feed the cone of depression.

Q. Is that what is essentially happening in the border issue involving Mississippi and Memphis?

MR. DAVID BEARMAN: Objection. Leading.

THE WITNESS: It could be one interpretation, yes. Cone of depression is moving outward.

BY MR. CAMERON:

Q. So the -- what is desaturation in the context of a ground-water act?

A. Desaturation, in particularly these cases where you have confined aquifers, as long as the water level is above the confining layer or the top of the aquifer, you have a completely saturated media. Once the water level begins to drop below the confining layer and into the top of the aquifer, you begin to desaturate the aquifer. And when that happens, you get very rapid readjustment of those grains and the change in storage.

Typically, an effect that can be seen in

sure, these are naturally-occurring phenomenon. They are not man-made?
A. Correct.
Q. They were there before pumping?
A. Correct.
Q. So generally speaking, when we talk about the aquifer system in the northern Mississippi, eastern Arkansas, west Tennessee area, we are really talking about aquifers that are stacked on top of each other. Is that a fair characterization?
A. That's correct.
Q. And they are separated by a layer of clay?
A. Correct.
Q. And these windows that you studied are places where the clay layer is either thin or absent?
A. Correct.
Q. And water from the surficial aquifer, that's the one above the Memphis Sands aquifer; correct?
A. Correct.
Q. Water from the surficial aquifer is pulled downward through these windows into the Memphis Sands aquifer; is that correct?
A. Under current pumping conditions, it is

now, yes.

Q. Now, water from the surficial aquifer also is pulled down into the Memphis aquifer, Memphis Sands aquifer through the clay layer; is that correct?

A. That's correct.

Q. And all of this movement of water is called leakage or leaking?

A. Yes.

Q. It's called -- it can also be called recharge?

A. Yes.

Q. So is it fair to say that the water leaking from the surficial aquifer into the Memphis Sands aquifer leaks at a faster rate than does the water leaking through the clay layer?

A. Yes.

Q. In fact, that's the focus of what you are studying; is that correct?

A. Yes.

Q. Now, in this stacked aquifer system that we were just talking about, there is the surficial aquifer on top; is that correct?

A. Correct.

Q. Then the Memphis Sands aquifer?

A. Clay layer in between.

Q. With a clay layer in between. Then there is another clay layer; correct?
A. Correct.
Q. Then below that, there is an aquifer called the Fort Pillow aquifer; is that correct?
A. Correct.
Q. And you are aware that scientific models have shown that water can leak from the Fort Pillow aquifer upward into the Memphis Sands aquifer; is that correct?
A. That's correct.
Q. And, in fact, the geology, or the way that the aquifer is naturally formed indicates that also; is that correct?
A. That's correct.
Q. Now, the fact that all of this water is leaking between these various aquifers, or moving between these various aquifers, means that they are all interconnected; is that correct?
A. That's correct.
Q. And, in fact, what happens in one of these aquifers, the surficial aquifer, for example, can affect another aquifer, like the Memphis Sands aquifer; is that correct?
A. That's correct.

Q. If we talk about pumping in the Memphis area where you studied, okay, let's focus on that area for a minute. Water coming from the surficial aquifer into the Memphis Sands aquifer, you have said will make that journey quicker through a window than it would if it came, for example, through the clay layer?

A. Correct.

Q. And that means, also, that water from the surficial aquifer is going to get to the pump quicker if it goes through the window. Is that correct?

A. If a window is close to the well, yes, it will get their quicker.

Q. So if the window is in the proximity of the pump, then water will come from the surficial aquifer into the Memphis Sands aquifer and into the pump quicker?

A. Than --

Q. Than water that, for example, leaked through the clay layer?

A. Yes.

Q. And that water that arrives at the pump quicker is sometimes called young water; is that correct?

A. That's correct.

Q. Or modern water some people call it.

A. Correct.

Q. And these windows that you have studied allow more of the young water to reach the pump than, for example, would reach the pump if there were no window?

A. I believe that's correct. Yes.

Q. Now, if we assume a steady pumping rate from a particular well, the more young water that comes into the well, or as the young water that comes into the well increases in volume, then that means that the older water, if you will, decreases. Is that correct?

A. That's correct.

Q. All right. Tell me -- tell the jury some of the sources of this other water, the older water.

A. The older water is when we were discussing water coming -- flowing in from the lateral areas, that's what we would consider the older water. In the terms that you used, modern versus older water, we were using technology that would allow us to look at sort of a 50-year window. So we could -- we could describe pre-hydrogen bomb versus post-hydrogen bomb-affected water. So most of the leakage, if you saw appreciable amounts of tritium and/or other tracers would indicate water from surficial leakage or possibly borehole leakage along the well, if there was damage there. The older water would be water that has had a travel time of greater than 50 years in the aquifer system either from the recharge area to the east, Arkansas from the west, or Mississippi to the south.

Q. So that older water could include, does include, in fact, the water that's coming from Mississippi?

A. It certainly could.

Q. Generally speaking then, leakage or recharge helped supply water to the Memphis Sands aquifer. Is that accurate?

A. That's correct.

Q. Let's assume a situation with the surficial aquifer and the Memphis Sands aquifer, if the pressure in both were the same, okay?

A. Yes.

Q. Are we together?

A. Yes.

Q. Okay. If the pressure in both those aquifers were the same, if there was a window present, for example, then there would be no leakage. Is that correct? Either way?

A. That's correct. We would call that at equilibrium.

Q. If you start pumping from the Memphis

Sands aquifer in this example that we are using, then that can have the effect of lowering the pressure in the Memphis Sands aquifer; is that correct?

A. Immediately it would, yes.

Q. And generally speaking, this water is going to move from higher pressure, higher energy, you said earlier, to lower pressure; is that correct?

A. That's correct.

Q. So if we start pumping from the Memphis Sands aquifer in this example, water would start leaking from the surficial aquifer downward to the Memphis Sands aquifer; is that correct?

A. Correct.

Q. And the more you pump, the faster the leakage would be; is that correct?

A. Well, it's the same concept that you would use laterally. As you see a gradient develop laterally, you would see a gradient where it was originally at equilibrium, you would see a gradient develop vertically. So as you increase pumping, the gradient is going to increase, and that would lead to an increase in flow.

Q. So the jury understands, when you talk about a change in gradient, you are talking about the change in pressure; is that right?

Exhibit 18

State of Mississippi's Exhibit List

(September 14, 2018)

No.	Description	Reference Information
P-1	Map of the State of Mississippi	MDEQ0019824
P-2	Miss. Code Ann. § 51-3-1, Policy Declarations	
P-3	Miss. Code Ann. § 51-3-3, Definitions	
P-4	Miss. Code Ann. § 51-3-5, Water use permit required	
P-5	Miss. Admin. Code § 11-7:1.1 through 7:1.7	MS SCT 105634-015661
P-6	U.S. Geological Survey Map of Principal Aquifers of the United States	https://water.usgs.gov/ogw/aquifer/map.html
P-7	Thomas E. Reilly, Kevin F. Dennehy, William M. Alley, and William L. Cunningham, U.S. Geological Survey Circular 1323, *Ground-Water Availability in the United States* (2008)	https://pubs.usgs.gov/circ/1323/
P-8	Robert A. Renken, U.S. Geological Survey Hydrological Investigations Atlas 730-F, *Ground Water Atlas of the United States, Segment 5 Arkansas, Louisiana, Mississippi* (1998)	MS SCT 001171-001200 https://pubs.usgs.gov/ha/730f/report.pdf
P-9	Orville B. Lloyd, Jr. and William L. Lyke, U.S. Geological Survey Hydrological Investigations Atlas 730-K, *Ground Water Atlas of the United States, Segment 10 Illinois, Indiana, Kentucky, Ohio, Tennessee*	https://pubs.usgs.gov/ha/730k/report.pdf https://pubs.usgs.gov/ha/ha730/ch_k/K-text6.html (high level preview with Figures 126-140)
P-10	Tony P. Schrader, U.S. Dep't of Interior, U.S. Geological Survey Scientific Investigations Map 3014, *Potentiometric Surface in the Sparta-Memphis Aquifer of the Mississippi Embayment, Spring 2007* (2008)	https://pubs.usgs.gov/sim/3014/pdf/sim3014.pdf
P-11	E. M. Cushing, E. H. Boswell, and R. L. Hosman, U.S. Geological Survey Professional Paper 448-B, *General Geology of the Mississippi Embayment* (1964)	MS SCT 000755-000786 https://pubs.er.usgs.gov/publication/pp448B
P-12	R. L. Hosman, A. T. Long, T. W. Lambert, and others, U.S. Geological Survey Professional Paper 448-D, *Tertiary Aquifers in the Mississippi Embayment* (1968) ("Paper 448-D")	MS SCT 001423-001455 https://pubs.er.usgs.gov/publication/pp448D
P-13	J. N. Payne, U.S. Geological Survey Professional Paper 569-A, *Hydrologic Significance of the Lithofacies of the Sparta Sand in Arkansas, Louisiana, Mississippi and Texas* (1968)	https://pubs.er.usgs.gov/publication/pp569A
P-14	J.E. Terry, R. L. Hosman, and C. T. Bryant, U.S. Geological Survey Professional Paper 813-N, *Summary Appraisals of the Nation's Ground-Water Resources--Lower Mississippi Region* (1979)	https://pubs.er.usgs.gov/publication/pp813N
P-15	R. L. Hosman and Jonathan S. Weiss, U.S. Geological Survey Professional Paper 1416-B, *Geohydrologic Units of the Mississippi Embayment and Texas Coastal Uplands Aquifer Systems, South-Central United States* (1991)	https://pubs.er.usgs.gov/publication/pp1416B
P-16	R. L.Hosman, U.S. Geological Survey Professional Paper 1416-G, *Regional Stratigraphy and Subsurface Geology of Cenozoic Deposits, Gulf Coastal Plain, South-Central United States* (1996)	https://pubs.usgs.gov/pp/1416g/report.pdf
P-17	J. Kerry Arthur and Richard E. Taylor, U.S. Geological Survey Professional Paper 1416-I, *Ground-Water Flow Analysis of the Mississippi Embayment Aquifer System, South-Central United States* (1998)	https://pubs.er.usgs.gov/publication/pp1416I
P-18	F. G. Wells, U.S. Geological Survey Water-Supply Paper 656, *Ground-Water Resources of Western Tennessee* (1933)	https://pubs.er.usgs.gov/publication/wsp656
P-19	J. H. Criner, P-C. P. Sun, and D. J. Nyman, U.S. Geological Survey Water-Supply Paper 1779-O, *Hydrology of Aquifer Systems in the Memphis Area, Tennessee* (1964)	https://pubs.er.usgs.gov/publication/wsp1779O
P-20	Gerald K. Moore, U.S. Geological Survey Water-Supply Paper 1809-F, *Geology and Hydrology of the Claiborne Group in Western Tennessee* (1965)	https://pubs.er.usgs.gov/publication/wsp1809F
P-21	Dale J. Nyman, U.S. Geological Survey Water-Supply Paper 1819-B, *Predicted Hydrologic Effects of Pumping from the Lichterman Well Field in the Memphis Area, Tennessee* (1965)	https://pubs.er.usgs.gov/publication/wsp1819B
P-22	Edwin A. Bell and Dale J. Nyman, U.S. Geological Survey Water-Supply Paper 1853, *Flow Pattern and Related Chemical Quality of Ground Water in the 500-Foot Sand in the Memphis Area, Tennessee* (1968) (with plates 1-4)	https://pubs.er.usgs.gov/publication/wsp1853

No.	Description	Reference Information
P-23	Ralph C. Heath, U.S. Geological Survey Water-Supply Paper 2220, *Basic Ground-Water Hydrology* (Revised 2004)	https://pubs.er.usgs.gov/publication/wsp2220
P-24	William S. Parks and Richard W. Lounsbury, U.S. Geological Survey Water-Resources Investigations Report 4-76, *Summary of Some Current and Possible Future Environmental Problems Related to Geology and Hydrology at Memphis, Tennessee* " (1976)	https://pubs.usgs.gov/wri/wri760004/pdf/wrir_4-76_a.pdf
P-25	James H. Criner and William S. Parks, U.S. Geological Survey Water-Resources Investigations Report 76-67, *Historic Water-Level Changes and Pumpage from the Principal Aquifers of the Memphis Area, Tennessee 1886-1975* (1996)	https://pubs.er.usgs.gov/publication/wri7667
P-26	David D. Graham, U.S. Geological Survey Water-Resources Investigations Report 79-80, *Potentiometric Map of the Memphis Sand in the Memphis Area, Tennessee* (1978)	https://pubs.er.usgs.gov/publication/wri7980
P-27	David D. Graham, U.S. Geological Survey Water-Resources Investigations Report 82-4024, *Effects of Urban Development on the Aquifers in the Memphis Area, Tennessee* (1982)	MS SCT 002511-002535 https://pubs.er.usgs.gov/publication/wri824024
P-28	D.D. Graham and W.S. Parks, U.S. Geological Survey Water-Resources Investigations Report 85‑4295, *Potential for Leakage Among Principal Aquifers in the Memphis Area, Tennessee* (1986)	MS SCT 001118-001168 https://pubs.usgs.gov/wri/wri85-4295/pdf/wrir_85-4295_a.pdf
P-29	J. Kerry Arthur and R. E. Taylor, U.S. Geological Survey Water-Resources Investigations Report 86-4364, *Definition of the Geohydrologic Framework and Preliminary Simulation of Ground-Water Flow in the Mississippi Embayment Aquifer System, Gulf Coastal Plain, United States* (1990)	MS SCT 000151-250 https://pubs.er.usgs.gov/publication/wri864364
P-30	J. V. Brahana and T. O. Mesko, U.S. Geological Survey Water-Resources Investigations Report 87-4000, *Hydrogeology and Preliminary Assessment of Regional Flow in the Upper Cretaceous and Adjacent Aquifers in the Northern Mississippi Embayment* (1988)	MS SCT 00532-00603 https://pubs.usgs.gov/wri/wri87-4000/pdf/wrir_87-4000_a.pdf
P-31	J. V. Brahana, W. S. Parks, and M.W. Gaydos, U.S. Geological Survey Water-Resources Investigations Report 87-4052, *Quality of Water from Freshwater Aquifers and Principal Well Fields in the Memphis Area, Tennessee* (1987)	MS SCT 000604-000630 https://pubs.usgs.gov/wri/wri87-4052/#pdf
P-32	W. S. Parks and J. K. Carmichael, U.S. Geological Survey Water-Resources Investigations Report 88‑4180, *Altitude of Potentiometric Surface, Fall 1985, and Historic Water-Level Changes in the Memphis Aquifer in Western Tennessee* (1990)	MS SCT 002367-002378 https://pubs.usgs.gov/wri/wri88-4180/pdf/wrir_88-4180_a.pdf
P-33	W. S. Parks and J. K. Carmichael, U.S. Geological Survey Water-Resources Investigations Report 88‑4180, *Altitude of Potentiometric Surface, Fall 1985, and Historic Water-Level Changes in the Memphis Aquifer in Western Tennessee* (1990) (with Plate 1)	GWI000078.10 https://pubs.usgs.gov/wri/wri88-4180/pdf/wrir_88-4180_a.pdf
P-34	W. S. Parks and J. K. Carmichael, U.S. Geological Survey Water-Resources Investigations Report 89‑4120, *Geology and Ground-Water Resources of the Fort Pillow Sand in Western Tennessee* (1989)	https://pubs.usgs.gov/wri/wri89-4120/pdf/wrir_89-4120_a.pdf
P-35	W.S. Parks and J.K. Carmichael, U.S. Geological Survey Water-Resources Investigations Report 88-4182, *Geology and Ground-Water Resources of the Memphis Sand in Western Tennessee* (1990)	MS SCT 002379-002412 https://pubs.usgs.gov/wri/wrir88-4182/pdf/wrir_88-4182_a.pdf
P-36	J.V. Brahana and R.E. Broshears,Water-Resources Investigations Report 89‑4131, *Hydrogeology and Ground‑Water Flow in the Memphis and Fort Pillow Aquifers in the Memphis Area, Tennessee* (2001)	https://pubs.usgs.gov/wri/wri894131/pdf/wri89-4131.pdf
P-37	Michael W. Bradley, U.S. Geological Survey Water-Resources Investigations Report 90-4075, *Ground-Water Hydrology and the Effects of Vertical Leakage and Leachate Migration on Ground-Water Quality Near the Shelby County Landfill, Memphis, Tennessee* (1991)	MS SCT 000251-297 https://pubs.usgs.gov/wri/wri904075/pdf/wrir_90-4075_a.pdf

No.	Description	Reference Information
P-38	William S. Parks, U.S. Geological Survey Water-Resources Investigations Report 90-4092, *Hydrogeology and Preliminary Assessment of the Potential for Contamination of the Memphis Aquifer in the Memphis Area, Tennessee* (1990)	MS SCT 002459-002502 https://pubs.usgs.gov/wri/wri904092/pdf/wrir_90-4092_a.pdf
P-39	James A. Kingsbury, U.S. Geological Survey Water-Resources Investigations Report 92-4002, *Altitude of the Potentiometric Surface, September 1990, and Historic Water-Level Changes in the Memphis Aquifer in the Memphis Area, Tennessee* (1992)	USGT0000004 https://pubs.usgs.gov/wri/1992/4002/plate-1.pdf
P-40	James A. Kingsbury and William S. Parks, U.S. Geological Survey Water-Resources Investigations Report 93-4075, *Hydrogeology of the Principal Aquifers and Relation of Faults to Interaquifer Leakage in the Memphis Area, Tennessee* (1993) (with Plates 1-3)	MS SCT 001478-001504, GWI000125.24-125.26 https://pubs.er.usgs.gov/publication/wri934075
P-41	William S. Parks, June E. Mirecki, and James A. Kingsbury, U.S. Geological Survey Water-Resources Investigations Report 94-4212, *Hydrogeology, Ground-Water Quality, and Source of Ground Water Causing Water-Quality Changes in the Davis Well Field at Memphis, Tennessee* (1995)	https://pubs.usgs.gov/wri/1994/4212/report.pdf
P-42	James A. Kingsbury, U.S. Geological Survey Water-Resources Investigations Report 96-4278, *Altitude of the Potentiometric Surfaces, September 1995, and Historical Water-Level Changes in the Memphis and Fort Pillow Aquifers in the Memphis Area, Tennessee* (1996)	USGT0000005
P-43	J.V. Brahana, U.S. Geological Survey Report, *Ground Water Supply, Chapter 3 ‑ Final Report, Memphis Metropolitan Area Urban Water Resources Study* (1981)	MS SCT 000362-000388, JVB 00647-673
P-44	J.V. Brahana, *Digital Ground-Water Model of the Memphis Sand and Equivalent Units, Tennessee-Arkansas-Memphis* (1981)	MS SCT 000389-000468, JVB00419-00497
P-45	J.V. Brahana, U.S. Geological Survey Open‑File Report 82‑99, *Two-Dimensional Digital Ground-Water Model of the Memphis Sand and Equivalent Units, Tennessee-Arkansas-Memphis* (1982)	MS SCT 000469-000531, JVB 01110-1171 https://pubs.er.usgs.gov/publication/ofr8299
P-46	Connor J. Haugh, U.S. Geological Survey Scientfific Investigations Report 2016-5072, *Evaluation of Effects of Groundwater Withdrawals at the Proposed Allen Combined-Cycle Combustion Turbine Plant, Shelby County, Tennessee* (2016)	https://pubs.usgs.gov/sir/2016/5072/sir20165072.pdf
P-47	John K. Carmichael, James A. Kingsbury, Daniel Larsen, and Scott Schoefernacker, U.S. Geological Survey Open-File Report 2018-1097, *Preliminary Evaluation of the Hydrogeology and Groundwater Quality of the Mississippi River Valley Alluvial Aquifer and Memphis Aquifer at the Tennessee Valley Authority Allen Power Plants, Memphis, Shelby County, Tennessee* (2018)	https://pubs.usgs.gov/of/2018/1097/ofr20181097.pdf
P-48	Brian R. Clark & Rheannon M. Hart, U.S. Geological Survey Scientific Investigations Report 2009-5172, *The Mississippi Embayment Regional Aquifer Study (MERAS) Documentation of a Groundwater-Flow Model Constructed to Assess Water Availability in the Mississippi Embaymen* t (2009)	MS SCT 002536-002605 https://pubs.usgs.gov/sir/2009/5172/pdf/SIR2009-5172.pdf
P-49	Brian R. Clark, Drew A. Westerman, and D. Todd Fugitt, U.S. Geological Survey Scientific Investigations Report 2013-5161, *Enhancements to the Mississippi Embayment Regional Aquifer Study (MERAS) Groundwater-Flow Model and Simulations of Sustainable Water-Level Scenarios* (2013)	https://pubs.usgs.gov/sir/2013/5161/pdf/sir2013-5161.pdf
P-50	Brian Waldron, Daniel Larsen, et al., EPA 600/R-10/130, *Mississippi Embayment Regional Groundwater Study* (2011)	https://nepis.epa.gov/Exe/ZyPDF.cgi/P100BKQK.PDF?Dockey=P100BKQK.PDF
P-51	James Eddie Outlaw, Jr., *A Ground Water Flow Analysis of the Memphis Sand Aquifer in the Memphis, Tennessee Area* (1994)	MS SCT 002228-366
P-52	"Memphis Water Termed 'Sweetest in the World,'" *Water World* (March 2003)	https://www.waterworld.com/articles/print/volume-19/issue-11/washington-update/memphis-water-termed-sweetest-in-the-world.html

No.	Description	Reference Information
P-53	Ward Archer, Jr., "Liquid Assets," *Memphis* magazine (March 2005)	https://issuu.com/contemporarymedia/docs/wardcombined2__1_/3
P-54	Palmer Water Pumping Station Wellfield (map)	MLGW SCT 000150
P-55	Davis Water Pumping Station Wellfield (map)	MLGW SCT 000151
P-56	Lichterman Water Pumping Station Wellfield (map)	MLGW SCT 000152
P-57	Excerpt from Well Field Maps to which scale has been added by GMA and well location information including address, longitude and latitude	MS SCT 016193-016196
P-58	Harold C. Mattraw, Jr. (USGS District Chief, Tennessee) letter to William S. Crawford (President, MLGW) dated October 4, 1994 (with attached draft project proposal)	MDEQ0019937-19947
P-59	Charles T. Branch, P.E., letter to Jim Hanes (Tennessee Department of Environment and Conservation), dated June 26, 1995	MDEQ0019981-19982
P-60	Jamie Crawford (Chief, Ground Water Planning Branch - MDEQ) letter to Charlie Pickel (MLGW), dated June 6, 1995 (with attachments)	MDEQ0019976-19980
P-61	MLGW Water Scanner Team Spring 2003 Presentation	MLGW 87450-87473
P-62	Michael Russell e-mail to Nicholas Newman dated March 13, 2003	MLGW 87603
P-63	MLGW Water Scanner Team Spring 2007 Report	MLGW 87745-87761
P-64	MLGW Water Scanner Team Spring 2007 Report	MLGW 87765-87783
P-65	Memorandum from Willie W. Herenton, Ph.D. to Director Bennie Lendermon dated February 23, 2000 (with attachments)	MLGW 87833-87944
P-66	Milton H. Hamilton, Jr. letter to Jon Kinsey and Willie W. Herenton dated February 16, 2000 (with attachments)	MLGW 87953-88077
P-67	Alonzo Weaver Interdepartmental Memorandum to Larry Thompson, Max Williams and Charlie Pickel dated April 25, 2000	MLGW 88370
P-68	Jerry Collins Interoffice Memorandum to Dr. Willie W. Herenton dated April 3, 2000	MLGW 88372-88373
P-69	Memorandum from Willie W. Herenton, Ph.D. to Herman Morris dated April 4, 2000 (with attachments)	MLGW 88402-405
P-70	Alonzo Weaver Interdepartmental Memorandum to Larry Thompson, Max Williams, Charlie Pickel dated April 25, 2000 (with attached Willie W. Herenton, Ph.D. Interoffice Memorandum to Herman Morris dated April 4, 2000)	MLGW 88884-88885
P-71	Tom Charlier *Commercial Appeal* article entitled "Water - a giant sucking sound?" May 1, 2005	MLGW 88311-88313
P-72	Mississippi, Arkansas, Tennessee - Regional Aquifer Study	MLGW 88265-88268
P-73	Overview of MLGW's Water Production System	MLGW 88278-88305
P-74	Memphis Light Gas & Water Division Valuation Analysis	HMO0003880-HMO0003892
P-75	Application for Water Permit submitted by City of Hernando (collective)	Hernando 0024-32
P-76	Letter from James L. Crawford, Director, Division of Permitting and Monitoring, Mississippi Department of Environmental Quality, enclosing four permits issued to the City of Hernando	Hernando 0059-63
P-77	Test data relating to City of Hernando Well No. 3 (collective)	Hernando 0094-96
P-78	Letter from James L. Crawford, Director, Division of Permitting and Monitoring, Mississippi Department of Environmental Quality, enclosing water use permits issued to the City of Holly Springs	Holly Springs 0085-90
P-79	Letter from Lloyd G. Long, Hydrologic Technician, Mississippi Department of Natural Resources, to City of Holly Springs	Holly Springs 0282-0283
P-80	Letters from Marlon G. Stewart, Jr., P.E., Chief, Groundwater Section, Mississippi Department of Natural Resources, to City of Holly Springs (collective)	Holly Springs 0288-0292

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P-81	Mississippi Department of Environmental Quality water use permits issued to Horn Lake Water Association, Inc. (collective)	HLWA 0004-0007
P-82	Mississippi Department of Environmental Quality water use permits issued to Marshall County Water Association, Inc. (collective)	Marshall 0009, 0015
P-83	Letter from James L. Crawford, Director, Division of Permitting and Monitoring, Mississippi Department of Environmental Quality, enclosing water use permits issued to North Mississippi Utility Company, Inc.	NMU0000004-0000014
P-84	Mississippi Department of Environmental Quality water use permit issued to Metro Desoto Utility Co.	Olive Branch 0133
P-85	Mississippi Department of Environmental Quality, Office of Land and Water Resources, Water Supply Information Sheet for Metro Desoto Utility Co.	Olive Branch 0133
P-86	Letter from David L. Hardin, Jr., Director, Division of Permitting and Monitoring, Mississippi Department of Environmental Quality, enclosing water use permit issued to City of Southaven	SOUTH 0036-37
P-87	Mississippi Department of Environmental Quality Water Use Permit issued to City of Southaven and related proof of publication documents (collective)	SOUTH 0091-95
P-88	Letter from David L. Hardin, Jr., Director, Division of Permitting and Monitoring, Mississippi Department of Environmental Quality, enclosing water use permits issued to City of Southaven	SOUTH 0119-0128
P-89	Southaven Well Test log information	SOUTH 0366-0367
P-90	United States Geological Survey Water Resources Division water well log information	SOUTH 0378-0382
P-91	Letter dated 05/04/2010 from Jim Hood, Attorney General for State of Mississippi, to Robert E. Cooper, Jr., Attorney General for State of Tennessee	
P-92	Letter dated 05/10/2010 from Robert E. Cooper, Jr., Attorney General for State of Tennessee, to Jim Hood, Attorney General for State of Mississippi	
P-93	Genealogy of MLGW (and description of operations) (Pickel Dep. Exh. 3)	MLGW 64687-64696
P-94	Charlier Commercial Appeal article 11/16/98 (Pickel Dep. Exh. 4)	RWG 000311
P-95	Strategic Planning 1996 (Pickel Dep. Exh. 6)	MLGW 02601, 2869-2873, 2909-2912, 2916-2920
P-96	Strategic Plan 2000 (Pickel Dep. Exh. 7)	
P-97	Scanner Team Reports 2002 (Pickel Dep. Exh. 8)	MLGW 05697-5698, 5991-5992, 6001-6003, 6033-6036, 6109-6123, 6203-6215
P-98	Scanner Team Reports 2003 (Pickel Dep. Exh. 9)	MLGW 06232-6233, 6246-6256, 6551-6596
P-99	Scanner Team Reports 2005 (Pickel Dep. Exh. 10)	MLGW 06746-6748, 6913-6937, 6991-6998
P-100	Scanner Team Reports 2006 (Pickel Dep. Exh. 11)	MLGW 07018-07019, 7032-7053
P-101	John G. Morgan (Comptroller of the Tennessee Treasury, Office of Research), *Special Report -- Tennessee's Water Supply Toward a Long-Term Water Policy for Tennessee* (March 2002) (Pickel Dep. Exh. 12)	
P-102	MATRAS meeting Tunica 01/08/03 - 01/09/03 (Pickel Dep. Exh. 13)	MLGW 66044-66048
P-103	Larry Hayes letter to Charles Pickel 7/13/84, with enclosures (Pickel Dep. Exh. 17)	USGT0000017-0000024
P-104	MLGW Water System Contingency Study (Pickel Dep. Exh. 21)	MLGW 29887-30026
P-105	Water Pumpage Reports (Pickel Dep. Exh. 31)	MLGW 00001-00002
P-106	MLGW Strategic Plan 2005-2009 Development Process (Pickel Dep. Exh. 32)	MLGW 07599-07602
P-107	MLGW Contract No. 9928 (Pickel Dep. Exh. 33)	MLGW 00955-00961
P-108	Correspondence and documents re MLGW/MSU Cooperative GIS Ground Water Project (Pickel Dep. Exh. 34)	MLGW2 00693-00698
P-109	Correspondence dated 1/7/1987 from W. H. Doyle to Jerry Olds, MLGW President, re ground water modeling (Pickel Dep. Exh. 35)	MLGW2 00598-00599

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P-110	E-mail dated 1/13/99 from C. Pickel to L. Thompson re GWI work (Pickel Dep. Exh. 36)	MLGW 18167
P-111	MLGW Water Operations documents (Pickel Dep. Exh. 37)	MLGW 63103-63175
P-112	MLGW Water Production 1990 (Pickel Dep. Exh. 38)	MLGW 64697-64741
P-113	MLGW contract with Olive Branch (Pickel Dep. Exh. 39)	MLGW 13513-13522
P-114	Brahana Dep. Exh. 1: Brahana Curriculum Vitae, September 2006	
P-115	Brahana Dep. Exh. 4: Memo Steven P. Larson to J.F. Daniel	JVB 00871-874
P-116	Brahana Dep. Exh. 5: Brahana USGS Report 1981, "Digital Ground Water Model of the Memphis Sand"	JVB 00419-497
P-117	Brahana Dep. Exh. 6: Brahana USGS Report, "Ground Water Supply"	JVB 00647-673
P-118	Brahana Dep. Exh. 7: Brahana USGS Report 82-99, "Two Dimensional Digital Ground-Water Model of the Memphis Sand"	JVB 01110-1171
P-119	Brahana Dep. Exh. 8: Hayes 7/12/84 ltr to Pickel with attachments	USGT 000017-24; JVB 00020-23
P-120	Brahana Dep. Exh. 9: Brahana USGS WIR 87-4752, "Quality of Water from Freshwater Aquifers and Principal Well Fields in the Memphis Area, Tennessee	JVB 01042-1069
P-121	Brahana Dep. Exh. 10: Brahana USGS WIR 89-4131, "Hydrogeology and Ground Water Flow in the Memphis and Fort Pillow Aquifers in the Memphis Area, Tennessee	
P-122	Brahana Dep. Exh. 11: Map "Altitude of the water level surface in the Memphis Sand, Fall 1980, and general direction of ground-water flow"	JVB 00193
P-123	Brahana Dep. Exh. 12: Map (same map as Ex. 11; different Bates number)	JVB 00201
P-124	Brahana Dep. Exh. 13: Map "Figure 38--Conceptual model of interaquifer hydrology"	JVB 00204
P-125	Brahana Dep. Exh. 14: Parks USGS WRI 4-76 "Summary of Some Current and Possible Future Environmental Problems Related to Geology and Hydrology at Memphis, Tennessee"	JVB 00222-263
P-126	Brahana Dep. Exh. 15: Map "Figure 34--Conceptual model of ground-water flow and significant features of the Memphis Sand"	JVB 00212
P-127	Brahana Dep. Exh. 16: Water Level Table 3	JVB 0213
P-128	Brahana Dep. Exh. 17: Parks USGS WIR 88-4182	JVB 00766-814
P-129	Brahana Dep. Exh. 18: Map "Figure 41--Flow net of the Memphis Sand, 1943," prepared by J. V. Brahana	JVB 00954
P-130	Brahana Dep. Exh. 19: Map "Figure 40--Flow net of the Memphis Sand, 1964 (after Bell & Nyman, 1968)" prepared by J. V. Brahana	JVB 00955
P-131	Brahana Dep. Exh. 20: Maps "Figure 39--Flow net of the Memphis Sand, 1980" and various figures	JVB 00956, 815-826
P-132	Brahana Dep. Exh. 21: Criner USGS Report cover page only , "Approximate Potentiometric Surface for the Aquifer Units A2, A3 & A4 . . ."	JVB 00004
P-133	Brahana Dep. Exh. 22: Criner USGS WRI 76-67 cover page and table of contents only, "Historic Water Level Changes and Pumpage from the Principal Aquifers of the Memphis Area, Tennessee 1886 - 1975"	JVB 00005-7
P-134	Brahana Dep. Exh. 23: Criner 1779-O cover page and table of contents only, "Hydrology of Aquifer Systems in the Memphis Area, Tennessee"	JVB 00044-46
P-135	Brahana Dep. Exh. 24: Nyman 1819-B cover page and table of contents only, "Predicted Hydrologic Effects of Pumping from the Lichterman Well Field in Memphis Area, Tennessee"	JVB 00047-49
P-136	Brahana Dep. Exh. 25: Wells 1933, cover page and table of contents only, "Ground Water Resources of Western Tennessee"	JVB 00050-53
P-137	Brahana Dep. Exh. 26: Moore USGS 1809-F, cover page and table of contents only, " Geology and Hydrology of the Claiborne Group in Western Tennessee"	JVB 00054-56

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P-138	Brahana Dep. Exh. 27: Bell USGS 1853, cover page and table of contents only, "Flow Pattern and Related Chemical Quality of Ground Water in the 500-Foot Sand in the Memphis Area, Tennessee	JVB 00057-59
P-139	Brahana Dep. Exh. 28: Map "Potentiometric Map of the Memphis Sand in the Memphis Area, Tennessee, August 1978," by David Graham, WRI 79-80	JVB 00957
P-140	Branch Dep. Exh. 1: Affidavit of Charles Branch dated August 31, 2007	Case 2:05-cv-00032-GHD-EMB, Document 240-2
P-141	Branch Dep. Exh. 2: Branch letter dated 6/26/1995 to Jim Hanes, Tennessee Department of Environment and Conservation funding of aquifer groundwater studies	MDEW0019981-19982
P-142	Branch Dep. Exh. 3: Tom Charlier, "Memphis taps into DeSoto County's well levels," *The Commercial Appeal* , November 16, 1998	RWG 000311
P-143	Gentry Dep. Exh. 1: Gentry Curriculum Vitae	
P-144	Gentry Dep. Exh. 2: Newspaper article from *The Commercial Appeal* , November 16, 1998, entitled "Memphis taps into DeSoto County's well levels," by Tom Charlier	RWG000311
P-145	Gentry Dep. Exh. 3: Newspaper article from *The Commercial Appeal* , Friday, May 12, 2000, entitled, "Issue of Water Quantity Hits Home in Region," by David L. Feldman	RWG000312
P-146	Gentry Dep. Exh. 4: David Lewis Feldman, Ph.D. and Julia O. Elmendorf, J.D., *Final Report--Water Supply Challenges Facing Tennessee Case Study Analyses and the Need for Long-Term Planning* (June 2000) prepared for the Environmental Policy Office, Tennessee Department of Environment and Conservation, Nashville, Tennessee	
P-147	Gentry Dep. Exh. 5: Map of potentiometric surface of Memphis Sands in 1988 (Parks, 1990)	RWG000313
P-148	Gentry Dep. Exh. 6: USGS abstract entitled"Ground-Water Levels and Flow in the Memphis Aquifer, Mississippi, Arkansas and Tennessee," (2001)	RWG000314
P-149	Gentry Dep. Exh. 7: Document prepared by Dr. Gentry, "Methodologies for Estimating a Directional Component of Ground-Water Flow"	
P-150	Gentry Dep. Exh. 8: J.K. Arthur and R.E. Taylor, U.S. Geological Survey Water-Resources Investigations Report 86-4364, *Definition of the Geohydrologic Framework and Preliminary Simulation of Ground-Water Flow in the Mississippi Embayment Aquifer System, Gulf Coastal Plain, United States* (1990)	RWG000315-415
P-151	Gentry Dep. Exh. 9: J.V. Brahana and R.E. Broshears, U.S. Geological Survey Water-Resources Investigations Report 89-4131, *Hydrogeology and Ground-Water Flow in the Memphis and Fort Pillow Aquifers in the Memphis Area, Tennessee*	RWG000416-479
P-152	Gentry Dep. Exh. 10: Map: Figure 41 - Flow net of the Memphis Sand, 1943	JVB 000954
P-153	Gentry Dep. Exh. 11: Map: Figure 50 - Flow net of the Memphis Sand, 1964	JVB 000955
P-154	Gentry Dep. Exh. 12: Map: Figure 39 - Flow net of the Memphis Sand, 1980	JVB 000956
P-155	Gentry Dep. Exh. 13: CD: "GIS Data" CD 08/07/06 provided by Dr. Gentry	RWG000480
P-156	Gentry Dep. Exh. 15: GWI Technical Brief #7, James Outlaw, *A Ground Water Flow Analysis of the Memphis Sand Aquifer in the Memphis, Tennessee Area*	
P-157	"Water Pumpage by Stations, Gallons Per Day, 1965-2012," Table 1A from June 2017 *Update Report on Diversion and Withdrawal of Groundwater from Northern Mississippi Into the State of Tennessee* prepared by David A. Wiley, P.G., WSP (clarification September 2018)	
P-158	"Pumpage Amounts from MLGW and DeSoto County," 1965-2016 Table 2A from June 2017 *Update Report on Diversion and Withdrawal of Groundwater from Northern Mississippi Into the State of Tennessee* prepared by David A. Wiley, P.G., WSP (clarification September 2018)	

No.	Description	Reference Information
P-159	“Volume of Groundwater Taken from Mississippi Due to MLGW Pumpage,” 1965-2016, Table 3 from June 2017 *Update Report on Diversion and Withdrawal of Groundwater from Northern Mississippi Into the State of Tennessee* prepared by David A. Wiley, P.G., WSP	
P-160	"Project Area," Figure No. 1 from June 2017 Update Report on Diversion and Withdrawal of Groundwater from Northern Mississippi Into the State of Tennessee prepared by David A. Wiley, P.G., WSP	
P-161	"Hydrogeologic Cross Section Showing an Example of Cones of Depression," Figure No. 2 from June 2017 *Update Report on Diversion and Withdrawal of Groundwater from Northern Mississippi Into the State of Tennessee* prepared by David A. Wiley, P.G., WSP	
P-162	"Three-Dimensional Illustration Showing Cone of Depression," Figure No. 3 from June 2017 *Update Report on Diversion and Withdrawal of Groundwater from Northern Mississippi Into the State of Tennessee* prepared by David A. Wiley, P.G., WSP	
P-163	"Hydrogeologic Cross Section Showing the Principle Aquifers and Confining Beds in the Study Area," Figure No. 4 from June 2017 *Update Report on Diversion and Withdrawal of Groundwater from Northern Mississippi Into the State of Tennessee* prepared by David A. Wiley, P.G., WSP	
P-164	"Map from the Northern Mississippi Embayment," Figure No. 5 from June 2017 *Update Report on Diversion and Withdrawal of Groundwater from Northern Mississippi Into the State of Tennessee* prepared by David A. Wiley, P.G., WSP	
P-165	"Hydrogeologic Cross Section Illustrating Recharge at Outcrop and Groundwater Flow," Figure No. 61 from June 2017 *Update Report on Diversion and Withdrawal of Groundwater from Northern Mississippi Into the State of Tennessee* prepared by David A. Wiley, P.G., WSP	
P-166	"Hydrogeologic Section of Principal Aquifers and Confining Units East to West Through the Mississippi Embayment With Groundwater Flow Direction," Figure No. 7 from June 2017 *Update Report on Diversion and Withdrawal of Groundwater from Northern Mississippi Into the State of Tennessee* prepared by David A. Wiley, P.G., WSP	
P-167	"Generalized Geology of Embayment and Pre-Development Potentiometric Surface of Middle Claiborne Aquifer," Figure No. 8 from June 2017 *Update Report on Diversion and Withdrawal of Groundwater from Northern Mississippi Into the State of Tennessee* prepared by David A. Wiley, P.G., WSP	
P-168	"1886 Estimated Potentiometric Surface Map for Predevelopment Conditions," Figure No. 9A from June 2017 *Update Report on Diversion and Withdrawal of Groundwater from Northern Mississippi Into the State of Tennessee* prepared by David A. Wiley, P.G., WSP (clarification October 2017)	
P-169	"Sparta/Memphis Sand Aquifer Hydrographs," Figure No. 10 from June 2017 *Update Report on Diversion and Withdrawal of Groundwater from Northern Mississippi Into the State of Tennessee* prepared by David A. Wiley, P.G., WSP	
P-170	"U.S. Geological Survey 2000 Potentiometric Surface Map," Figure No. 11A from June 2017 *Update Report on Diversion and Withdrawal of Groundwater from Northern Mississippi Into the State of Tennessee* prepared by David A. Wiley, P.G., WSP (clarification October 2017)	

No.	Description	Reference Information
P-171	"1886 Estimated Potentiometric Surface Map for Predevelopment Conditions," Figure No. 12A from June 2017 *Update Report on Diversion and Withdrawal of Groundwater from Northern Mississippi Into the State of Tennessee* prepared by David A. Wiley, P.G., WSP (clarification October 2017)	
P-172	"1980 Potentiometric Surface Map from Brahana Groundwater Model," Figure No. 13A from June 2017 *Update Report on Diversion and Withdrawal of Groundwater from Northern Mississippi Into the State of Tennessee* prepared by David A. Wiley, P.G., WSP (clarification October 2017)	
P-173	"2013 Drawdown Contour Map Developed from Groundwater Model," Figure No. 14A from June 2017 *Update Report on Diversion and Withdrawal of Groundwater from Northern Mississippi Into the State of Tennessee* prepared by David A. Wiley, P.G., WSP (clarification October 2017)	
P-174	"2014 Drawdown Contour Map Developed from Groundwater Model" Figure No. 15A from June 2017 *Update Report on Diversion and Withdrawal of Groundwater from Northern Mississippi Into the State of Tennessee* prepared by David A. Wiley, P.G., WSP (clarification October 2017)	
P-175	"2015 Drawdown Contour Map Developed from Groundwater Model," Figure No. 16A from June 2017 *Update Report on Diversion and Withdrawal of Groundwater from Northern Mississippi Into the State of Tennessee* prepared by David A. Wiley, P.G., WSP (clarification October 2017)	
P-176	"2016 Drawdown Contour Map Developed from Groundwater Model," Figure No. 17A from June 2017 *Update Report on Diversion and Withdrawal of Groundwater from Northern Mississippi Into the State of Tennessee* prepared by David A. Wiley, P.G., WSP (clarification October 2017)	
P-177	"2013 Potentiometric Surface Map Developed from Groundwater Model," Figure No. 18A from June 2017 *Update Report on Diversion and Withdrawal of Groundwater from Northern Mississippi Into the State of Tennessee* prepared by David A. Wiley, P.G., WSP (clarification October 2017)	
P-178	"2014 Potentiometric Surface Map Developed from Groundwater Model," Figure No. 19A from June 2017 *Update Report on Diversion and Withdrawal of Groundwater from Northern Mississippi Into the State of Tennessee* prepared by David A. Wiley, P.G., WSP (clarification October 2017)	
P-179	"2015 Potentiometric Surface Map Developed from Groundwater Model," Figure No. 20A from June 2017 *Update Report on Diversion and Withdrawal of Groundwater from Northern Mississippi Into the State of Tennessee* prepared by David A. Wiley, P.G., WSP (clarification October 2017)	
P-180	"2016 Potentiometric Surface Map Developed from Groundwater Model," Figure No. 21A from June 2017 *Update Report on Diversion and Withdrawal of Groundwater from Northern Mississippi Into the State of Tennessee* prepared by David A. Wiley, P.G., WSP (clarification October 2017)	
P-181	"Volume of Groundwater Contributed to Shelby County, TN from DeSoto County, MS Due to MLGW Pumpage (1965-2016), Figure 22 from June 2017 *Update Report on Diversion and Withdrawal of Groundwater from Northern Mississippi Into the State of Tennessee* prepared by David A. Wiley, P.G., WSP	

No.	Description	Reference Information
P-182	"1886 Estimated Potentiometric Surface Map for Predevelopment Conditions," Figure No. 23A from June 2017 *Update Report on Diversion and Withdrawal of Groundwater from Northern Mississippi Into the State of Tennessee* prepared by David A. Wiley, P.G., WSP (clarification October 2017)	
P-183	"2016 Potentiometric Surface Map Developed from Groundwater Model" Figure No. 24A from June 2017 *Update Report on Diversion and Withdrawal of Groundwater from Northern Mississippi Into the State of Tennessee* prepared by David A. Wiley, P.G., WSP (clarification October 2017)	
P-184	"Pre-Development Flow Paths in Northwestern Mississippi," Figure No. 1 from 07/31/2017 Addendum to June 2017 *Update Report on Diversion and Withdrawal of Groundwater from Northern Mississippi Into the State of Tennessee* prepared by David A. Wiley, P.G., WSP	
P-185	"USGS MERAS Model Pre-Development MSSA Potentiometric Surface With Generalized Flow Directions," Figure No. 2 from 07/31/2017 Addendum to June 2017 *Update Report on Diversion and Withdrawal of Groundwater from Northern Mississippi Into the State of Tennessee* prepared by David A. Wiley, P.G., WSP	
P-186	"Model Simulated Pre-Development Potentiometric Head Contours for the Middle Claiborne Aquifer," Figure No. 3 from 07/31/2017 Addendum to June 2017 *Update Report on Diversion and Withdrawal of Groundwater from Northern Mississippi Into the State of Tennessee* prepared by David A. Wiley, P.G., WSP	
P-187	"Generalized Geology of Embayment and Pre-Development Potentiometric Surface of Middle Claiborne Aquifer," Figure No. 4 from 07/31/2017 Addendum to June 2017 *Update Report on Diversion and Withdrawal of Groundwater from Northern Mississippi Into the State of Tennessee* prepared by David A. Wiley, P.G., WSP	
P-188	"1886 Estimated Potentiometric Surface Map for Predevelopment Conditions," Figure No. 5 from 07/31/2017 Addendum to June 2017 *Update Report on Diversion and Withdrawal of Groundwater from Northern Mississippi Into the State of Tennessee* prepared by David A. Wiley, P.G., WSP	
P-189	"Simulated Flow in Memphis Sand Sparta Aquifer," Figure No. 6 from 07/31/2017 Addendum to June 2017 *Update Report on Diversion and Withdrawal of Groundwater from Northern Mississippi Into the State of Tennessee* prepared by David A. Wiley, P.G., WSP	
P-190	"Heads Above and Below the Top of MSSA Aquifer from Equal Amounts of Pumpage Occurring in Mississippi and Tennessee (Based on 2016 MLGW and DeSoto County Estimates)" Figure No. 7 from 07/31/2017 Addendum to June 2017 *Update Report on Diversion and Withdrawal of Groundwater from Northern Mississippi Into the State of Tennessee* prepared by David A. Wiley, P.G., WSP	
P-191	"Figure 1: Groundwater Distribution in the Shallow Subsurface (modified from Alley et al., 1999)," from p. 7 of June 30, 2017, *Expert Report, Hydrogeologic Evaluation and Opinions for State of Mississippi versus State of Tennessee, City of Memphis, and Memphis Light, Gas & Water Division*, prepared by Richard K. Spruill, Ph.D., P.G., Principal Hydrogeologist, Groundwater Management Associates, Inc.	
P-192	"Figure 2: Confined versus Unconfined Aquifers and Artesian Wells," from p. 9 of June 30, 2017, *Expert Report, Hydrogeologic Evaluation and Opinions for State of Mississippi versus State of Tennessee, City of Memphis, and Memphis Light, Gas & Water Division*, prepared by Richard K. Spruill, Ph.D., P.G., Principal Hydrogeologist, Groundwater Management Associates, Inc.	

No.	Description	Reference Information
P-193	"Figure 3: Physiographic Provinces of the Mississippi Embayment (Clark et al., 2011, Figure 1)," from p. 12 of June 30, 2017, *Expert Report, Hydrogeologic Evaluation and Opinions for State of Mississippi versus State of Tennessee, City of Memphis, and Memphis Light, Gas & Water Division* , prepared by Richard K. Spruill, Ph.D., P.G., Principal Hydrogeologist, Groundwater Management Associates, Inc.	
P-194	"Figure 4: Stratigraphic Correlation of Paleocene and Younger Sedimentary Units and Aquifers in Northern Mississippi and Western Tennessee (Haugh, 2016, Table 1)," from p. 14 of June 30, 2017, *Expert Report, Hydrogeologic Evaluation and Opinions for State of Mississippi versus State of Tennessee, City of Memphis, and Memphis Light, Gas & Water Division* , prepared by Richard K. Spruill, Ph.D., P.G., Principal Hydrogeologist, Groundwater Management Associates, Inc.	
P-195	"Figure 5: Surface Distribution of Regional Aquifers and Confining Unites in the Mississippi Embayment and Gulf Coastal Plain (Grubb, 1998, Figure 7)," from p. 15 of June 30, 2017, *Expert Report, Hydrogeologic Evaluation and Opinions for State of Mississippi versus State of Tennessee, City of Memphis, and Memphis Light, Gas & Water Division* , prepared by Richard K. Spruill, Ph.D., P.G., Principal Hydrogeologist, Groundwater Management Associates, Inc.	
P-196	"Figure 6: Cones of Depression and Groundwater Flow Paths Associated with Municipal Well Fields in Shelby County, Tennessee (LB&G, 2014, Figure 31)," from p. 18 of June 30, 2017, *Expert Report, Hydrogeologic Evaluation and Opinions for State of Mississippi versus State of Tennessee, City of Memphis, and Memphis Light, Gas & Water Division* , prepared by Richard K. Spruill, Ph.D., P.G., Principal Hydrogeologist, Groundwater Management Associates, Inc.	
P-197	"Figure 7: Block Diagram Illustrating Surface Recharge and Groundwater Flow Paths within the Sparta-Memphis Sand Aquifer in Northern Mississippi (LB&G, 2014, Figure 6)," from p. 19 of June 30, 2017, *Expert Report, Hydrogeologic Evaluation and Opinions for State of Mississippi versus State of Tennessee, City of Memphis, and Memphis Light, Gas & Water Division* , prepared by Richard K. Spruill, Ph.D., P.G., Principal Hydrogeologist, Groundwater Management Associates, Inc.	
P-198	"Figure 8: Schematic West-East Cross-Section of the Geology of the Mississippi Embayment and Generalized Pre-Development Groundwater Flow Patterns (modified from Figure 4 of Hart et al., 2008)," from p. 20 of June 30, 2017, *Expert Report, Hydrogeologic Evaluation and Opinions for State of Mississippi versus State of Tennessee, City of Memphis, and Memphis Light, Gas & Water Division* , prepared by Richard K. Spruill, Ph.D., P.G., Principal Hydrogeologist, Groundwater Management Associates, Inc.	
P-199	"Figure 9: Pre-Development Groundwater Equipotential Map and Flow Patterns in the Middle Claiborne Aquifer (modified from Plate 5 of Arthur and Taylor, 1998)," from p. 21 of June 30, 2017, *Expert Report, Hydrogeologic Evaluation and Opinions for State of Mississippi versus State of Tennessee, City of Memphis, and Memphis Light, Gas & Water Division* , prepared June 30, 2017, by Richard K. Spruill, Ph.D., P.G., Principal Hydrogeologist, Groundwater Management Associates, Inc.	

No.	Description	Reference Information
P-200	"Figure 10: Post-Development Groundwater Equipotential Map and Flow Patterns in the Middle Claiborne Aquifer (modified from Plate 7 of Arthur and Taylor, 1998)," from p. 22 of June 30, 2017, *Expert Report, Hydrogeologic Evaluation and Opinions for State of Mississippi versus State of Tennessee, City of Memphis, and Memphis Light, Gas & Water Division* , prepared by Richard K. Spruill, Ph.D., P.G., Principal Hydrogeologist, Groundwater Management Associates, Inc.	
P-201	"Figure 11: Unconfined Aquifers and Local Flow Systems (Modified from Grannemann et al., 2000)," from p. 25 of June 30, 2017, *Expert Report, Hydrogeologic Evaluation and Opinions for State of Mississippi versus State of Tennessee, City of Memphis, and Memphis Light, Gas & Water Division* , prepared by Richard K. Spruill, Ph.D., P.G., Principal Hydrogeologist, Groundwater Management Associates, Inc.	
P-202	"Figure 12: Piezometers are used to define Groundwater Recharge, Discharge, and Flow Patterns in Unconfined Aquifers (modified from Winter et al., 1998)," from p. 26 of June 30, 2017, *Expert Report, Hydrogeologic Evaluation and Opinions for State of Mississippi versus State of Tennessee, City of Memphis, and Memphis Light, Gas & Water Division* , prepared by Richard K. Spruill, Ph.D., P.G., Principal Hydrogeologist, Groundwater Management Associates, Inc.	
P-203	"Figure 1: Waldron and Larsen (2015) Pre-Development Equipotential Map for the Middle Claiborne Aquifer (aka, SMS or Memphis Aquifer)," from p. 8 of July 31, 2017, Expert Report, Addendum #1, Hydrogeologic Evaluation and Opinions for State of Mississippi versus State of Tennessee, City of Memphis, and Memphis Light, Gas & Water Division, prepared by Richard K. Spruill, Ph.D., P.G., Principal Hydrogeologist, Groundwater Management Associates, Inc.	
P-204	"Figure 2: Criner and Parks (1976) Graph of Groundwater Withdrawals from the Middle Claiborne Aquifer (aka, SMS or Memphis Aquifer) between 1886 and 1975," from p. 9 of July 31, 2017, *Expert Report, Addendum #1, Hydrogeologic Evaluation and Opinions for State of Mississippi versus State of Tennessee, City of Memphis, and Memphis Light, Gas & Water Division* , prepared by Richard K. Spruill, Ph.D., P.G., Principal Hydrogeologist, Groundwater Management Associates, Inc.	
P-205	"Figure 3: Criner and Parks (1976) Equipotential Map for Confined Portions of the Middle Claiborne Aquifer (aka, SMS or Memphis Aquifer) in 1886," from p. 12 of July 31, 2017, *Expert Report, Addendum #1, Hydrogeologic Evaluation and Opinions for State of Mississippi versus State of Tennessee, City of Memphis, and Memphis Light, Gas & Water Division* , prepared by Richard K. Spruill, Ph.D., P.G., Principal Hydrogeologist, Groundwater Management Associates, Inc.	
P-206	"Figure 4: Reed (1972) Equipotential Map for Confined Portions of the Middle Claiborne Aquifer (aka, SMS or Memphis Aquifer) in 1886," from p. 13 of July 31, 2017, *Expert Report, Addendum #1, Hydrogeologic Evaluation and Opinions for State of Mississippi versus State of Tennessee, City of Memphis, and Memphis Light, Gas & Water Division* , prepared by Richard K. Spruill, Ph.D., P.G., Principal Hydrogeologist, Groundwater Management Associates, Inc.	

No.	Description	Reference Information
P-207	"Figure 5: Comparison of Equipotential Maps for Confined Portions of the Middle Claiborne Aquifer (aka, SMS or Memphis Aquifer) in 1886 Produced by Criner and Parks (1976) and Reed (1972), Top and Bottom, Respectively," from p. 14 of July 31, 2017, *Expert Report, Addendum #1, Hydrogeologic Evaluation and Opinions for State of Mississippi versus State of Tennessee, City of Memphis, and Memphis Light, Gas & Water Division* , prepared by Richard K. Spruill, Ph.D., P.G., Principal Hydrogeologist, Groundwater Management Associates, Inc.	
P-208	"Figure 6: Local versus Regional Groundwater Flow Systems in Unconfined and Confined Aquifers, Respectively," from p. 19 of July 31, 2017, *Expert Report, Addendum #1, Hydrogeologic Evaluation and Opinions for State of Mississippi versus State of Tennessee, City of Memphis, and Memphis Light, Gas & Water Division* , prepared by Richard K. Spruill, Ph.D., P.G., Principal Hydrogeologist, Groundwater Management Associates, Inc.	

Exhibit 2

Excerpts from Expert Report Addendum #1
of Richard K. Spruill, Ph.D., P.G.

(July 31, 2017)

EXPERT REPORT
Addendum #1

Hydrogeologic Evaluation and Opinions
for State of Mississippi versus
State of Tennessee, City of Memphis,
and Memphis Light, Gas & Water Division

PREPARED FOR:
Daniel Coker Horton & Bell, P.A.
265 North Lamar Boulevard, Suite R
Oxford, Mississippi 38655
Telephone: (662) 232-8979

PREPARED BY:
Groundwater Management Associates, Inc.
4300 Sapphire Court, Suite 100
Greenville, North Carolina 27834
Telephone: (252) 758-3310

GMA

July 31, 2017

Richard K. Spruill, Ph.D
Principal Hydrogeologist

I. Introduction

Groundwater Management Associates (GMA) was retained by the firm of Daniel Coker Horton & Bell, P.A. (DCH&B) to provide expert geologic and hydrogeologic consulting regarding the origin and distribution of groundwater, interactions between surface water and groundwater, natural and man-induced migration patterns of groundwater, and specific topics regarding the geology and hydrogeology of predominantly sandy sediments in the Eocene-age Middle Claiborne Group that host the Sparta-Memphis Sand aquifer system in northwestern Mississippi and southwestern Tennessee. GMA's services included production of an expert report by Dr. Richard Spruill that focused on known or likely impacts on groundwater distribution and migration patterns within the Sparta-Memphis Sand (aka, SMS, Sparta Sand, Memphis Sand, Sparta Aquifer, Memphis Aquifer, Middle Claiborne aquifer, among others) in response to historic and ongoing pumping in Shelby County, Tennessee.

The expert report was produced for DCH&B on June 30, 2017. The report provided here is Addendum #1 to that expert report, and it is primarily an evaluation and critique of (1) the 2015 report by Waldron and Larsen that forms the basis of claims that, prior to intense pumping in Tennessee, the Sparta-Memphis Sand (SMS) has always had substantial northwestward-directed groundwater flow from Mississippi across the state border and generally into the area of the City of Memphis and Shelby County, Tennessee, and (2) the expert reports submitted on June 30, 2017, by two of the three individuals retained on behalf of the State of Tennessee, the City of Memphis, and the Memphis Light, Gas & Water Division (MLGW). My review and evaluation of new or previously-available information have not changed the opinions that I provided in my expert report.

II. Qualifications

I, Richard K. Spruill, am submitting this addendum to my expert report dated June 30, 2017. My descriptions, interpretations, conclusions, and professional opinions described evaluation of expert reports submitted by two of three representatives for the defendants.

Overall, it is my opinion that these reports do not directly address the geological and hydrological issues that must be addressed in any dispute between states over the right to regulate and take groundwater naturally occurring and present within each separate state. High-quality groundwater stored underground in hydraulically-confined aquifers over thousands of years is a valuable and finite natural resource. Each state regulates the use of its groundwater resources. Unlike rivers and streams that generally reveal their presence and water supply at the surface, each confined aquifer has unique characteristics based on the local geology which determine the groundwater's origin, movement, quality, availability, and the amount of development through pumping that can be undertaken consistent with long-term sustainability. Because of these unique characteristics, the natural resource question must be focused on the specific origin, characteristics, and flow of groundwater that is subject to the regulations of each state while it naturally resides within its borders.

The two expert reports that I evaluated appear to intentionally conflate geologic relationships and the common presence of groundwater without significant scientific analysis of the actual groundwater that occurs naturally within the separate states of Mississippi and Tennessee. Groundwater is the natural resource that must be examined for the purpose of its regulation, protection, conservation, and sustainability. Beyond the failure of these two reports to deliver clear, credible scientific analysis, the hydrological analysis that was offered was not developed using well-established methodologies or reliable data, and therefore should not be considered in determining whether the disputed groundwater is "interstate" or "intrastate" groundwater.

I offer the following opinions on the three main areas of review that I performed in connection with preparation of my expert report addendum.

- I performed a detailed evaluation of the study published by Waldron and Larsen (2015) that purports to provide a superior and more accurate depiction of the natural, pre-pumping hydraulic pressures (the "equipotential surface") in the

Middle Claiborne aquifer (aka, SMS) in the vicinity of the Mississippi-Tennessee border in and near Shelby County, Tennessee. I consider the dataset employed by Waldron and Larsen (2015) to be wholly unreliable, thus rendering their depiction of the SMS' pre-development (1886) equipotential map meaningless in the context of sound science and the litigation under discussion.

- Mr. Larson's (no relation to Dr. Larsen) expert report can be distilled to one opinion; the Middle Claiborne aquifer, and all groundwater stored over many thousands of years within it, is an interstate resource. To reach that conclusion, Larson: (1) conflates a massive geologic feature (Claiborne Group sedimentary deposits) with a hydrogeologic feature (water producing portions within the Claiborne Group that qualify as an aquifer system); (2) takes the simplistic view that, because a geological formation qualifying as an aquifer system may cross state lines, all of the groundwater residing within that formation must be considered an interstate resource, apparently without regard to current or pre-development patterns of flow within each separate state; (3) conveniently ignores the natural manner by which the groundwater was recharged and moves over many hundreds to thousands of years; and (4) claims that because a specific agency of the federal government (United States Geological Survey; USGS) created a regional computer model to mimic aspects of the regional aquifer system, that entire system is obviously an interstate resource. In my opinion, Mr. Larson's core opinion and his supporting justifications do not represent a disciplined scientific analysis or interpretation of the available geological and hydrological evidence.
- The expert report by Dr. Waldron is a curious mixture of arguments. He adopts and argues the superiority of a study in which he participated (Waldron and Larsen, 2015), and he attacks the work of the same USGS scientists that Mr. Larson holds in high esteem. In my opinion the Waldron and Larson (2015) report is so badly flawed as to render Waldron's conclusions gleaned from that study fundamentally unreliable.
- I provide opinions and illustrative examples, calculations, and analogies that reveal some of the special characteristics of groundwater not considered in these three reports, including the surprisingly slow rate of movement of groundwater

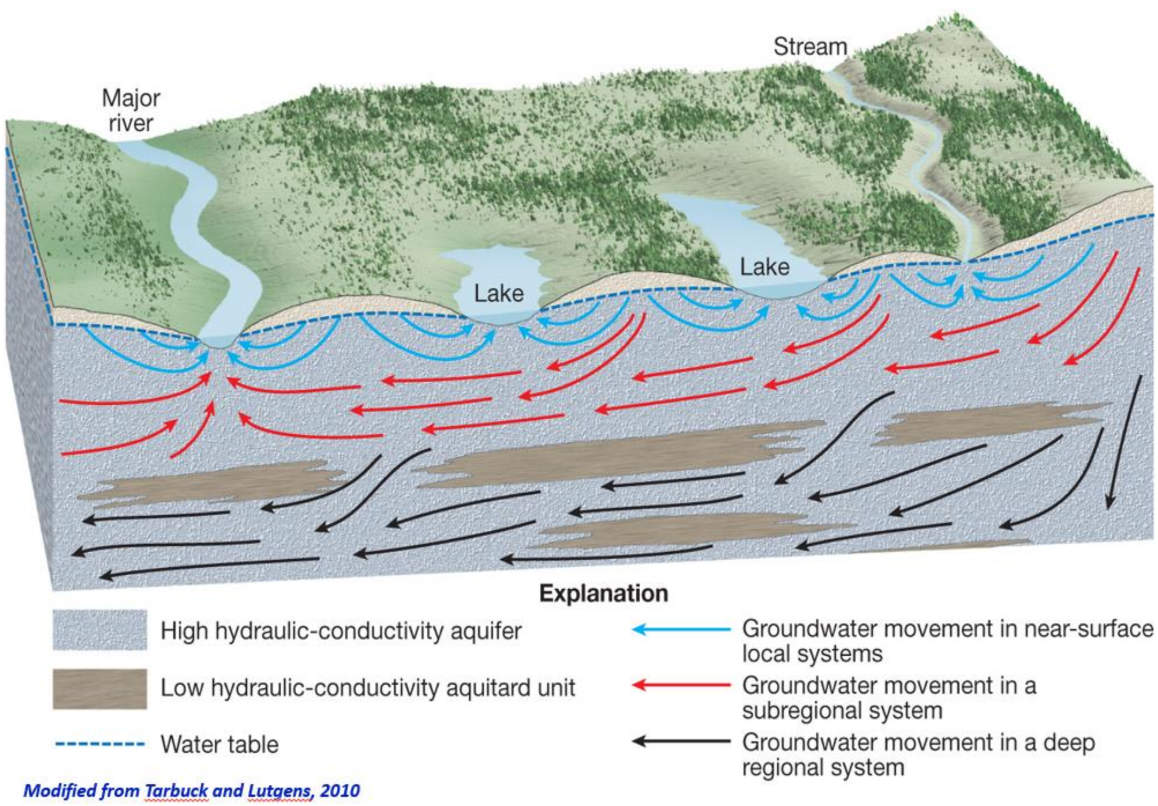
1. Many "wells" cited W&L 2015 *are <u>not</u> actually wells.* Instead, those "wells" are generic observations or claims about zones that were being targeted in particular areas for the potential drilling of water-supply wells in the late 1800s or very early 1900s. In the following discussion, I will refer to all W&L 2015 data points as "wells" to simplify the discussion, but the fact remains that a significant percentage of the data cited in W&L 2015 is invalid for this reason alone.
2. Exact locations for most wells used by W&L were simply not known, so they estimated the locations based on various lines of information, narrative , and/or assumption. W&L 2015 assumed land surface elevations based upon criteria of their choosing, and those values often do not match the elevations reported in the three source documents that date from 1903 and 1906 (see Appendix B-1).
3. Methods of measurement of water levels are not documented in any of the three original source reports. This fact alone introduces an unacceptable level of uncertainty for the stated or assigned values for depth to groundwater.
4. All of these historic measurements represent a period of time that post-dates the start of municipal/commercial pumping in the vicinity of Memphis in 1886, typically by at least a decade.
5. Historic water-level values in the three data-source reports used in W&L 2015 are listed as whole numbers in feet, which, at best, provide accuracy to the nearest foot (~0.305 meters). W&L rounded all land elevations used for calculating water level elevations to the nearest meter, which further degrades the accuracy of contoured head values presented on their Figure 4.
6. Historical records of groundwater measurements do not specify the pumping conditions of the wells. It is not known if the reported water levels were measured during active pumping or under non-pumping (static) conditions.
7. Reference points for water-level measurements are not given. Many of the historical publications list the depth to water below the "mouth" of the well, and the height of the mouth of the well (above or below land surface) is not listed.
8. The total head difference presented in Figure 4 of W&L 2015 is 79 meters (259 feet). W&L 2015 reported the estimated vertical errors for land surface elevations of up to 5.5 meters (18 feet; approximately a 7% error). The estimated vertical error for elevation reference does <u>not</u> take into account the inherent error in

rounding values to the nearest meter for each water level value used for contouring head in Figure 4.

9. Head values used to produce Figure 4 of W&L 2015 do not consider the effects of well construction on the reliability of the water level data. If a well installed into a confined aquifer does not have a properly grouted casing seal, there will be vertical hydraulic interconnection with the unconfined surficial aquifer via the ungrouted borehole. Until relatively recently, it was common practice to 'seal' water-supply well casings using very little grout that typically extended just a short distance below the land surface. Historic records used in W&L 2015 to obtain water level data do not provide any information about well construction and grouting.
10. Figure 4 of W&L 2015 does not discriminate between head values representing confined and unconfined portions of the aquifer system, and fully 60 percent of the data set used by W&L represent wells that are placed within unconfined portions of the SMS aquifer. In contrast, maps produced by Criner and Parks (1976) and Reed (1972) only consider groundwater-flow conditions in the confined portions of the aquifer. The distinction between confined and unconfined portions of the aquifer system correlates with the differences in regional versus local groundwater flow systems, respectively, as illustrated generically below in Figure 6.
11. W&L's dataset lists Well #3 (Forest City, Arkansas), but the well was excluded from their map even though it is located closer to Memphis than many other wells used to construct their Figure 4. Well #3 had an estimated elevation of 28 meters, the lowest head value reported in W&L 2015. Had this data point been used in contouring, the orientation of groundwater flow via equipotential lines in the confined portion of the aquifer system would have been more westerly, rather than northwesterly. Two other wells (#1 and #2) in eastern Arkansas were used to construct Figure 4, and W&L 2015 offers no justification for ignoring Well #3.
12. W&L 2015 commonly uses the land surface elevation as the head elevation for wells reported to be free-flowing (artesian). That assignment of head elevation is not accurate because those values are too low for those locations. By definition, a free-flowing (artesian) well has a hydraulic head that is at some elevation *above*

the local land surface. To determine the correct head for free-flowing wells, the well must be equipped with a pressure gauge, or the well casing must be extended above the land surface to a height that prevents free flow of water from the top of the pipe. Only then can the amount of hydraulic pressure above the land surface at those locations be determined accurately. The historic records relied upon by W&L 2015 never include this information, so it not scientifically-reliable data to use to produce their Figure 4.

Figure 6: Local versus Regional Groundwater Flow Systems in Unconfined and Confined Aquifers, Respectively.



13. Figure 4 of W&L 2015 contains numerous errors in contouring the pre-pumping equipotential surface, including: (1) an inconsistent contour interval that varies from 9 to 13 meters, (2) assigning Well #16 (Taylor's Chapel, Tennessee) a head value of 91 meters, but the data point is contoured incorrectly on the inside (i.e., lower elevation) of the 91-meter contour line, (3) Well #17 (Bell Eagle, Tennessee) is located in a contoured area that should give the well a head

elevation greater than 91 meters, but the value assigned to Well #17 is only 82 meters, and (4) Well #6 (Hudsonville, Mississippi) has an estimated head elevation of 104 meters, yet the well is shown almost 6 miles (~9,500 meters) up-gradient from the 104 meter contour line in an area where W&L's contouring indicates that the elevation should be more than 106 meters. Collectively, these issues demonstrate that W&L's Figure 4 does not conform to standard contouring rules and thus presents a fundamentally flawed interpretation of the pre-pumping equipotential surface in the aquifer system.

14. An area of low head elevation is illustrated in Figure 4 in southern Tennessee near the Mississippi border. The head representation of this area is dominated by values assigned to Wells #12 (Moscow, Tennessee) and #14 (Rossville, Tennessee). These are fundamentally flawed data points that should not have been considered for pre-pumping equipotential contouring. Historic data for Well #12 does not reflect a specific well at a known location, and there is no specific reference of water level for Well #12, only the meaningless statement that "*water is found in abundance at depths of 60 to 80 feet".* In the context of the discussion by Glenn (1906), these depths identify drilling target depths at which known water-producing strata occur, not the depth of the water level in any well. Similarly, the data from Well #14 at Rossville, Tennessee, does not include a reported water level in a well. Like Well #12, it only reflects a general statement of the drilling depth to a sand layer from which water can reportedly be obtained. Simply put, there are no reported water level values for Wells #12 and #14 that can be used to construct Figure 4. When the fictitious head values assigned to these wells are removed from Figure 4 of W&L 2015, there is no longer any indication of a steep pre-development hydraulic gradient directed northward.

15. It is clear that most of the water levels presented in Figure 4 of W&L 2015 are not scientifically supportable. At many locations, Waldron and Larsen's map suggests pre-development equipotential surface elevations that are actually lower than more recent post-development observations. This is especially noticeable in areas of eastern and central Fayette County, Tennessee. A comparison of head elevations shown in Figure 4 of W&L 2015 with post-development equipotential measurements shown in Schrader (2008) indicates that Moscow, Tennessee, has

a post-development head of approximately 107 meters, which is 20 meters (more than 65 feet) higher than the estimated pre-development head. The estimated head at Moscow, Tennessee, presented on Figure 4 of W&L 2015 is significantly in error because this location is within the well-known pumping cone of depression centered on Shelby County, Tennessee. Likewise, there is a post-development head of approximately 96 meters at Rossville, Tennessee, which is 10 meters (more than 32 feet) higher than the estimated pre-development equipotential values shown in Figure 4 of W&L 2015. These are two clear examples of egregious errors in the interpretations of W&L 2015.

The following are my concluding opinions regarding Waldron and Larsen's approach to investigating and illustrating the pre-development groundwater flow patterns in their study area:

- The study lacks the rigorous data control that is essential to producing any meaningful hydrological interpretations or conclusions.
- Minimal data control requirements include precisely known locations and elevations of the measuring point at the tops of well casings. The specific screened interval(s) of the wells must be known, not assumed. Well construction records should also be available and considered, in addition to other information such as driller's logs. Measured depth to water in the well must be reported. It must be known that the well has not been pumped recently (i.e., the water level is static) and that there are no nearby wells pumping from the same aquifer. The data used by Waldron and Larsen in their 2015 study *do not meet any of these requirements*, making their Figure 4, and any conclusions or inferences drawn from it, completely unreliable.
- As described and illustrated in my report, monitoring wells with short screen intervals placed at accurately known depths must be used for evaluations of groundwater flow in unconfined aquifer systems. Data in the Waldron and Larson 2015 report indicate that this was not done.
- Interpretations of flow patterns based on incomplete or inaccurate well and head data fail to account for local flow patterns in the unconfined portions of the

groundwater system, wherein groundwater generally moves from recharge to discharge areas along circuitous flow paths, as illustrated above in Figure 6.

- Groundwater flow patterns in unconfined portions of the groundwater system are complex, and reflect relatively small, local groundwater 'basins.' Data for the unconfined aquifer system should never be used to define groundwater flow patterns in the confined portions of the aquifer system which reflect regional flow patterns.
- Considering the unreliability of the data employed, and the fundamental errors identified in their study, I assert that (1) Waldron and Larson did *not* provide a scientifically-reliable basis to support the pre-development distribution of hydraulic head and associated flow patterns for the SMS aquifer that are described and illustrated as Figure 4 in their 2015 report, and (2) there is no meaningful application of their work or their interpretations in Figure 4 to the border region between northwestern Mississippi and southwestern Tennessee.
- Interpretations by other researchers regarding the pre-development equipotential surface of the Middle Claiborne aquifer are properly focused on the confined portions of the groundwater system, and thus provide the best evidence and basis for accurate groundwater modeling and evaluation.
- It is my opinion that, with limited variations near the common border between Mississippi and Tennessee, the natural groundwater flow in the confined portions of the Middle Claiborne aquifer and other regional aquifers in both Mississippi and Tennessee is from eastern recharge areas toward western discharge areas. As demonstrated by computer simulations (e.g., LBG, 2014), there is a small area near the border between Mississippi and Tennessee where limited cross-border flow may occur under natural conditions. However, almost all groundwater in these regionally-important aquifers in Mississippi originates from recharge occurring inside the state. This groundwater naturally travels within the confined portions of the aquifer system in Mississippi and, absent intense pumping in Tennessee, the same water ultimately discharges to the Mississippi River many thousands of years later by moving upward through younger strata.

between states, as implied by Dr. Waldron's report. Alternatively, Mr. Larson's view that groundwater flow in a stratigraphically-equivalent aquifer located elsewhere in a very large sedimentary basin (e.g., northeastern Texas), and as modeled with a computer program replete with inherent assumptions and simplifications, has no potential bearing on this issue. It is well known that groundwater-flow patterns in an aquifer located within a state can be dramatically altered by groundwater withdrawals occurring nearby within adjacent states. An example of the impact of groundwater withdrawals on flow patterns in an adjacent state is the case of Hilton Head Island, South Carolina, a focus area for my own research for more than a decade. Prior to any development on Hilton Head Island, groundwater in the preferred aquifer was from south to north across the island. Extensive pumping by the City of Savannah, Georgia, located south of Hilton Head Island, resulted in a reversal of the natural groundwater-flow direction and caused saltwater to migrate into the aquifer beneath the island. Development in Georgia has rendered much of the preferred aquifer beneath Hilton Head Island unusable without costly treatment. This is but one example of predevelopment groundwater flow being dramatically changed by withdrawals initiated in an adjacent state.

It is clear that some aquifers extend over very large areas, including multiple states. However, the geographic distribution of those aquifers does not define the groundwater resources as interstate. Imagine a layer of coal that underlies the border region between two states; is the coal layer an interstate or intrastate resource? Would one state have the right to directionally bore and mine the coal from beneath the adjacent state? My opinion is that the answer to that question is no. Likewise, groundwater in the case of the Middle Claiborne aquifer in Mississippi is an intrastate resource that would not leave the state to any appreciable extent in the absence of intense pumping in adjacent Tennessee.

There is no dispute that withdrawing more than 180 Million gallons per day in southwestern Tennessee has changed the natural flow patterns in the Middle Claiborne aquifer in the trans-border region. Unless these withdrawals are reduced dramatically, the groundwater-flow patterns will not be returned to their natural, pre-development condition. The development potential of the natural groundwater resource (e.g.,

- An aquifer system is *not* an interstate resource because the aquifer's geologic framework (i.e., solid parts of the system such as grains of sand, sedimentary rock, etc.) extends over large areas.
- An aquifer system is *not* an interstate resource because hydrogeologists and hydrologists study aquifer systems over large areas.
- An aquifer system is *not* an interstate resource because some well-meaning scientists have produced groundwater computer models that extend over multi-state regions.
- An aquifer system is *not* an interstate resource because a small percentage of groundwater flowing in the aquifer crosses the boundary from one state to another state.
- An aquifer system in *not* an interstate resource because a scientist says it is an interstate resource based on an interpretation of what the USGS may or may not have said.

It is my opinion that the definition of an intrastate groundwater resource must be based on the fate of water in the groundwater system under natural conditions. If the majority of groundwater in an aquifer enters the groundwater system by recharge within a specific state, and that water flows *VERY* slowly through the aquifer within that same state, such that the water remains in the state for *VERY* long periods of time before ultimately being discharged from the groundwater system, then that groundwater is an intrastate resource.

Aquifers are *not* rivers of water flowing underground. The residence time for groundwater in the hydraulically-confined portions of the Middle Claiborne aquifer within Mississippi is measured in thousands of years, not days. Groundwater in this important and valuable aquifer is a life-sustaining resource for the residents of Mississippi, and it is an intrastate resource as based on my definition.

It is also my opinion that decisions regarding the classification of groundwater resources as intrastate versus interstate should not be conducted without a detailed consideration of the advantages and disadvantages of such a classification on the ability of a state to protect and manage the resource for the full benefit of its citizens. My professional experience has provided many examples of groundwater resource management issues that involve the problematic withdrawal of water from regionally-extensive confined aquifer systems by water purveyors located in border regions between states. In my experience, it is _*not*_ the withdrawal of groundwater from these aquifers by production well fields located significant distances from state borders that is problematic. The conflicts occur in border regions between states when water purveyors unilaterally develop large-scale groundwater systems near state borders and create regional-scale cones of depression. My recommendation is to encourage states to use their state-specific regulatory framework to _*not*_ allow the development of large-scale pumping centers located in trans-border regions if scientific studies indicate that such development will have a clear detrimental impact on the groundwater resources of the neighboring state.

Appendix B-1: Evaluation of the Well Data Used by Waldron and Larsen (2015) to Produce Figure 4 of Their Report

Data Sources Cited by Waldron and Larsen (2015)

Crider, A.F., and Johnson, L.C., 1906, Summary of the underground-water resources of Mississippi: U.S. Geological Survey Water-Supply and Irrigation Paper No. 159, 86 p.
Fuller, M.L., 1903, Contributions to the hydrology of eastern United States: U.S. Geological Survey Water-Supply and Irrigation Paper No. 102, 522 p.
Glenn, L.C., 1906, Underground waters of Tennessee and Kentucky west of Tennessee River and of an adjacent area in Illinois: U.S. Geological Survey Water-Supply and Irrigation Paper No. 164, 173 p.

Well #1 at Turrell, Arkansas (Fuller, 1903). Exact location of the well is not known. Location of the Baker Lumber Company property was apparently selected from a search of the name Baker within the Tyranza Township. Then, the land surface elevation was estimated for this property location. Local elevations at Turrell range from approximately 202 feet (61.5 M) at Big Creek to approximately 225 feet (68.6 M) in the center of Turrell. Well construction details are not reported (i.e., screen interval of the well and whether or not the casing was grouted). Method of water depth measurement is not reported. Height of the top of well casing is also not reported.

Well #2 at Helena, Arkansas (Fuller, 1903). Means of water level measurement not specified. Accuracy of reading reported is unknown. Well construction details (screened interval and status of grouting of the well casing) are unknown. Status of well pumping relative to water-level measurement is unknown (i.e., was the reported water level the original static level or had the well been in operation for some period of time before the water level was reported). Water level is referenced below the "mouth" of the well, but the height of the well "*mouth*" relative to land surface is not referenced. Because the elevation of the original "*mouth*" of the well is unreported, and because Waldron and Larsen rounded the reported water level to the nearest meter, it is incorrect to list the estimated vertical error as 0.0 M within Table 1. Rounding the water level from 30 feet to 9 meters already introduces a minimum error of 0.146 meters.

Well #3 at Forest City, Arkansas (Fuller, 1903). Well construction details (screen placement, grout interval, and height of "*mouth*" of the well) are unknown. Rounding of water level from 160 feet to 49 meters incorporates an error of 0.22 meters. Rounding of the land surface elevation to the nearest whole meter also incorporates an error. Likewise, the unknown height of the "*mouth*" of the well adds uncertainty as to the elevation reference for the reported water level. Therefore, it is incorrect to represent the estimated vertical error as 0.0 meters. Status of well pumping relative to water-level measurement is unknown (i.e., was the reported water level the original static level or had the well been in operation for some period of time before the water level was reported).

Well #4 at Hernando, Mississippi (Crider and Johnson, 1906). The data source describes, in general terms, some information about depth, stratigraphy, yield, and water level for "*a well in Hernando*." Ownership of the well and the well's specific location are not provided. Methods of measurement of water level are not presented. Waldron and Larsen summarize information about the well in Table 1. The reported well depth (165 feet on Table 1) does not match the documentation in Crider and Johnson (1906) where the total drilling depth can be calculated to be 220 feet. Well construction details (depth, screened interval, and depth of any grout seal) are not presented in Crider and Johnson. Waldron and Larsen locate the well at the "*City center*" and they estimate the land surface elevation to be 109 meters AMSL. A review of the USGS topographic quadrangle map of Hernando indicates that land surface elevation within Hernando ranges from about 350 feet (106.7 meters) to over 400 feet (~122 meters), a range of more than 15 meters. However, Waldron and Larsen suggest that their estimated vertical error is only 4.2 meters. Furthermore, the method of measurement of the estimated water level, the date of measurement, and whether the water level is an original static level versus the reported level in 1906 after some years of pumping at the reported 150 gallons per minute is unknown.

Well #5 at Holly Springs, Mississippi (Fuller, 1903). Reportedly, there are two adjacent wells on the same site. It is not known how the water-level was measured and whether or not one or both of the wells on site may have been pumping. Height of the mouth of the well is unreported. Waldron and Larsen report that method of location is "*Located in the town center.*" Exact location of well (and associated land elevation) is unknown. Local land elevation at Holly Springs varies from 530 feet (161.5 m) to 620 feet (189 m) AMSL. Waldron and Larsen indicate a vertical error of only 2.5 meters, but clearly the elevation error is likely much greater than that.

Well #6 at Hudsonville, Mississippi (Fuller, 1903). The data source does not identify specific well location at Hudsonville. Waldron and Larsen researched property records from 1900 census to identify property that they assumed to represent the well site, they then assumed a location (and associated elevation) on that property. The local topography near Hudsonville includes significant elevation variances, ranging from about 460 feet (140 m) to about 520 feet (158.5 m). Therefore, the potential elevation error for the well location could be as much as 18.5 meters. The height of the mouth of the well above land surface is unknown. The method of water-level measurement and the accuracy of measurement is unknown. The depth of the well is reported to be 168 feet, and the well was indicated to have only 15 feet of water depth. Details of well construction are unknown, including type and depth of well opening, construction method, and grout seal (if any). The reported water depth of 153 feet is much deeper than would be expected for an unconfined section of the aquifer, especially considering that the nearby perennial stream (Coldwater River) at Hudsonville has a local elevation of 460 feet (140 m). The calculated water elevation (104 m) presented in the Waldron report would be 36 meters <u>lower</u> than the Coldwater River elevation. This would not be expected if the Memphis Aquifer were unconfined at Hudsonville. Based upon documentation of Well #6 at Hudsonville, it is not appropriate to rely upon this well for mapping the pre-development potentiometric surface mapping for the aquifer.

Well #7 at Canadaville, Tennessee (Glenn, 1906). However, the discussion of groundwater conditions at Canadaville is <u>not</u> about any specific individual well example. Glenn discusses generalities about depths of wells and estimated depths to groundwater levels. Waldron and Larsen incorrectly list a specific well at Canadaville with a depth of 150 feet. No such well is mentioned in Glenn for this location. Likewise, the mention of depth to the water level being 125 feet is not specific to a particular well. Rather, the report states "*Some small bored wells, ranging from 90 to 140 feet in depth, yield an abundant supply of good soft water, but in the deeper wells it rises only within 125 feet of the surface.*" It is important to note that topography in the area near Canadaville varies from a high of about 477 feet (145 M) MSL to a low of about 375 feet (114 M). Because no specific well location is referenced in Glenn for the reported 125 feet depth to groundwater, the selection of an estimated land surface elevation in the Waldron report is arbitrary and unreliable. The elevation error for this estimated location could be as much as 31 meters, depending upon the specific location selected as representative of the well site used for Well #7. The water-level contouring presented in Waldron and Larsen's Figure 4 or their report is strongly influenced by the estimated water level value shown for Well #7. This is unfortunate, because the cited reference for this water-level does not reflect any specific well location in the area.

Well #8 at Claxton, Tennessee (Glenn, 1906). The discussion of conditions at Claxton does <u>not</u> reference any specific well, and instead Glenn describes wells typical in the area and states that wells "*may go 75 to 100 feet deep, and the water rises within about 40 feet of the surface.*" The location selected for the well is based upon an interview with an elderly lady who supposedly worked for the Claxton family. No specific details of well locations are available for this station. Clearly this discussion of generalities and approximations should not be relied upon for contouring of an equipotential map.

Well #9 at Ina, Tennessee (Fuller, 1903). The exact location of the well is not known. The location of the well was assumed by Waldron and Larsen based upon property records and research of the OMNI Gazetteer. Well location and elevation cannot be verified, and the height of the well opening is not known. The reported well depth and water depth cannot be verified, and the method of water-level measurement (and accuracy of measurement) is also not known. Using topographic maps, the land elevation near Ina ranges from 480 feet (146 m) to 520 feet (158 m).

Well #10 at LaGrange, Tennessee (Glenn, 1906). The exact locations of wells referenced in the source publication are not known. General statements are made about wells being drilled to 175 and 213 feet depth. No specific measurement of water depth is referenced for these wells in LaGrange. Waldron and Larsen assume incorrectly that well depth equates to non-pumping water level depth by selecting a water depth of 194 feet (59 m). Because one well referenced by Glenn was stated to be 175 feet depth, it is certainly not clear that the depth to water was less than 175 feet pre-development. There is no reasonable way that one could conclude that the pre-development water level could be as deep as 194 feet at LaGrange. It is obvious that there is no reliable means of determining a pre-development water level for the Town of Lagrange to use for preparing an equipotential contour map. Furthermore, the Glenn (1906) publication states explicitly that the Town of LaGrange is "*532 feet above the sea.*" But, the Waldron report selects a land surface elevation of 165 meters (541 feet) for calculating a water elevation. Because the specific locations of wells are not known, the adjustments of land elevation for this datum are based upon assumptions that simply cannot be tested. The estimated water level for LaGrange are totally unreliable and further render the pre-pumping equipotential map of Figure 4 to be incorrect.

Well #11 at Moorman, Tennessee (Glenn, 1906).. As with many other wells used by Waldron and Larsen to produce their pre-development equipotential map, the exact location of the well(s) is not identified. Glenn reports that, "*One 103 feet deep struck water of good quality at 53 feet.*" This statement does not say that the static water level was 53 feet deep, it just implies that water was "*struck*", which could mean that water-bearing strata were encountered at 53-feet depth during drilling. The non-pumping water level is not known for this well. Nonetheless, Waldron and Larsen chose to use the 53 feet depth as a non-pumping water level for a well with an unknown location and unknown construction. Furthermore, the location listed in Table 1 of Waldron and Larsen is "*Intersection of Hwy 222 and Winfrey*" which corresponds closely to the location of Well #8 at Claxton.

Well #12 at Moscow, Tennessee (Glenn, 1906). Again, the reference provided by Glenn only relates to the target depth of drilling at which water-producing materials are reportedly encountered. No specific wells are referenced as to location and specific construction details. Glenn makes no explicit statement referring to the depth to which water is measured in a well, let alone under non-pumping conditions, so this location should not be used for contouring the pre-development equipotential surface of the aquifer. Instead, Waldron and Larsen chose to arbitrarily select the location of the "*well*" at the town center, which is not supported by any specific historical records. Glenn also reports generally that "*…water is found in abundance at depths of 60 to 80 feet*". Waldron and Larsen assumed a specific value of 69 feet as the water level for their mapping purposes, which is 9 feet below the reported minimum depth of 60 feet referenced by Glenn. There is no justification for Waldron and Larsen's arbitrary assignment of this water level depth. Finally, Table 1 incorrectly lists the estimated water elevation as 27 meters; the estimated value shown on Figure 4 for this station is 87 meters.

Well #13 at Oakland, Tennessee (Fuller, 1903). Specific location of the well is not known from information presented by Fuller. Waldron and Larsen arbitrarily select a location in the center of a block defined by four roads, even though the "s*upplemental information*" in their Table 1 states that there is "*no location information*". Based upon a USGS topographic map, the land elevation at Oakland ranges from 350 to 400 feet elevation. Waldron and Larsen use an assumed land elevation at the assumed well location of 116 meters (380.5 feet), but the actual well elevation could be as low as 107 meters to as high as 122 meters, depending on where the actual well was originally located. Although the depth to the water level in the well is reported as 75 feet below the "mouth" of the well, the method of water-level measurement is not stated, and the degree of accuracy of this water level is simply not known. Also, the height of the "mouth" of the well above land surface is not known. Finally, the original source (Glenn, 1906) states that "*At Oakland, elevation 388 feet, the wells are from 60 to 125 feet in depth.*" This information suggests that water level depths shallower than 75 feet may have occurred at Oakland prior to extensive pumping of the aquifer at Memphis.

Well #14 at Rossville, Tennessee (Glenn, 1906). No specific location of a well is given for the Town of Rossville. Waldron and Larsen arbitrarily selected a well location at the intersection of Main Street and the railroad. Glenn actually states that "*At Rossville, elevation 311 feet, water is obtained from white sand beneath a layer of pipe* *clay at 28 to 35 feet*". No well depth is reported, and no specific water level measurement is reported for a well tapping the "white sand". Waldron and Larsen assumed a depth to water of 32 feet (10 M) for the pre-development water level at Rossville, but this assumption is not supported by any actual data for a well at Rossville.

Well #15 at Somerville, Tennessee (Glenn, 1906).. Glenn presents some generalities about multiple wells drilled from depths of 100 to 150 feet at Somerville. No specific well location is described, however, Glenn does reference a land elevation of 356 feet (108.5m). Inexplicably, Waldron and Larsen decided to adjust the assumed land surface elevation at Somerville upward by 8 meters (or 26 feet) based upon their arbitrary selection of the well location. This is a large adjustment and injects a significant potential error to the Well #15 data. Furthermore, Waldron and Larsen use a water depth of 50 feet (15 m) for this location, despite Glenn's specific statement that "*The water rises in some of these* (wells) *within 50 feet of the surface*". Because Glenn's term "*within*" means inside of or less than, assigning 50 feet as the water depth for Well #15 will produce a water elevation that is too low. [Fuller (1903) mentions a specific well owned by C.W. Robertson, but the location of that well is still not known.]

Well #16 at Taylor's Chapel, Tennessee (Fuller, 1903). The exact location of well is not identified. Waldron and Larsen assumed a land surface elevation of 109 meters (357.5 feet). Local topography of the Taylor's Chapel area ranges from approximately 340 feet to 370 feet in the vicinity of Taylor's Chapel church and the Taylor's Chapel cemetery. Water depth is reported at 60 feet below the "mouth" of the well, but the actual elevation of the "mouth" is not known. Means and accuracy of the water depth measurement is not reported. Glenn (1906) provides additional information about water depth at Taylor's Chapel, stating that "*At Taylors Chapel water is obtained from some good strong springs and wells that range from 25 to 125 feet in depth. In many places at depths of 30 to 40 feet a stratum of black mud is struck, averaging about 40 feet thick and furnishing foul-smelling water. It is underlain by a thin ironstone layer and when this is pierced good water, that rises 30 or 40 feet, is found in abundance.*" Based on Glenn's description, a well drilled to 70 or 80 feet depth would have a non-pumping water level of 30 to 50 feet depth. This suggests that the 60 feet water depth assigned by Waldron and Larsen to the Taylor's Chapel area may be too deep by 10 to 30 feet.

Well #17 at Belle Eagle, Tennessee (Fuller, 1903). Fuller does not indicate the land surface elevation of Belle Eagle or the exact location of the well used by Waldron and Larsen. The well location is only referenced relative to a property owner (R.H. Taylor). The USGS topographic map of the Belle Eagle area indicates that local land elevation ranges between approximately 320 and 370 feet AMSL. The method of water depth measurement and height of the well casing are not reported. Well construction details are not provide, nor is information about the lithology of sediments encountered or tapped by the well. The well depth is 70 feet, which makes it uncertain if this well actually penetrates the Memphis Sand.

Well #18 at Brownsville, Tennessee (Glenn, 1906). Glenn states that the land surface elevation at Brownsville is 344 feet (105 meters) AMSL. Waldron and Larsen adjusted the assigned land elevation upward to 108 meters AMSL. Glenn reports multiple wells at Brownsville, and the water level depth (14 meters) reported for Well #18 is apparently an average from a number of wells in Brownsville. Averaging the depth to water is inappropriate where the land surface elevation has variability. The topographic variation at Brownsville is substantial (ranging locally from less than 337 feet to more than 390 feet AMSL). The method of water depth measurement is not reported, nor is the height of the top of well casing. Glenn describes large withdrawals (150,000 to 500,000 gallons per day) from individual municipal wells at Brownsville. The original (pre-development) static water level at Brownsville is not reported. Considering the large withdrawals reported from multiple wells at Brownsville, one must conclude that the water levels reported by Glenn have been lowered as a result of local groundwater withdrawals. Therefore, these water-levels cannot be equated with pre-development groundwater levels, but Waldron and Larsen elected to do so anyway.

Well #19 at Forked Deer, Tennessee (Fuller, 1903). No data on the land surface or exact well location is provided by Fuller for the well at Forked Deer. Waldron and Larsen estimated the land surface to be 106 meters AMSL based upon the well owner named H.A. Rainey. The method of water depth measurement is not reported, nor is the height of the top of well casing. Waldron and Larsen describe the well as being free flowing, but Fuller lists the depth to water at -0 feet. If the well was a free-flowing artesian well, then the static water level would actually be at some (unknown) height above the top of the well casing.

Well #20 at Ged, Tennessee (Glenn, 1906). The elevation was determined for Ged by triangulation "from current road intersections to historic location". The "Hinkle well" was located "half a mile" in no specific direction from the town of Ged on "high ground". So, it seems the elevations assigned to the town and to the Hinkle well are essentially guesses that render any water level elevation data suspect or useless. The Hinkle well is listed as having a water level that rises to "within" 60 feet of the surface. Waldron and Larsen assign 60 feet (18m) as the depth to water at this unknown location on "high ground". The reality is that Waldron and Larsen have no reliable knowledge of the well location or depth to water at Ged.

Well #21 at Keeling, Tennessee (Glenn, 1906). Very minimal well information is listed by Glenn, essentially that there are a number of wells in the area and one of them is 96 feet deep with a water-level within 46 feet of the land surface. The exact location of that, or any, well is not known. The land surface elevation was estimated based upon a general location of the town, and the land surface elevation in the immediate vicinity of Keeling can vary by more than 40 feet. Well construction details are not reported, nor is the method of measuring the depth to water. Lithology penetrated by the well is not reported, and it is not known if the well reported by Glenn actually taps the Memphis Sand.

Well #22 at Stanton Depot, Tennessee (Glenn, 1906). Glenn says that the town elevation is 290 feet AMSL, but there is no mention of land surface elevation for any specific well in or near the town. Glenn states that water rose to within 40 feet of the land surface when an "indurated layer had been penetrated", but there is no mention of a specific well or location. Waldron and Larsen decided that the land surface elevation at the "well" was 13 meters (41 feet) higher than the elevation reported by Glenn.

There is no justification for making this large adjustment in land surface elevation. If the depth to water was 40 feet and the land surface was 290 feet, as stated by Glenn, then the water-level elevation would be 250 feet (76 meters) AMSL. The method of water depth measurement, the height of the top of well casing, and the construction of the well are not reported by Glenn.

Well #23 at Arlington, Tennessee (Fuller, 1903). The depth of the well listed in Waldron and Larsen's Table 1 (228 feet) does not match the original data provided by Fuller (221 feet). Waldron and Larsen incorrectly report the water-level elevation that they assigned to Well #25 in Table 1 as 25 meters, although they correctly list the water level elevation (81 meters) on Figure 4. The exact location of the well is not known. The land surface elevation was estimated based upon a general location of the town. Well construction details, height of the top of well casing, and the method of measuring the depth to water are not known.

Well #24 at Bleak, Tennessee (Glenn, 1906). Only minimal well information is listed by Glenn, although he reports that there is a well 176 feet deep with a water level within 47 feet of the land surface. The exact location of the well is not known, and Bleak is no longer an established town. The land surface elevation was estimated based upon a general location of the town from a 1916 U.S. Soils Map. Well construction details, height of the top of well casing, and the method of measuring the depth to water are not known.

Well #25 at Collierville, Tennessee (Glenn, 1906). Glenn states that there are two wells, six feet apart, at depths of 239 and 248 feet with water levels between 95 and 100 feet below land surface. Waldron and Larsen assigned 95 feet as the depth to water, but that depth could just as easily have been 100 feet based on Glenn's report. Once again, the water-level elevation is incorrectly listed in Waldron and Larsen's Table 1 as 27 meters, although the correct water level value (90 meters) is listed on Figure 4. The method of water depth measurement is not reported. Well construction details, height of the top of well casing, and the method of measuring the depth to water are not known.

Well #26 at Cordova, Tennessee (Fuller, 1903). The location of the well is not known, and the land surface elevation was estimated based upon a general location of the historic community. Well construction details, height of the top of well casing, and the method of measuring the depth to water are not known.

Well #27 at Eads, Tennessee (Fuller, 1903). Minimal well details are reported by Fuller. The exact location of the well is not known, and the land surface elevation was estimated based upon a general location of the well owner from the 1910 Census. The local relief of the land surface elevation in Eads varies by as much as 50 feet, so a significant potential error is introduced by not knowing the location and assigning an elevation for the well head. Well construction details, height of the top of well casing, and the method of measuring the depth to water are not known. Fuller reported that the well was 100 feet deep, so it may be too shallow to be open to the confined aquifer.

Well #28 at Massey, Tennessee (Fuller, 1903). Fuller provides minimal well information. Well construction details, height of the top of well casing, and the method of measuring the depth to water are not known.

Well #29 at Memphis, Tennessee (Glenn, 1906). Minimal details are provided in the original data source. Well construction details, height of the top of well casing, and the method of measuring the depth to water are not known. Glenn states that the well is "artesian", and Waldron and Larsen uses the land surface elevation to assign the water elevation, which by the very definition of a free-flowing well tapping a confined aquifer is too low. The height of the water elevation above the "mouth of the well" is not known.

Well #30 at Covington, Tennessee (Glenn, 1906). The discussion of conditions at Covington does not reference any specific well, and instead describes typical wells in the area by stating that the wells "*may go 75 to 100 feet deep, and the water rises within about 40 feet of the surface.*" Clearly, such a discussion of generalities and approximations should not be relied upon for contouring an equipotential map. This same situation describes other "wells" used by Waldron and Larsen (e.g., Well #8).

Well #31 at Ina, Tennessee (Fuller, 1903). The exact location of the well is not known, and the location and elevation were assumed based upon property records and research into the OMNI Gazetteer. Well construction, height of the well opening and method of measuring the depth to water are not known. USGS topographic maps indicate that the land elevation near Ina ranges from 480 feet (146 m) to 520 feet (158 m), so any assumed elevation based upon property records without specific details of a well location can result in an error in elevations assigned to the land surface and water level of up to 40 feet .

Exhibit 3

Excerpts from Deposition of Richard Spruill

(Sept. 28 2017)

In the Matter Of:

STATE OF MISSISSIPPI vs

STATE OF TENNESSEE

OF TENNESSEE,

RICHARD SPRUILL

September 28, 2017

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forth. What I would say in response to that is there is no significant physical barrier that stops the flow of groundwater within the Middle Claiborne Aquifer, but I think it is really important for everybody to recognize the Claiborne Aquifer is incredibly complex. It was formed in the Eocene time in a geological environment that can be only described as incredibly complex. I said that twice.

There are lateral and vertical changes in the Claiborne Aquifer system that cause significant variations in the rate of groundwater movement, which is incredibly slow, and the direction of water movement in both the lateral and vertical sense. So while there are no physical barriers that would prevent the movement of water downgradient in response to decreasing total hydraulic head in this aquifer system, there is amazing complexity.

Q. We'll talk about the complexity in a bit. I want to make sure the record is clear. You initially said in response to my question that there is no significant physical barrier I think along the Mississippi state boundary. I

Middle Claiborne Aquifer every molecule of groundwater in that aquifer under natural conditions was moving to some extent, correct?

A.   Yes.

Q.   Dr. Spruill, how do you define an interstate aquifer?

A.   I've never defined an interstate aquifer. I didn't come to this project with the "interstate aquifer" definition in mind. I was originally retained to evaluate the groundwater systems in this area and help educate people about how groundwater flows. I only came to the issue of interstate and intrastate late in the game here. Again, that was not my initial charge.

I have the opinion that there really aren't any interstate aquifers, that groundwater flow in our aquifer systems throughout this country are intrastate-type flows.

Q.   So in your view there are no interstate aquifers anywhere in the United States?

A.   What is the definition of an interstate aquifer?

Q.   That's why I'm asking you.

A. I know that you get to ask the questions.

Q. You are the one offering an opinion in this case. Unfortunately I don't get to do that.

A. I'm offering an opinion on what an intrastate aquifer is.

Q. Q. What is an intrastate aquifer?

A. An intrastate aquifer in my opinion is one this which -- is an aquifer or aquifer system or hydrostratographic unit in which the water enters that aquifer within an individual state and moves incredibly slowly over a long period of time, especially with respect to human perception of time.

So it resides in that state for long periods of time available for consumptive use of citizens in terms of potable water, irrigation and so forth to meet their demand before ultimately being discharged tens of thousands of years later from that state.

Q. Under that definition of an intrastate aquifer that you just articulated, are you aware of any aquifer in the United States that did not meet your definition?

A. It is a broad definition. I have not found an aquifer system that I have studied that does not meet that definition.

Q. Taking for a second -- assuming that the term "interstate" means one that does not meet your definition of an intrastate aquifer. If that's the case, then your view is you can't identify any interstate aquifer in the United States?

A. That's my opinion.

Q. You said you came to your definition late in the game in this case. When did you reach your opinion about what an intrastate aquifer is?

A. After reading the reports of the -- the expert reports of Mr. Langseth, Mr. Larson and Dr. Waldrop.

Q. When you submitted your opening report that we've marked as Exhibit 1, at that point in time you did not have any opinion about what an intrastate aquifer is?

A. I was searching the literature at that time because I knew that there was a case that

A. I don't recall articulating that test, those criteria, at any point in time.

Q. (BY MR. BRANSON) Before the context of this case have you ever articulated any test --

MR. ELLINGBURG: Objection to form.

MR. BRANSON: I'm not quite done.

Q. (BY MR. BRANSON) -- any test for what an intrastate aquifer is?

MR. ELLINGBURG: I apologize. Objection to form.

A. Not using those specific words.

Q. (BY MR. BRANSON) Have you used some other word that would you consider a synonym for "interstate aquifer" that you articulated before the context of this case?

A. I argued throughout my entire career that when we develop water resources with an eye toward sustainability, you absolutely must understand the hydraulic properties of the aquifer and the impacts of development of a well field on adjacent states and not just on adjacent states but on adjacent proximal users. So these criteria I just described, that is, water enters the aquifer, flows very slowly, responds to large scale withdrawals by developing large cones of depression, are the things that I have articulated for thirty years that must always be considered in the context of groundwater development and sustainability issues. So I've had all these things in my mind, but I never simply said "intrastate."

Q. I want to make sure that we're understanding your factors correctly.

A. Sure.

Q. It sounded to me like you might have added one. Let's go through them piece by piece. The first factor in your view of what an intrastate aquifer is is that the groundwater enters the aquifer in a state. Is that right?

A. The majority of water enters the aquifer in a state.

Q. What is the significance of the word "majority" in your answer?

A. It is absolutely clear that the geological world and state boundaries are intertwined and a small amount of water may enter an aquifer in one state and end up in another state over really long period of time.

So what I'm talking about is the majority of water entering the aquifer in a state.

Q. Would it change your view about whether a given aquifer is intrastate or not if less than the majority of the water entered the aquifer in a given state?

A. I've not considered that before. Can you repeat that?

Q. You said -- you attached some significant to the premise of your definition that a majority of the water in the aquifer is entering in a given state. Is that right?

A. Uh-huh.

Q. So my question is would it change your view of whether that aquifer is an intrastate aquifer or not if we change that premise and said less than a majority of the water is entering in that same state?

MR. ELLINGBURG: Objection to form.

A. I don't think so.

Q. (BY MR. BRANSON) The word "majority" that you articulate is not necessary to your test. Is that right?

A. You say "majority." Are we going to

nitpick 51 percent or 50 percent?

Q. It is your test. You used the word. Can you tell me what you mean by it?

MR. ELLINGBURG: Objection to form.

Could you go back, Brian, and just read back his original answer that he is now asking about.

(The requested testimony was read by the reporter.)

Q. (BY MR. BRANSON) If you what to change what I said before or if I got it wrong, you can clarify, but you used the word "majority" in your answer. My question is it sounded like from what you just said that is not necessary to your test, it doesn't have to be a majority. Is that right?

A. I think it needs to be a majority.

Q. It does?

A. Yeah.

Q. You would define that as anything over 50 percent?

A. I guess.

Q. What if it is 49 percent?

A. I don't know of any cases like that

where you could distinguish with that. Given the complexity of a groundwater system, I don't know that you could ever distinguish to a level of sophistication of 49 or 51 percent. To me it is not an important distinction.

Q. Would you be able to distinguish between 25 percent and 51 percent?

A. I suppose if you have adequate knowledge of the groundwater system and the hydraulic properties of the system and studied it extensively for years and years, it might be possible.

Q. 25 percent would not be enough under your test for an aquifer to be intrastate. Is that right?

A. If 25 percent of the water that enters the state only falls within that state, I can't even imagine such a system. I think it is the majority.

Q. Just to make sure I'm following you, for this first factor of your test it has got to be over 50 percent of the water that is entering the state that we're talking about that then proceeds through the next couple factors?

A. I think that is the definition of majority. I would say that is a reasonable expectation from for aquifer systems.

MR. BRANSON: I'm going to keep going through this. Why don't you take a bathroom break.

(Brief recess.)

Q. (BY MR. BRANSON) Okay. Welcome back, Dr. Spruill.

A. Thank you.

Q. Did you talk to Mr. Ellingburg about the substance of this deposition during the break we just took?

A. Yeah.

Q. What did he tell you?

A. Slow down, speak slowly.

Q. Did he tell you anything about the nonstylistic substance of your answers? Did he advise you to change any of your answers?

A. No.

Q. Did he give you any advice about answers you should give to upcoming questions?

A. No.

Q. Other than slow down and change

stylistic things, which is good advice, he didn't tell you anything else pertinent to the deposition?

A. We didn't really have time to talk. He went somewhere else. I don't know where he went.

Q. Let's go back to the factors of the test we were talking about. I think we've covered the first part about a majority of the water being within a single state. We talked about that. I want to move to the next factor, which I understand you said the water moves incredibly slowly. Is that right?

A. Yes.

Q. How do you define "incredibly slowly" for purposes of this test?

A. With numbers, with actual velocities of groundwater movement. I've done a lot of those kind of calculations based on the range of hydraulic properties of the aquifer in the specific region that are available in the literature. I tried to look, for example at average numbers for hydraulic properties that would be representative of the formation that is

A. Also compared to other velocities that we experience in our lifetimes every day. For example, it is really difficult for me to sit here and not look at the Mississippi River and recognize that a drop of water in that river could easily move 20 miles today. That's 20 miles today.

When I flew out here from the beautiful coast of North Carolina, I was traveling at 400 miles per hour and nearly that fast in the cab that took me from the airport to here. The velocities that we're exposed to every day give us a reference point for "incredibly slow."

So "incredibly slow" for me is velocities of a fraction of a foot per day. That's sort of a general feel for what I mean. I'm telling you that I think about it in terms of every-day things we can see like river velocity and so forth.

Q. You say fractions of a foot per day. Generally speaking it is your view for purpose of this test about whether this aquifer is an interstate aquifer that the groundwater is moving incredibly slowly if it is moving fractions of a foot per day?

A. Almost all groundwater is moving at velocities ever a fraction of a foot per day.

Q. And you anticipated my next question. Are you aware of any groundwater in any aquifer in the United States that is moving at a speed that you would consider not to be incredibly slowly?

A. Yes.

Q. Where?

A. There are zones within aquifers that have very high permeabilities. In those types of aquifers groundwater velocities can be appreciably larger measured in distances of feet and even tens of feet per day.

Q. If groundwater were flowing more than a foot per day and it were flowing in an aquifer across state lines at that rate of speed, would that cause you to consider the aquifer to be not an intrastate aquifer under your definition?

MR. ELLINGBURG: Objection to form.

A. I haven't thought about that. I thought we were relating it to this particular case. My groundwater velocity calculations are for reasonable values for the Middle Claiborne Aquifer in this area.

Q. (BY MR. BRANSON) I understand that you have not performed groundwater velocity calculations for other aquifers. I'm trying to understand the limits of the test that you articulated for what an interstate aquifer is.

My question is, if you were to take one of the examples you just gave of groundwater moving more than a foot per day and some of that flow eventually went across a state boundary in an aquifer, would that cause you to view that aquifer as not intrastate?

MR. ELLINGBURG: Objection to form.

A. I would still consider that to be a really slow velocity. I'd remove the word "incredibly" in front of the word "slow." I'd still consider it to be a very slow velocity. Something moving two feet per day in the groundwater system in a cavernous limestone aquifer still resides in that aquifer for incredibly long periods of time.

Q. (BY MR. BRANSON) So it is not necessary for your test of an intrastate aquifer for the

groundwater to be moving incredibly slow, it is enough for it to be moving slowly at a rate of a foot or two per day. Is that right?
A. My definition would involve typical groundwater flow velocities.
Q. I think I understand you. There is no groundwater that you know of that would be flowing quickly enough for it not to meet this second factor of your test for an interstate aquifer?
A. I would agree.
Q. I believe that the next factor you articulated was that the water has to have a long residency time in the state. Is that right?
A. Right.
Q. How do you understand -- withdrawn. How long does a residency time need to be in terms of years for you to consider it long enough to satisfy this factor?
MR. ELLINGBURG: Objection to form.
A. Groundwater in the Middle Claiborne Aquifer in this area is moving in my opinion at a velocity of about .05, .06 feet per day. So

at that rate groundwater would move hardly the distance of the width of this room, maybe twenty feet. In 100 years, which is my lifetime, it night move 2,100 feet. In 300 years it might move a little more than a mile. Those are residence times that are just beyond our human lifetime understanding. They are there for really long period of time.

That's the way I perceive how the groundwater system works. This water moves so slowly, especially in this particular aquifer, that in three years, longer than our country has been established, groundwater has hardly moved a mile.

Q. My understanding is you are again using the framework of a human lifetime as a rough benchmark to determine whether residency time is long for purposes of your definition?

MR. ELLINGBURG: Objection to form.

A. You have no other reference other than human time.

Q. (BY MR. BRANSON) Just to take a hypothetical, and I understand that's not you what think the Middle Claiborne is, let's say there was really skinny aquifer such that water could flow entirely through a state even at a slow rate of speed and it would only take it 50 years to navigate the entire width of a state. Would you consider a 50-year time frame to be long for the purpose your test?

MR. ELLINGBURG: Object to the form of the hypothetical.

A. There would be no state where that would be possible because groundwater velocities are so slow that wouldn't be possible in any state in the US.

Q. (BY MR. BRANSON) I fully admit this is not a real state I'm asking you about in terms of testing how you are thinking about this factor. If there were such a state, my question is would the fact that the residence time had slipped below the average human lifespan, would that cause this factor to change in your view or not?

MR. ELLINGBURG: Objection to form. The hypothetical is improper.

A. There just is no real-world example. I live in the real world. That whole question

makes no sense to me.
Q. (BY MR. BRANSON) When you say that it makes no sense, it makes no sense because it is not a real state?
MR. ELLINGBURG: Objection to form, argumentative, asked and answered.
Q. (BY MR. BRANSON) Go ahead and answer, Dr. Spruill.
A. Ask me again.
Q. Do you understand what I'm asking is with the caveat that it is not a real state?
A. I really don't. Ask me again. First you said it was a thin aquifer like this. There are no thin aquifers like this. Help me understand your question.
Q. This is a hypothetical. I'm not implying that that this applies to the actual geology of the Middle Claiborne. I'm asking you this: Let's say the residence time in an aquifer is within a given state 50 years. Would you consider that to be a long residence time for purposes of your test?
MR. ELLINGBURG: Objection to form.
A. That is a pretty long residence time

especially compared to a molecule of water in the Mississippi River.

Q. (BY MR. BRANSON) Is there any point at which you would consider -- withdrawn. You are comparing it to the Mississippi River. Is the basic point that residence time of groundwater is significantly longer than flowing surface waters? Is that what I'm understanding you to say?

A. It is significantly longer.

Q. Is there any point in terms of years at which you would consider the residency time of groundwater to be low enough that it would change your assessment of whether or not it is intrastate or not?

A. Given the size of states and the tremendous distances that water can move, once water enters an aquifer within a state with respect to its groundwater velocity, it is going to reside in that state for the use of people in that state for really long period of time.

Q. This might be slightly a more real-world example. What if we're talking about a molecule of water that is near the state border of time available for use by the people in that state, then it is an intrastate resource. The fact that a molecule of water might move across the border in a short amount of time because it is really close to the border just has significance to me.

Q. I think I -et it. Your answer to that question turns on -- that is coming back to our discussion about "majority" earlier, that in your view you apply the residency time and the velocity inquiries to what a majority 50-plus percent of groundwater in an aquifer is doing. Is that right?

A. Especially in this particular case.

Q. Would there be -- are there other cases where you would apply the factors differently?

A. I don't know of any I've studied.

Q. So for the close-to-the-border molecule that we've postulated, for that to make a difference in your assessment of whether the aquifer is interstate or intrastate, that type of molecule would have to make up more than 50 percent of the groundwater in the aquifer. Am I understanding you correctly?

A. Well, again, I developed that definition with respect to this particular case. It is absolutely clear to me that a small amount of cross-boundary flow occurs, but it doesn't change my definition of an intrastate resource as applicable to this case.

Q. Just to make sure I'm understanding your test, I understand that you think in the Middle Claiborne there are not enough of those molecules to alter your assessment?

A. Right.

Q. You think that the existence of these molecules that would flow across the border in a short period of time would only materially affect the outcome of your test if they made up a majority of the water in the aquifer?

MR. ELLINGBURG: Objection to form.

A. As I said, in this case it is absolutely clear that only a small percentage of water crosses the state border. In this case it is clear to me the majority of water falling within the State of Mississippi resides in the state for long periods of time.

Q. (BY MR. BRANSON) Understanding that you underlain by an aquifer system that receives recharge and majority of the water that enters that state aquifer system flows slowly through the aquifer system and is available for people to use in that state, then it is an interstate resource. A small amount of cross-border flow does not an interstate aquifer make.

Q.   (BY MR. BRANSON) You had said "small amount." I'm questioning what do you conceive of in that answer you just gave as a small amount?

A.   The amount that in this case that is entering the State of Tennessee from the confined portions of the aquifer system from Mississippi.

Q.   What methodology do you apply? You have some understanding of what a small amount is when it you are looking at an aquifer to determine whether the amount of cross-border flow under natural conditions is small?

A.   You have to --

Q.   My question is how do you define "small"?

A.   You have to determine how much water is actually crossing the state border relative to the total volume of water that is in the aquifer in that state. I've not done that calculation, but I have seen models that have been prepared that show some cross-boundary flow. My opinion is that it is a very small percentage of total flow within the system.

Q. For purposes of your test, what percentage would you consider to be very small so that the aquifer is intrastate under your definition?

A. A percentage like that which is flowing from Tennessee to Mississippi today, which is small.

Q. Can you put a number on it?

A. No.

Q. If you can't quantify, how do you know it is small?

A. I know the volume of water in Mississippi in the aquifer system is very, very large. It is almost inconceivably large in the Claiborne Aquifer. When I look at the flow patterns just there in that little small area in Northern Mississippi, I can conclude it is a small percentage.

Q. Let's say I'm a hydrologist and I'm trying to apply the Dr. Spruill test of an intrastate aquifer. I'm looking at an aquifer and I see less than the majority of the groundwater in the aquifer that is flowing across the state boundary in a relatively quick time under natural conditions. How do I decide whether that is small or not for purposes of the Dr. Spruill test?

MR. ELLINGBURG: Objection to form. He is not going to --

MR. BRANSON: You can say "object to form." Don't be coaching him otherwise.

MR. ELLINGBURG: I'm not coaching him at all. You are generalizing.

A. That distracted me from your question.

MR. BRANSON: Could you read the question back?

(The pending question was read by the reporter.)

A. I don't have a number for "small." I'm not going to put a number on "small." I'm not going to do it.

Q. (BY MR. BRANSON) Is it in the eye of the beholder? I'm asking. One of the things I'm trying to do here is understand how you reach your conclusion that this is small. So far, other than the adjective "small," I'm not really following you why you made that conclusion.

If you are not going to give me a number, can you give us anything else about how you determine whether a quantity of groundwater for this purpose is small or not?

MR. ELLINGBURG: Objection to form.

A. With respect to this particular case and the Middle Claiborne Aquifer, the volume of water entering the groundwater system from all different directions, from all different recharge areas and zones within the Middle Claiborne is a phenomenal amount of water, much larger than the amount of water that is moving across the state in the small area of the northern part of Mississippi.

Q. (BY MR. BRANSON) The question is you are not going to offer an opinion in this case numerically identifying what "small" percentage

groundwater means for purposes of your test. Is that right?
MR. ELLINGBURG: Objection to form.
A. I haven't done a calculation for this particular case of my definition with respect to the volume of water in the Claiborne aquifer that doesn't cross the border relative to that which does cross the border.
Q. (BY MR. BRANSON) You also did not have in your head a number that -- if you did perform that calculation, that there is no number in your head that you would be looking for it to be smaller than IN order for you to say it is a small percentage for purposes of your test?
A. At this time, no. I've only compared the cross-border flow in this aquifer with the total amount of water I perceive to be in the aquifer in Mississippi.
Q. If I were to have one of my experts do that calculation and he came up with ten percent, would that ten percent number, would you consider that very small for purposes of your test?
MR. ELLINGBURG: Objection to form.

A. I'd really want to look at how the individual did those calculations to see if I agreed with him. I'd want to know the total volume in the state. That. Would seem to me to be a small percentage, ten. It would depend on residence time and all the things that I think are important with respect to the complexity of the groundwater system. I just don't have a number.

Q. (BY MR. BRANSON) Am I following you correctly that you do not have an opinion on -- withdrawn. You are not aware of any aquifer in the United States where the natural cross-boundary flow is something other than small as you've articulated it. Is that right?

A. I've not studied that. My general opinion is for most of the aquifers like the ones we're discussing here, the majority of flow is within the state. That's certainly true for the majority of aquifers in Virginia, North Carolina, Georgia, et cetera.

I think it would be my opinion that most of, if not all, these aquifer systems are characterized by very long residence time times about physically underlies the geographical extent of the aquifer?

A. Yes.

Q. Is the Middle Claiborne a transboundary aquifer?

A. The Middle Claiborne underlies multiple states in this region.

Q. It does meet your understanding of what a transboundary aquifer is?

A. If a transboundary aquifer is simply one that is defined as a physical aquifer system underlying multiple states,, then the Middle Claiborne fits the definition of a transboundary aquifer.

MR. BRANSON: I would like to mark this Exhibit 3.

(The above-mentioned document was marked as Exhibit 3.)

MR. ELLINGBURG: He think he is making notes himself.

MR. BRANSON: It looks like he is doodling.

THE WITNESS: I'm a doodler.

(Document passed to the witness.)

Q. (BY MR. BRANSON) Dr. Spruill, I've handed you an exhibit that has been marked Exhibit 3. This is a figure from Dr. Waldron's expert report in this case that is drawn from his 2015 paper. I assume you have reviewed this figure before?

A. Yes.

Q. I understand you have some differences with this figure. We'll get to those. I'm asking for purposes of this question let's assume that Dr. Waldron is correct. I understand you don't. Let's assume that he is correct over your objections.

If Dr. Waldron were correct in that this Exhibit 3 accurately depicts the predevelopment potentiometric surface in the Middle Claiborne, would you consider the Middle Claiborne to be an intrastate aquifer?

MR. ELLINGBURG: Objection to form, foundation.

A. As a scientist that is not a question I can even deal with. I can't deal with that question.

Q. (BY MR. BRANSON) Why can't you deal

with it?

A. I can't deal with the question because you are asking me to assume that something is correct that I know is totally incorrect.

Q. You were not capable for a moment assuming this is correct and telling me what that would mean for your test about whether the Middle Claiborne is an intrastate aquifer?

MR. ELLINGBURG: Objection to form. Incomplete based on his definition.

A. As a scientist I just have real trouble dealing with that question of asking me to assume that something is correct that I feel vehemently is incorrect.

Q. (BY MR. BRANSON) You are not willing to offer an opinion on whether the Middle Claiborne would be an intrastate aquifer or not if Dr. Waldron's potentiometric surface map were correct?

MR. ELLINGBURG: Objection to form and incompleteness of hypothetical.

A. Dr. Waldron's equipotential surface map in my opinion is fundamentally flawed.

Q. (BY MR. BRANSON) That's not what I'm

asking you. Because you believe it is flawed, you are not capable of telling me whether the Middle Claiborne is an intrastate resource under your definition if you take Dr. Waldron's analysis as correct in Exhibit 3?

MR. ELLINGBURG: Objection, form, incompleteness of the hypothetical as stated.

A. No. I can't deal with that question.

Q. (BY MR. BRANSON)You are not going to offer an opinion at the hearing -- if you get asked if Dr. Waldron's potentiometric surface map is a correct depiction of predevelopment flow in the Middle Claiborne, you are not going to offer an opinion one way or the other about whether the Middle Claiborne would be an intrastate aquifer in that case?

A. I'm going to offer an opinion that is very clear that I don't think this is correct.

Q. You are not going to do what I said, you are not going to offer an opinion about -- whether the judge disagrees with you and if the judge accepts Dr. Waldron's map, you are not going to say one way or the other whether the Middle Claiborne is an intrastate aquifer or preparing this report other than the three individuals you identified at the beginning of today?

A. No.

Q. Let's flip to Page 3 of this report. I want to focus on the last paragraph on this page that spills over onto the next page.

A. Okay.

Q. "It is also my opinion that the decisions regarding the classification ever groundwater resources as intrastate versus intrastate should not be conducted without a detailed consideration of the advantages and disadvantages of such a classification on the availability of the state to protect and manage the resource for the full benefit of its citizens." Do you see that?

A. Yes.

Q. Is that an accurate recitation of one of your opinions in this case?

A. Yes.

Q. Have you performed such a detailed consideration of the advantages and disadvantages referenced in this sentence with respect to the Middle Claiborne?

A. I've performed an analysis that led me to define what an intrastate resource is. I have opinions about the advantages and disadvantages of classification of something as an intra versus interstate, but I've not performed a detailed consideration of all the advantages and disadvantages.

Q. What I'm not following is as I read this sentence, you say that you do not believe that the classification of groundwater resources as intrastate or interstate should be conducted until that type of detailed consideration is performed. Is that right?

A. I think it should be part of the decision process to adopt an intra versus intrastate determination.

Q. If you've not performed that type of detailed consideration in this case, how is it you have an opinion about whether the Middle Claiborne is intrastate at all?

A. The issue here for me is a detailed consideration. I've given a lot of consideration to my definition of an intrastate

resource and the reasons for that.
Q. Have you -- I understand you to be saying you have not given a detailed consideration as to the advantages and disadvantages of such a classification for the Middle Claiborne on Mississippi and Tennessee. Is that right?
MR. ELLINGBURG: Objection, form.
A. I've given consideration to what the advantages and disadvantages might be based on such a determination.
Q. (BY MR. BRANSON) But you would not characterize that consideration as detailed?
MR. ELLINGBURG: Objection to form.
A. They are as detailed as I can make them. I think I wrote that statement because I'm a geologist and I think about these advantages and disadvantages based on my experiences, and I suspect there are other factors involved that are beyond my ability to make those conclusions, but my statement really is aimed at the precision process of the people that have offered their opinions about whether it is an interstate or intrastate resource.

Q. What other factors? You mentioned some you've not looked at in this case. Give me some examples of those type of factors.

A. I suspect there are legal issues that are beyond my ability to understand. There may be economic issues that I have not considered. I don't know. I base my decisions on my experience as a hydrogeologist.

Q. Have you considered the economic benefits to Tennessee of an interstate classification of the Middle Claiborne?

A. I think only the State of Tennessee can safeguard its water resources, thus protecting that economic aspect of groundwater resources. I don't think Mississippi can protect those resources for Tennessee. From that perspective, it is clearly an intrastate issue in my mind.

Q. You don't have a view as to whether classifying the Middle Claiborne as an interstate resource would benefit Tennessee economically or not? That is not something you have an opinion on?

MR. ELLINGBURG: Objection to form.

A. I'm not an economist. I've not done

any of those calculations or considerations.
Q. (BY MR. BRANSON) What about the economic impact on Mississippi from a classification of the Middle Claiborne as interstate. Have you looked at that issue?
A. I thought about it.
Q. Have you studied it?
A. Thinking about is a form of studying in my mind.
Q. Have you looked at any data that would lead you to a scientific conclusion about what the economic impact on Mississippi would be from a classification of the Middle Claiborne as interstate?
MR. ELLINGBURG: Objection to the form.
A. If a classification of the Middle Claiborne as an interstate resource led to what I would describe as business as usual, that is pumping volumes of water from the groundwater system that have impact in the adjacent state, then you can begin to think about the economic impact, because large-scale cones of depression that extend into adjacent states have pretty serious consequences for that state's ability to

Q. (BY MR. BRANSON) Do you have an opinion about whether existing pumping -- withdrawn. Do you have an opinion about whether Mississippi currently is able to pump the Middle Claiborne in sufficient quantities to meet demand for water in DeSoto County?
MR. ELLINGBURG: Objection to form.
A. I'm not sure exactly what you asked me. I'd like you to try again.
Q. (BY MR. BRANSON) Do you have an opinion about whether Mississippi is currently able to meet demand for water within DeSoto County by pumping from the Middle Claiborne?
MR. ELLINGBURG: Objection to form.
A. My opinion is that at the current demand in DeSoto County, water purveyors are able to meet those demands of pumping from the Middle Claiborne Aquifer, although it is clear to me that their costs for producing that water are impacted by cross-border pumping.
Q. (BY MR. BRANSON) You don't know how much the economics have been impacted?
A. I've not done any calculations like that.

reports from the USGS did not include a review of the USGS MERAS model, correct?

A. It included the review of USGS reports, technical reports, but not running the model.

Q. Did you review the MERAS model report from Clark and Hart?

A. Yes.

Q. And so you were aware that the report existed -- I'm sorry. You were aware that the MERAS model existed?

A. Yes.

Q. And you chose not to use that for the reasons we discussed earlier?

A. Correct. We continued to use the Brahana model.

Q. Does your list of references include all of the documents that you considered? That would be on Pages 21 through -- 21 and 22.

A. It probably does. There may be others out there that we've seen since this reference list was put together, but I would say most of them are probably all here.

Q. You know, if you look at that reference list, the first one, Arthur and Taylor, 1990, that is the diagram you used in your Figure -- your Figure 8. That's from Arthur and Taylor 1990.

A. Yes.

Q. You are aware that Arthur and Taylor's 1990 paper was a preliminary report, right, and was updated in 1998?

A. I'm familiar there was a -- yeah, there was a follow-up report in 1998.

Q. Is there a reason why you used the potentiometric surface from the 1990 report, which was a preliminary report, rather than the final report in 1998?

A. This was a map that I already had.

Q. So you used it because you already had it?

A. Yes.

Q. Did you check to see if it had changed at all?

A. Yeah. If I recall, the maps are similar, the 1998.

Q. Mr. Wiley, as I read your list of references, I see only three that are later than 2007 when you had your -- did your first report,

interstate aquifer. Is that right?
A. In Case 1?
Q. Yes.
A. This is an areally-extensive aquifer. I drew two hypothetical states, A and B. I drew flow lines across both of these states. I concluded that if all of the groundwater was moving really, really slowly and resided in any state for a period of time, someone might consider this an interstate aquifer with interstate flow.
In my earlier statement today, in terms of refinement, I don't remember if I put a statement in here or not, but I don't find any real-world examples where this actually exists in North America.
Q. You mentioned refinements. Have you refined your opinion about whether this hypothetical aquifer in Case 1 is an interstate aquifer?
A. If such an aquifer exists, it is as close to an interstate aquifer in terms of its flow, but I don't think it exists.
Q. You said it is close to an interstate

aquifer. Is it actually an interstate aquifer?
A. It is an interstate aquifer. It exists beneath both states. If an aquifer exists beneath individual states, I described it as an aquifer that exists beneath both of these states as an interstate aquifer, but I separate it from the physical aquifer the flow pattern in the aquifer, but I think I mention in this the really long patterns or residence times.
Q. I didn't see that mentioned. That was going to be my next question. Let's assume you had mentioned it. I do want to know. If you assume that residence times are really long and groundwater velocity is really slow but the flow patterns otherwise look like you've drawn them in Case 1, would you consider that interstate aquifer or an intrastate aquifer?
MR. ELLINGBURG: Objection to form.
A. I clearly have established that this aquifer lies beneath both states and the flow flows from one state to the other. That's the way I use those words. The flow is from one state to the other. In terms of my definition that the flow enters a state and reside within

that state, you can't assume from looking at this diagram that all the water in this aquifer originates at that flow line, an individual flow line, the head of that flow line. In this aquifer groundwater can enter the aquifer system from all different spots.

This is really important. There seems to be this idea that recharge to aquifers occurs only where the aquifer occurs close to the land surface. That's fundamentally incorrect. So groundwater can be added along any of these flow lines, and the residence time of water along these flow lines is incredibly long.

Q. Agreeing with that last statement that the residence time along those flow patterns is really long, do you nonetheless consider the Case 1 aquifer to be an interstate aquifer or do you not in light of that residence time?

MR. ELLINGBURG: Objection to form.

A. I'm using the words "interstate aquifer" as an aquifer that exists beneath both of these states.

Q. (BY MR. BRANSON) If I were to apply that exact same definition of the term "interstate aquifer," Middle Claiborne would be an interstate aquifer under that definition, correct?

A. Under that definition I'm saying that it exists beneath, say, Tennessee and Mississippi.

Q. The answer is yes, under that definition that you just applied to Case 1 of the term "interstate aquifer," the Middle Claiborne would be an interstate aquifer?

A. In terms of its physical presence.

Q. Earlier I thought that you said there were a lot of other factors other than the physical presence that goes into whether an aquifer is interstate or not in your definition. Is that right?

A. Yes.

Q. So under that test that you articulated earlier that goes beyond the physical factors, would you think that Case 1 aquifer would or would not be an interstate aquifer?

MR. ELLINGBURG: Objection to the form.

A. I'm simply using the words "interstate aquifer" similar to the Figure 13 in my report.

I tried to draw this analogy of a river system like the St. Johns River in Florida in which the entire river system exists within that state versus the Swaneee River, which flows from one state cross the state border into another state. By use of this term "interstate aquifer," it deals with the aquifer extent. It exists beneath both states. It exists beneath eight states in the embayment.
Q.   Let's do Case 2 now, the next case.
A.   Okay.
Q.   This is on Page 34 is the picture as you see it.
A.   Yes.
Q.   This has been labeled "Interstate Aquifer/Intrastate Flow."
A.   Yes.
Q.   I take it you are applying the same definition of "interstate aquifer" to Case 2 that you just applied to Case 1. Is that right?
A.   It is a rock or sediment layer capable of producing usable quantities of water and it underlies both of my State A and B and beyond.
Q.   Because it underlies both State A and

State B, that's where you labeled it "interstate aquifer"?
A. Drawing the analogy to river systems that I described earlier --
Q. Yes.
A. -- it underlies both states.
Q. That is why you have used the term "interstate aquifer" in Case 2?
A. That's correct.
Q. You use the term "intrastate flow" at the top of this picture. Do you see that?
A. Yes.
Q. What did you mean by that?
A. That water enters in this example of two hypothetical states the groundwater system in State A and moves from east to west and west to east on opposite sides of this hypothetical river system, and the same would be true in State B. So that the water enters the groundwater system by in this case, say, recharge on the eastern side, and all long that flow path new water would enter the groundwater system by recharge, and water flowing in the groundwater system at rates from an inch to two

inches a day would have really long residence time. So I call that flow within a state, intrastate flow.

Q. Once the groundwater -- withdrawn. The assumption of this Case 2 is the groundwater discharges into that river in the middle, that's the assumption in this case?

A. Once the groundwater reaches the river in this Case 2 hypothetical, it then proceeds to flow south through the river out of those states, right.

It could flow upward into overlying aquifers before discharging to that river as base flow to the river, and then the flow would be in this case to the bottom of the diagram.

Q. If the water in this Case 2 -- withdrawn. The groundwater in the Case 2 hypothetical, because it eventually reaches the river and then flows out of those states, over a long enough time the groundwater is going to leave the states, correct?

A. In this case that's what I'm showing. It is going to do that over -- regardless of what aquifer you choose, it is going to have

A river is a channel that has water in it. If it doesn't have water in it, it is a river channel. When you put water in it, it becomes a river.

Q. I've got you.

A. That's the distinction for me.

Q. Under that distinction, and I'm following you, the river in the case I've described where it dries up before it reaches border, that would be an intrastate river, but the river channel would be interstate?

A. I would agree with that.

Q. Let's talk about Lake Michigan, another surface body water that is not a river.

A. Hold one second.

Q. Sure. We're going to talk specifically about Michigan, Lake Michigan. I'm using that as an example of a lake the geographical extent crosses multiple states.

Would you consider a lake like that to be an interstate or intrastate lake given there is no meaningful flow?

MR. ELLINGBURG: Objection to form.

A. I think Lake Michigan occurs at the

state boundary of multiple states. I don't know for a fact if -- let's see. Illinois is on this side. I don't know for a fact if the state border for Illinois goes to the middle of the southern part of Lake Michigan or not. I don't know what the state boundary is.

Q. (BY MR. BRANSON) I take that caveat to mean -- maybe we can look at the break and figure it out. Assume the state boundary -- the lake physically is in multiple states. That's an assumption for right now. Under your surface-water methodology that you have articulated, would you consider that lake to be an interstate lake?

MR. ELLINGBURG: Objection to form, foundation.

A. I wouldn't have an opinion on that. I've not studied these lakes at all. I wouldn't have an opinion on it. Even this issue of interstate streams and so forth, I simply use that as an example to try to get some understanding that I'm talking about the difference between flow and the physical feature, the river and the flow in the river,

the aquifer and the flow in the aquifer. Going off in this direction of whether rivers are interstate or not is not what I've done in this study.
Q. I guess you are not going to have an opinion on this, either. What about a glacier that crosses state lines but the flow is very slow? How would you answer that?
A. Really?
Q. Yeah.
MR. ELLINGBURG: Object to form and foundation. What glacier, where?
Q. (BY MR. BRANSON) I'm doing them in the style of your Case 1 and Case 2.
A. There are no glaciers, I'm totally convinced of this, in the United States that cross state lines.
Q. This is not going to apply to a real glacier. Let's take the case -- you have given these hypotheticals in your report. I'm trying to understand them. If a glacier did cross state lines but the flow was extremely slow --
MR. ELLINGBURG: Objection to form and foundation.

Q. (BY MR. BRANSON) -- would you consider that intrastate glacier or not?

MR. ELLINGBURG: Objection to form and foundation if it is a completed question.

A. That's so far-fetched for me, I have real trouble even dealing with it. There simply aren't any. I don't understand the relevance of the question.

Q. (BY MR. BRANSON) You don't have to understand the relevance of the question.

A. I think I do. The relevance of the question is really important. If you want to explain that to me legally, that's okay. There are no glaciers, I'm really confident of this, in the United States that cross state lines. There are no glaciers in Canada that cross state lines because they don't have states, they have provinces.

Q. Would you agree there are no aquifers in the United States that are in your Case 2, that it is not depicting a real-world aquifer?

MR. ELLINGBURG: Objection to form, foundation.

A. My Case 2?

280-foot contour that is not included in your figure. Is there a reason that was left out?
A.   No.
Q.   Isn't that important if the 280-foot contour continued further than where you have indicated here in East Shelby County?
A.   It probably should have been on there, but I don't believe it would have affected any of the results. It probably should have been on there to be consistent.
Q.   Your Figures 14 through 17 are drawdown contour maps, correct?
A.   Yes.
Q.   And the only pumping that is included on these drawdown maps or that was used to formulate these drawdown maps was MLG&W pumping and DeSoto County pumping, correct?
A.   That's correct.
Q.   On each of these figures, 14 through 17, there is a note at the bottom right that says "Source: Tennessee USGS." That is just an error?
A.   It is carried over from whatever base map was used for something else.

"The figure only addresses flows in the Memphis area and not regional flows." That is your criticism of Figure 3.2.1a, right?
A. Yes.
Q. What is a regional flow?
A. By the way, could I see that figure, 3.2.1a? I don't think it I have it in here.
MR. DAVID BEARMAN: Let's go off the record. Well, that's all right.
Q. (BY MR. DAVID BEARMAN) If you will look at I think your Figure Number 2.
A. Okay.
Q. Dr. Langseth's flow arrows are shown in the larger figure on the left, but I've got a copy if you would like to see it.
A. It looks like -- this looks like the right one.
Q. My question to you is how are you defining regional flows on Page 7?
A. Regional flows would be over a larger area where you are looking at more than just one flow path.
Q. What area would you suggest would be a regional flow area?

A. Well, for example, in the red box area that he has --

Q. All right. We're talking about -- you are looking at your Figure Number 2, correct?

A. Yes.

Q. You are looking at the larger-scale predevelopment potentiometric map on the left of the page?

A. On the right of the page.

Q. You were talking about --

A. Okay. I'm just saying for an example of regional would be that -- the whole thing is a regional map. This whole thing is a big regional map. I'm saying this is a smaller region, but it is another -- it is a regional depiction that we can use for an example in this red box, which I used on my Figure 2 to show more flow paths.

Q. All right. So in the enlarged map on the right of the page Dave Langseth included one flow path arrow, correct?

A. Yes, on his original map.

Q. As you are looking at your Figure 2, it would be the one at the top of the page, the top that equipotential surface or line in the confined aquifer is a vertical line. When you drill a well down into a confined aquifer, if you drill it to this depth, you get that head.

If you drill it to this depth, you get that head. If the equipotential line is at a angle, if you drill to this depth, you get a head that is different from here or here.

It is actually a lot easier to determine the distribution of head in a confined aquifer with wells that have screens of any length than it is in an unconfined aquifer where you have to have very, very short-screen lengths.

Q. Were you able to determine the methods of water level measurements that Criner and Parks used to get their water level reading from the wells that they used for Figure 3?

A. It was important to me that Criner and Parks used observation wells located at various distances from well fields and away from the estimated center of pumping. I like that about their study that they were using observation wells, because observation wells by their very nature don't have pumps in them. The water level has not been influenced in observation wells by pumping. They give a truer picture of groundwater conditions than using water levels taken in production wells.

Q. How do you know that the wells that Criner and Parks were using were observation wells?

A. I referenced Criner and Parks 1976, Page 11, and I quoted -- I'll read my entire sentence. "Significantly Criner and Parks only relied upon data from observation wells located at various distances from well fields and away from the estimated center of pumping." I referenced Criner and Parks 1976, Page 11.

Q. Where were you reading from?

A. Top bullet on Page 11.

Q. Did you go back to the underlying record for those wells to verify whether they were actually observation wells?

A. I would say yes. I would have noticed they were not wells that had been pumped. They are not areas that have on an equipotential map cones of depression around them.

Q. When you say "documentation," are you talking about documentation outside of the Criner and Parks report itself?

A. I would think that we searched for that but mainly relied on the Criner and Parks report that was provided to me.

Q. Sitting here today, you don't remember anything outside of the Criner and Parks report itself that would have been the source of your conclusion that the control wells were well-documented?

A. No.

Q. We were talking about -- I want to make sure I've got your entire opinion on the extent to which the Criner and Parks study is imperfect. I believe you said it doesn't attempt to extend into the unconfined area. It may not accurately depict leakance values. Anything else?

A. I can't think of anything offhand.

Q. Do I know the time period from which Criner and Parks derived their water-level measurements that they used from their control wells for Figure 3?

Criner and Parks' attempt to define the equipotential surface in the confined portions of the groundwater system. Their equipotential lines actually make sense to me, make geological sense to me.

Q. Let me ask you about the contour lines you were just pointing at in Figure 3. Do you see how the contour lines -- let's focus on the 220 through 250 lines as they are going south of Memphis. They are at a northeast-southwest angle orientation roughly. Do you see that?

A. South of Memphis, yes.

Q. Do you see how the contour lines generally bend toward a more north-south orientation right around the Tennessee-Mississippi border?

A. Uh-huh. Yes.

Q. Do you agree with that bend as depicted in the Criner and Parks map?

MR. ELLINGBURG: Objection to the form. Which lines are you referring to?

MR. BRANSON: 220 through 250.

A. It is a contouring interpretation by well-meaning scientists, and so I would have no reason to take extreme exception to it.

Q. (BY MR. BRANSON) Do you see any control data on this Figure 3 that would justify the bend that we were just talking about?

A. Not on this particular figure.

Q. Are you aware of any other control data that Criner and Parks had that would justify that bend?

A. Are you talking about just where the contours go nearly north-south south of the border?

Q. Yes.

A. I think it is an interpretation by two scientists who are attempting to draw an accurate picture of the equipotential surface in that area.

Q. But you don't know what data they used in order to justify that data around the border?

A. That is not plotted on this map. If this was a hand-drawn map, it could have been computer-generated because they are contouring packages. I'm not talking about modeling. I don't know.

Q. Do you see the City of Arlington in the

northeast quadrant of this Figure 3?
A. Yes.
Q. Do you see the black dot just to the upper left of the word "Arlington"? It is right on the 270 contour line?
A. Yes.
Q. Do you interpret that as a control well on which Criner and Parks relied?
A. I don't remember. There is not -- there is -- in the legend or explanation there is an indication of small dots that should appear on this map. I need a blowup to really see those. I suppose there is one there.
Q. And you didn't re-engage in any contour-line-drawing exercise yourself to decide if you would have drawn the same contours based on Criner and Parks' control points?
A. No.
Q. Let's flip to Page 12. We're already there. Same page that we're on in your rebuttal report, your top bullet. Do see that?
A. Uh-huh.
Q. You say "Waldron-Larson 2015 does not mention earlier USGS study Reed in 1972 that

A. I don't recall doing that, no.

Q. If you hadn't looked at Reed's underlying control data that he used to generate Figure 4 in the rebuttal report, do you have confidence that the equipotential surface map he generated was accurate?

A. These maps produced by a person like Reed back in 1972 were not drawn to try to prove that groundwater was flowing across the state boundary. They were a scientist's best interpretation of groundwater flow patterns on a regional scale. They could be off. They could be wrong. But they are 1972 interpretations of somebody's understanding of how the groundwater system worked.

Q. So in light of that it sounds like you don't have a lot of coincidence in whether Reed got the potentiometric surface correct in Figure 4?

A. The surface makes sense to me as a hydrologist. If somebody handed my this map without those lines on it and said, with no data at all, tell us what the equipotential surface looks like, most hydrologists draw recharge flow points along a river. I'm sure he had some control points. I see some dots there. I don't know how many. They may be cities. These are reasonable 1972 interpretations. I also point out it is for the confined part of the groundwater system.

Q. You don't know whether Reed had any -- was relying on any control wells that were, for instance, properly grouted?

A. No. I'll tell you what I was looking for is the consistency. As I look through the various maps, the only equipotential surface maps I found until the 2013 MERAS report were an attempt by Waldron and the MERAS report to show groundwater flow patterns in the unconfined portions of the system on the eastern side of the area.

Q. On that point on Figure 4, if look right along the Arkansas -- I'm sorry, the Mississippi-Tennessee boundary on the 35 degree latitude and look at the unconfined portion of the aquifer on the eastern side of the confined portion -- do you see that?

A. Yes.

Q. Do you see that Reed appears to have drawn a 400-foot head contour through that unconfined area?

A. Uh-huh. I have seen that before.

Q. Help me understand why do you see that Reed was mapping only the confined area in light of that contour line that is going through the unconfined area?

A. I can't tell you why in 1972 he decided to draw a line up there. That line in general terms makes sense to me as hydrologist. That head would be about 400 feet up there. It would be 340 and then 200 and so forth out toward the center of the axis of the Mississippi Embayment.

I can't tell you why he decided to draw one contour line there. The contour line makes general sense. I think of this in terms of what we knew in 1972. I think you have to look at it from that perspective. That's not what we know now. The map is a reasonable interpretation based on the timing.

Q. Just to make sure I'm following you, we're on the same page that Reed did draw a 400-foot contour line through the unconfined

portion of the Middle Claiborne?
A. I see it. It is a fact it is there.
Q. If you look up a bit over to the upper left of where the capital word "Tennessee" is, do you see that?
A. Yes.
Q. You see to the left of that there is a 360 contour that also appears to go in the unconfined area of the aquifer?
A. It is there. It is on map.
Q. The existence of those contour lines going through the unconfined area of the aquifer in Reed, that doesn't cause you to doubt the accuracy of his map?
A. I doubt seriously that those lines in the unconfined portion of the aquifer system truly represent how groundwater flows in the unconfined part of the system. I have much more confidence in flow patterns in the confined portions of the groundwater system. That's because it has an amazing amount of complexity in the groundwater flow patterns. I think that's a broad generality.
Q. To make sure I'm following your answer,

the existence of the contour lines in the unconfined area of Reed in 1972 does not cause you to doubt the potentiometric surface map that he has drawn for the confined portions?

A. I think it was a very reasonable interpretation based on what he knew in 1972.

Q. You don't know whether Reed might have relied on a water-level reading in part to generate the potentiometric surface lines on Figure 4 that came from the unconfined area?

A. I don't, but if there was one well in the unconfined area and he drew all those contours based on that one well, I'd want to know the construction details of that one well. I say emphatically that contour line doesn't make a lot of sense to me, but the ones in the confined aquifer do.

Q. You don't know whether he did or did not rely on water-level readings from such a well in the unconfined area?

A. I do not.

Q. Let's go back to Page 11. Focus on the last bullet, the second sentence. "Likewise, USGS and other computer simulations of the

Q. Did you go back and review the primary source references on which Dr. Waldron relied in the 2015 article?

A. I studied it extensively.

Q. Why did you go study the primary source references on which Dr. Waldron relied but not do the same for the Reed 1972 map, for instance?

A. I suppose it is because Reed was not an expert in this case. Reed didn't read my expert report and comment on it. I'm specifically responding to a rebuttal report of my opinions.

In my primary expert report I simply said I have real issues with how you study groundwater flow patterns in the unconfined portion of the groundwater system, and because of that I didn't rely on Dr. Waldron's study. Then I get this report from him with all of this verbiage in it, so I responded to it with some detail.

Q. I assume the same answer applies to why you didn't go back and check the primary source references for Criner and Parks?

A. Yeah.

Q. Let's focus on Point 4 on Page 17. You again?

Q. (BY MR. BRANSON) I'm sorry. Had Head Number 3 been included. That's what I meant.

A. Let me try to find it.

Q. So you say that "Had the data point been included on the map, the orientation of the groundwater flow via equipotential lines in the confined portion of the aquifer system would have been more westerly rather than northwesterly." My question is did you attempt to draw such a map with that point included?

A. I sketched it. I didn't include it in the rebuttal report. The equipotential line that would have a value of 61, that's the far left equipotential line on his Figure 13, the head between there and the well that we called Forrest City, Arkansas, Well Number 3, the head difference is significant. I don't remember the head in that well exactly, but the head difference is tremendous, a significant number of feet lower than 61.

So the point of this Line 61 says if you drill a well anywhere on that line that is four or five hundred feet deep and taps into the

Exhibit 4

Excerpts from Preliminary Report on Diversion of Ground-Water from DeSoto and Marshall Counties Mississippi Due to Memphis Area Pumpage (Expert Report of David Wiley)

(Dec. 31, 2006)

LEGGETTE, BRASHEARS & GRAHAM, INC.

PROFESSIONAL GROUND-WATER AND
ENVIRONMENTAL ENGINEERING SERVICES

10014 NORTH DALE MABRY HIGHWAY
SUITE 205
TAMPA, FLORIDA 33618
813-968-5882
FAX 813-968-9244
www.lbgweb.com

January 2, 2007

VIA E-MAIL
Jim Hood, Attorney General
State of Mississippi
Attention: Alan B. Cameron, Esq.
Daniel Coker Horton & Bell, P.A.
E-mail: acameron@danielcoker.com

Re: Preliminary Report on Diversion of Ground-Water From DeSoto and Marshall Counties Mississippi Due to Memphis Area Pumpage

Dear Mr. Cameron:

Enclosed is our preliminary Technical Memorandum regarding the captioned matter. LBG is still awaiting additional data to be provided from Memphis-MLGW and other sources. We intend to update and refine our analyses and conclusions, and this initial report will be supplemented in a timely manner, as the data become available and more accessible and refined in character.

Sincerely,

LEGGETTE, BRASHEARS & GRAHAM, INC.

David A. Wiley

David A. Wiley, P.G.
Vice President

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TECHNICAL MEMORANDUM

TO: Jim Hood, Attorney General of the State of Mississippi

FROM: David A. Wiley, P.G.

DATE: December 31, 2006

SUBJECT: Preliminary Report on Diversion of Ground-Water from DeSoto and Marshall Counties, Mississippi Due to Memphis Area Pumpage

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INTRODUCTION

Leggette, Brashears and Graham, Inc. (LBG) has prepared this Technical Memorandum with the intent of evaluating the effects on ground-water flows in relation to the Memphis Sand or Sparta aquifer underlying northwestern Mississippi as a result of pumpage in the Memphis area of Tennessee. It is our opinion that, as a result of ground-water pumpage that has been occurring historically over, at least, the past four decades in the Memphis area, the natural ground-water flow direction or gradient of the aquifer has been significantly altered. This alteration of the gradient has extended into the ground-water system beneath northwestern Mississippi, primarily in DeSoto and Marshall Counties. **Figure 1** attached to this Technical Memorandum shows the location of the project area. As a result of Memphis area pumpage, the most significant amount of which is attributed to Memphis Light, Gas and Water Division of the City of Memphis, Mississippi ground water is now, and has been, flowing northward out of Mississippi into Memphis. This Technical Memorandum demonstrates this change in the aquifer flow gradient and preliminarily, the amount of ground water diverted annually from Mississippi into Memphis for the period of 1985 to 2005. Diversions prior to this period will be reported in a supplemental memorandum.

The key activities performed by LBG include: the review of existing technical reports and hydrologic data from the United States Geological Survey (USGS), University of Memphis Ground Water Institute (GWI), Memphis Light, Gas and Water

Table 1 - Water Budget Flows From Desoto & Marshall Counties

Year	Marshall. MS (MGD)	Desoto, MS (MGD)
1886-1924	0.0023	4.18
1924-1941	0.004	9.22
1941-1955	0.007	13.55
1955-1960	0.2	19.946
1960-1965	0.17	22.66
1965-1970	0.133	28.21
1970-1975	0.147	32.22
1975-1980	0.16	33.32
1980-1983	0.161	34.35
1983-1991	0.17	35.38
1991-1993	0.17	35.4
1993-1995	0.168	32.1
1995-2000	0.169	33
2000-2005	0.17	33.1

Table 2 - Pumpage Amounts From Each County

Year	Marshall, MS (MGD)	Tate, MS (MGD)	Tunica, MS (MGD)	Desoto, MS-- Pumpage From Model (MGD)
1886-1924	0.1	0.284	0.3553	0
1924-1941	0.232	0.63	0.775	0
1941-1955	0.375	0.94	1.105	0
1955-1960	1.07	2.47	1.99	0.497
1960-1965	1.105	2.65	2.26	0.898
1965-1970	1.221	2.836	2.69	1.23
1970-1975	1.4212	3.44	3.25	4.18
1975-1980	1.47	3.58	3.37	4.18
1980-1983	1.58	3.6	3.28	3.6
1983-1991	1.63	3.65	3.36	3.6
1991-1993	1.62	3.695	3.388	3.6
1993-1995	1.78	4.86	4.031	13.05
1995-2000	1.815	4.97	4.14	13.4
2000-2005	1.822	5.07	4.22	14

Exhibit 5

Excerpts from Report on Diversion of Ground Water from Northern Mississippi Due to Memphis Area Well Fields (Expert Report of David Wiley)

(May 2007)

REPORT ON DIVERSION OF GROUND WATER FROM NORTHERN MISSISSIPPI DUE TO MEMPHIS AREA WELL FIELDS

Prepared For:

Jim Hood, Attorney General of the State of Mississippi

May 2007

Prepared By:

LEGGETTE, BRASHEARS & GRAHAM,, INC.
Professional Ground-Water and Environmental Engineering Consultants
10014 North Dale Mabry Highway, Suite 205
Tampa, FL 33618

TABLES

Table 2 - Pumpage Amounts From Each County

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1995-2000	1.815	4.97	4.14	13.4
2000-2005	1.822	5.07	4.22	14

Table 3

MEMPHIS LIGHT, GAS AND WATER DIVISION

CITY OF MEMPHIS

Water Pumpage By Stations

Gallons Per Day

1965-2007

	Sheahan	Mallory	Allen	Lichterman	McCord	Davis	Palmer	Morton	LNG.	Shaw	TOTAL	Starting	Ending	Monthly	Comments (If not raw pumpage data)
Row	41	41	45	44	33	50	48	33	26	33		Bates #	Bates #	or Yearly	
Column	25	17	21	29	25	17	24	18	26	32					
1965	17,773,000	13,268,000	22,519,000	4,220,000	14,181,000						71,961,000	MLGW 66416		Yearly	Net Pumpage
1966	16,991,000	12,618,000	22,969,000	9,697,000	13,472,000						75,747,000	MLGW 66417		Yearly	Net Pumpage
1967	15,870,000	12,364,000	22,592,000	13,277,000	13,599,000						77,702,000	MLGW 66417		Yearly	Net Pumpage
1968	15,961,000	12,582,000	23,430,000	14,621,000	14,487,000						81,081,000	MLGW 66417		Yearly	Net Pumpage
1969	15,063,000	11,961,000	23,934,000	16,192,000	15,495,000						82,645,000	MLGW 66418		Yearly	Net Pumpage
1970	15,556,000	11,231,000	27,167,000	16,775,000	16,211,000	3,258,000			101,000		90,299,000	MLGW 66418		Yearly	Net Pumpage
1971	18,332,000	12,953,000	25,420,000	15,585,000	15,930,000	7,487,000			151,000		95,858,000	MLGW 66418		Yearly	Net Pumpage
1972	15,927,000	15,973,000	22,024,000	16,373,000	15,491,000	10,204,000	2,801,000		249,000		99,042,000	MLGW 66419		Yearly	Net Pumpage
1973	17,167,583	18,880,000	21,578,667	18,084,333	17,281,583	10,867,333	2,776,333	1,660,000	174,166		108,469,998	MLGW 67682	MLGW 67741	Monthly	
1974	17,579,833	20,101,500	22,193,750	18,142,667	15,353,667	10,617,083	2,944,833	2,354,083	255,750		109,543,166	MLGW 67622	MLGW 67681	Monthly	
1975	18,130,916	19,148,583	21,276,750	17,378,916	19,111,750	11,688,416	3,047,666	160,500	243,833		110,187,330	MLGW 67562	MLGW 67621	Monthly	
1976	19,007,000	20,641,000	19,947,000	18,148,000	18,721,000	11,370,000	3,158,000	3,000	260,000		111,255,000	MLGW 66420		Yearly	Net Pumpage
1977	18,564,000	22,114,000	21,680,000	18,809,000	19,986,000	13,226,000	3,360,000	5,000	268,000		118,012,000	MLGW 66420		Yearly	Net Pumpage
1978	16,055,000	20,785,000	21,316,000	20,517,000	21,086,000	13,779,000	3,545,000	34,000	361,000		117,478,000	MLGW 67562	MLGW 67848	Monthly	
1979	17,419,000	20,294,000	19,867,000	22,645,000	22,164,000	14,125,000	2,869,000	4,000	327,000		119,714,000	MLGW 67831	MLGW 67835	Monthly	
1980	20,744,000	20,953,000	21,591,000	23,151,000	20,700,000	13,262,000	3,186,000	53,000	343,000		123,983,000	MLGW 67818	MLGW 67882	Monthly	
1981	21,229,000	20,375,000	19,305,000	21,633,000	21,556,000	11,526,000	3,425,000	20,000	339,000		119,408,000	MLGW 67805	MLGW 67809	Monthly	
1982	21,465,000	17,526,000	20,508,000	22,524,000	19,124,000	11,591,000	2,850,000	5,618,000	421,000		121,627,000	MLGW 67791	MLGW 67795	Monthly	
1983	22,914,000	17,338,000	20,947,000	22,163,000	17,269,000	12,705,000	179,000	10,874,000	465,000		124,855,983	MLGW 67778	MLGW 67782	Monthly	
1984	20,743,000	18,693,000	21,102,000	21,850,000	20,772,000	12,244,000	724,000	11,091,000	460,000		127,680,984	MLGW 67765	MLGW 67769	Monthly	
1985	20,499,000	21,784,000	23,607,000	21,550,000	20,764,000	11,294,000	255,000	11,402,000	500,274	-	131,655,274	MLGW 0003		Yearly	Net Pumpage
1986	20,310,411	20,834,795	24,906,027	24,151,781	20,575,068	12,620,548	138,904	12,447,671	554,247	-	136,539,452	GWI 013666	GWI 013684	Monthly	
1987	18,876,438	20,218,082	24,590,411	24,483,562	20,714,795	12,785,753	293,425	12,953,425	530,411	-	135,446,301	GWI 013685	GWI 013722	Monthly	
1988	21,445,479	21,059,178	24,733,973	25,466,575	20,743,562	12,714,521	1,681,096	14,218,082	526,849	-	142,589,315	GWI 012946	GWI 013051	Monthly	
1989	19,761,096	19,727,397	21,925,753	24,121,370	20,559,726	11,349,589	3,776,712	13,705,753	397,260	-	135,324,658	GWI 013082	GWI 013208	Monthly	Some Net pumpage used for Nov - MLGW 00005
1990	21,005,205	19,690,959	24,137,260	23,247,945	19,839,178	10,447,671	4,101,644	12,236,712	434,247	5,867,397	141,008,219	GWI 01321	GWI 013384	Monthly	Net pumpage used for Jan - MLGW 00005
1991	20,998,082	20,714,795	21,012,603	21,771,507	18,516,438	10,135,890	5,079,178	10,465,753	393,151	10,983,562	140,070,959	GWI 012341	GWI 012487	Monthly	
1992	20,023,836	20,626,849	20,444,110	21,130,685	19,223,562	9,701,918	5,337,534	10,458,904	423,014	11,872,603	139,243,014	GWI 012490	GWI 012636	Monthly	
1993	19,548,219	20,222,192	21,248,767	21,801,644	18,483,836	9,960,000	4,808,767	12,719,726	497,534	10,325,479	139,616,164	GWI 012639	GWI 012785	Monthly	
1994	20,627,397	15,901,370	21,576,712	21,936,438	17,695,890	11,866,027	4,938,356	14,360,548	477,260	12,982,466	142,362,466	GWI 012787	GWI 012943	Monthly	
1995	20,570,137	16,029,315	22,800,548	21,915,342	17,398,082	12,569,863	4,903,562	17,106,301	529,589	14,177,260	148,000,000	GWI 011938	GWI 012085	Monthly	
1996	20,170,137	17,329,589	22,532,055	21,929,041	17,373,425	14,135,616	4,668,767	18,168,767	515,342	13,058,630	149,881,370	GWI 012087	GWI 012235	Monthly	
1997	19,556,438	15,529,315	22,114,521	21,377,534	15,968,493	14,602,466	4,284,658	16,915,068	444,384	14,880,000	145,672,877	GWI 012239	GWI 012337	Monthly	Net pumpage used for Sept-Dec - MLGW 00009
1998	21,355,068	17,229,863	22,910,137	23,288,767	15,794,795	15,442,466	4,090,411	17,976,986	419,726	17,894,795	156,403,014	GWI 011534	GWI 011631	Monthly	Net pumpage used for Jan-Apr - MLGW 00009
1999	21,441,370	18,560,548	25,246,575	23,447,397	16,404,932	12,718,356	5,067,945	18,886,027	493,425	19,609,863	161,876,438	GWI 011632	GWI 011767	Monthly	Some Net pumpage used - MLGW 00010
2000	21,641,370	17,321,096	24,287,123	22,502,466	17,129,589	13,992,603	4,998,082	19,012,329	369,315	20,854,521	162,108,493	GWI 011773	GWI 011911	Monthly	Net pumpage used for May - MLGW 00010
2001	19,443,014	17,588,767	19,972,329	19,626,575	16,318,904	17,500,548	4,785,205	17,477,260	446,301	20,248,493	153,407,397	MLGW 00011		Yearly	Net Pumpage
2002	18,140,000	17,300,000	22,000,000	18,550,000	15,550,000	19,000,000	4,525,000	18,000,000	475,000	20,983,333	154,523,333	MLGW2 03771 CD		Monthly	
2003	15,616,666	15,708,333	22,383,333	18,133,333	16,066,667	19,508,333	5,108,333	18,941,667	334,167	20,100,000	151,900,832	MLGW2 03771 CD		Monthly	
2004	15,775,000	16,075,000	21,858,333	17,700,000	16,341,667	19,641,667	5,150,000	18,741,667	400,000	22,666,667	154,350,001	MLGW2 03771 CD		Monthly	
2005	15,266,667	17,141,667	21,675,000	19,158,333	17,700,000	20,225,000	3,383,333	18,783,333	558,333	23,000,000	156,891,666	MLGW2 03771 CD		Monthly	
2006	16,658,333	16,575,000	21,358,333	19,550,000	17,458,333	20,566,667	4,166,667	18,341,667	358,333	21,200,000	156,233,333	MLGW2 03771 CD		Monthly	

Table 4 - Volume of Ground Water Diverted from Mississippi Due to MLGW Pumpage

Year	MGD
1965	13.7
1966	15.2
1967	16.0
1968	16.8
1969	17.2
1970	19.4
1971	20.7
1972	22.0
1973	23.5
1974	23.8
1975	22.7
1976	22.8
1977	24.4
1978	24.5
1979	24.9
1980	26.0
1981	24.5
1982	24.8
1983	24.8
1984	24.8
1985	25.3
1986	26.7
1987	26.6
1988	28.2
1989	26.8
1990	27.1
1991	26.0
1992	25.5
1993	25.7
1994	26.3
1995	24.0
1996	24.5
1997	23.7
1998	25.4
1999	25.9
2000	25.6
2001	24.0
2002	24.3
2003	24.1
2004	23.9
2005	23.8
2006	24.2

Exhibit 6

Excerpts from Update Report on Diversion and Withdrawal of Groundwater from Northern Mississippi into the State of Tennessee (Expert Report of David Wiley)

(April 14, 2014)

EXHIBIT 1

UPDATE REPORT ON DIVERSION AND WITHDRAWAL OF GROUNDWATER FROM NORTHERN MISSISSIPPI INTO THE STATE OF TENNESSEE

Prepared For:

Jim Hood, Attorney General
of the State of Mississippi

April 14, 2014

Prepared By:

LEGGETTE, BRASHEARS & GRAHAM, INC.
Professional Groundwater and Environmental Engineering Consultants
10014 North Dale Mabry Highway, Suite 205
Tampa, FL 33618

Table 1

MEMPHIS LIGHT, GAS AND WATER DIVISION
CITY OF MEMPHIS
Water Pumpage By Stations
Gallons Per Day
1965-2012

	Sheahan	Mallory	Allen	Lichterman	McCord	Davis	Palmer	Morton	LNG	Shaw	TOTAL	Starting	Ending	Monthly	Comments (If not raw pumpage data)
Row	41	41	45	44	33	50	48	33	26	33		Bates #	Bates #	or Yearly	
Column	25	17	21	29	25	17	24	18	26	32					
1965	17,773,000	13,268,000	22,519,000	4,220,000	14,181,000						71,961,000	MLGW 66416		Yearly	Net Pumpage
1966	16,991,000	12,618,000	22,969,000	9,697,000	13,472,000						75,747,000	MLGW 66417		Yearly	Net Pumpage
1967	15,870,000	12,364,000	22,592,000	13,277,000	13,599,000						77,702,000	MLGW 66417		Yearly	Net Pumpage
1968	15,961,000	12,582,000	23,430,000	14,621,000	14,487,000						81,081,000	MLGW 66417		Yearly	Net Pumpage
1969	15,063,000	11,961,000	23,934,000	16,192,000	15,495,000						82,645,000	MLGW 66418		Yearly	Net Pumpage
1970	15,556,000	11,231,000	27,167,000	16,775,000	16,211,000	3,258,000			101,000		90,299,000	MLGW 66418		Yearly	Net Pumpage
1971	18,332,000	12,953,000	25,420,000	15,585,000	15,930,000	7,487,000			151,000		95,858,000	MLGW 66418		Yearly	Net Pumpage
1972	15,927,000	15,973,000	22,024,000	16,373,000	15,491,000	10,204,000	2,801,000		249,000		99,042,000	MLGW 66419		Yearly	Net Pumpage
1973	17,167,583	18,880,000	21,578,667	18,084,333	17,281,583	10,867,333	2,776,333	1,660,000	174,166		108,469,998	MLGW 67682	MLGW 67741	Monthly	
1974	17,579,833	20,101,500	22,193,750	18,142,667	15,353,667	10,617,083	2,944,833	2,354,083	255,750		109,543,166	MLGW 67622	MLGW 67681	Monthly	
1975	18,130,916	19,148,583	21,276,750	17,378,916	19,111,750	11,688,416	3,047,666	160,500	243,833		110,187,330	MLGW 67562	MLGW 67621	Monthly	
1976	19,007,000	20,641,000	19,947,000	18,148,000	18,721,000	11,370,000	3,158,000	3,000	260,000		111,255,000	MLGW 66420		Yearly	Net Pumpage
1977	18,564,000	22,114,000	21,680,000	18,809,000	19,986,000	13,226,000	3,360,000	5,000	268,000		118,012,000	MLGW 66420		Yearly	Net Pumpage
1978	16,055,000	20,785,000	21,316,000	20,517,000	21,086,000	13,779,000	3,545,000	34,000	361,000		117,478,000	MLGW 67562	MLGW 67848	Monthly	
1979	17,419,000	20,294,000	19,867,000	22,645,000	22,164,000	14,125,000	2,869,000	4,000	327,000		119,714,000	MLGW 67831	MLGW 67835	Monthly	
1980	20,744,000	20,953,000	21,591,000	23,151,000	20,700,000	13,262,000	3,186,000	53,000	343,000		123,983,000	MLGW 67818	MLGW 67882	Monthly	
1981	21,229,000	20,375,000	19,305,000	21,633,000	21,556,000	11,526,000	3,425,000	20,000	339,000		119,408,000	MLGW 67805	MLGW 67809	Monthly	
1982	21,465,000	17,526,000	20,508,000	22,524,000	19,124,000	11,591,000	2,850,000	5,618,000	421,000		121,627,000	MLGW 67791	MLGW 67795	Monthly	
1983	22,914,000	17,338,000	20,947,000	22,163,000	17,269,000	12,705,000	179,000	10,874,000	465,000		124,855,983	MLGW 67778	MLGW 67782	Monthly	
1984	20,743,000	18,693,000	21,102,000	21,850,000	20,772,000	12,244,000	724,000	11,091,000	460,000		127,680,984	MLGW 67765	MLGW 67769	Monthly	
1985	20,499,000	21,784,000	23,607,000	21,550,000	20,764,000	11,294,000	255,000	11,402,000	500,274	-	131,655,274	MLGW 0003		Yearly	Net Pumpage
1986	20,310,411	20,834,795	24,906,027	24,151,781	20,575,068	12,620,548	138,904	12,447,671	554,247	-	136,539,452	GWI 013666	GWI 013684	Monthly	
1987	18,876,438	20,218,082	24,590,411	24,483,562	20,714,795	12,785,753	293,425	12,953,425	530,411	-	135,446,301	GWI 013685	GWI 013722	Monthly	
1988	21,445,479	21,059,178	24,733,973	25,466,575	20,743,562	12,714,521	1,681,096	14,218,082	526,849	-	142,589,315	GWI 012946	GWI 013051	Monthly	
1989	19,761,096	19,727,397	21,925,753	24,121,370	20,559,726	11,349,589	3,776,712	13,705,753	397,260	-	135,324,658	GWI 013082	GWI 013208	Monthly	Some Net pumpage used for Nov - MLGW 00005
1990	21,005,205	19,690,959	24,137,260	23,247,945	19,839,178	10,447,671	4,101,644	12,236,712	434,247	5,867,397	141,008,219	GWI 01321	GWI 013384	Monthly	Net pumpage used for Jan - MLGW 00005
1991	20,998,082	20,714,795	21,012,603	21,771,507	18,516,438	10,135,890	5,079,178	10,465,753	393,151	10,983,562	140,070,959	GWI 012341	GWI 012487	Monthly	
1992	20,023,836	20,626,849	20,444,110	21,130,685	19,223,562	9,701,918	5,337,534	10,458,904	423,014	11,872,603	139,243,014	GWI 012490	GWI 012636	Monthly	
1993	19,548,219	20,222,192	21,248,767	21,801,644	18,483,836	9,960,000	4,808,767	12,719,726	497,534	10,325,479	139,616,164	GWI 012639	GWI 012785	Monthly	
1994	20,627,397	15,901,370	21,576,712	21,936,438	17,695,890	11,866,027	4,938,356	14,360,548	477,260	12,982,466	142,362,466	GWI 012787	GWI 012943	Monthly	
1995	20,570,137	16,029,315	22,800,548	21,915,342	17,398,082	12,569,863	4,903,562	17,106,301	529,589	14,177,260	148,000,000	GWI 011938	GWI 012085	Monthly	
1996	20,170,137	17,329,589	22,532,055	21,929,041	17,373,425	14,135,616	4,668,767	18,168,767	515,342	13,058,630	149,881,370	GWI 012087	GWI 012235	Monthly	
1997	19,556,438	15,529,315	22,114,521	21,377,534	15,968,493	14,602,466	4,284,658	16,915,068	444,384	14,880,000	145,672,877	GWI 012239	GWI 012337	Monthly	Net pumpage used for Sept-Dec - MLGW 00009
1998	21,355,068	17,229,863	22,910,137	23,288,767	15,794,795	15,442,466	4,090,411	17,976,986	419,726	17,894,795	156,403,014	GWI 011534	GWI 011631	Monthly	Net pumpage used for Jan-Apr - MLGW 00009
1999	21,441,370	18,560,548	25,246,575	23,447,397	16,404,932	12,718,356	5,067,945	18,886,027	493,425	19,609,863	161,876,438	GWI 011632	GWI 011767	Monthly	Some Net pumpage used - MLGW 00010
2000	21,641,370	17,321,096	24,287,123	22,502,466	17,129,589	13,992,603	4,998,082	19,012,329	369,315	20,854,521	162,108,493	GWI 011773	GWI 011911	Monthly	Net pumpage used for May - MLGW 00010
2001	19,443,014	17,588,767	19,972,329	19,626,575	16,318,904	17,500,548	4,785,205	17,477,260	446,301	20,248,493	153,407,397	MLGW 00011		Yearly	Net Pumpage
2002	18,140,000	17,300,000	22,000,000	18,550,000	15,550,000	19,000,000	4,525,000	18,000,000	475,000	20,983,333	154,523,333	MLGW2 03771 **CD**		Monthly	
2003	15,616,666	15,708,333	22,383,333	18,133,333	16,066,667	19,508,333	5,108,333	18,941,667	334,167	20,100,000	151,900,832	MLGW2 03771 **CD**		Monthly	
2004	15,775,000	16,075,000	21,858,333	17,700,000	16,341,667	19,641,667	5,150,000	18,741,667	400,000	22,666,667	154,350,001	MLGW2 03771 **CD**		Monthly	
2005	15,266,667	17,141,667	21,675,000	19,158,333	17,700,000	20,225,000	3,383,333	18,783,333	558,333	23,000,000	156,891,666	MLGW2 03771 **CD**		Monthly	
2006	16,658,333	16,575,000	21,358,333	19,550,000	17,458,333	20,566,667	4,166,667	18,341,667	358,333	21,200,000	156,233,333	MLGW2 03771 **CD**		Monthly	
2007	15,944,167	16,335,833	19,518,333	19,852,500	16,528,333	21,447,500	4,173,333	16,946,533	360,000	22,879,167	153,985,700			Monthly	
2008	13,724,167	12,552,075	19,653,333	17,886,667	15,801,667	19,312,500	4,002,500	17,174,167	471,667	22,777,500	143,356,242			Monthly	
2009	12,895,000	13,594,167	19,072,500	17,191,667	16,713,333	17,517,500	4,173,333	17,405,000	414,167	21,349,167	140,325,833			Monthly	
2010	14,673,333	15,620,833	19,414,167	19,205,833	18,050,833	19,156,667	3,945,833	18,084,167	555,000	22,617,500	151,324,167			Monthly	
2011	12,204,167	13,573,333	16,038,333	17,151,667	16,538,333	17,512,500	3,195,000	15,785,833	414,167	20,342,500	132,755,833			Monthly	
2012	13,055,000	14,755,833	17,163,333	18,685,833	16,694,167	19,038,333	4,275,000	17,343,333	461,667	22,120,833	143,593,333			Monthly	

Table 2 - Pumpage Amounts From Shelby and DeSoto Counties

Year	Shelby County (MGD)	DeSoto County (MGD)
2007	154.9	11.09
2008	144.3	10.69
2009	141.2	12.44
2010	152.3	14.44
2011	133.6	13.37
2012	144.4	15.31

Table 3 - Volume of Groundwater Taken from Mississippi Due to MLGW Pumpage

Years	MGD
1965	13.64
1966	15.27
1967	16.08
1968	16.86
1969	17.32
1970	19.44
1971	20.73
1972	21.98
1973	23.46
1974	23.80
1975	22.85
1976	23.01
1977	24.59
1978	24.70
1979	25.11
1980	26.26
1981	24.73
1982	25.00
1983	24.96
1984	24.95
1985	25.41
1986	26.90
1987	26.72

1988	28.33
1989	26.95
1990	27.26
1991	26.17
1992	25.61
1993	25.85
1994	26.39
1995	24.14
1996	24.65
1997	23.83
1998	25.53
1999	26.02
2000	25.66
2001	24.05
2002	24.33
2003	24.08
2004	23.95
2005	23.81
2006	24.29
2007	25.00
2008	22.86
2009	21.29
2010	22.59
2011	19.47
2012	20.98

Exhibit 7

Excerpts from Update Report on Diversion and Withdrawal of Groundwater from Northern Mississippi into the State of Tennessee (Expert Report of David Wiley)

(June 30, 2017)

UPDATE REPORT ON DIVERSION AND WITHDRAWAL OF GROUNDWATER FROM NORTHERN MISSISSIPPI INTO THE STATE OF TENNESSEE

Prepared For:

Jim Hood, Attorney General of the State of Mississippi

June 30, 2017

Prepared By:

LEGGETTE, BRASHEARS & GRAHAM, INC.
Professional Groundwater and Environmental Engineering Consultants
10014 North Dale Mabry Highway, Suite 205
Tampa, FL 33618

REPORT ON DIVERSION OF GROUND WATER FROM NORTHERN MISSISSIPPI DUE TO MEMPHIS AREA WELL FIELDS

EXECUTIVE SUMMARY

Ground-water conditions can be affected by a number of things that include climatic conditions and hydrogeologic characteristics. But, in many instances ground-water conditions are impacted by pumpage from wells. Impacts due to well pumpage can be significant should the quantities withdrawn be significant, such as the MLGW well field operation in the Memphis, Tennessee area. The continual increase in ground-water withdrawals in the Memphis area has caused a long-term decline in ground-water levels in the Memphis Sand aquifer as observed in historical hydrographs and potentiometric surface maps for area monitoring wells and regional ground-water flow models.

It is our opinion that, as a result of ground-water pumpage (withdrawals) that has been occurring historically over, at least, the past four decades in the Memphis area, the natural ground-water flow direction or gradient of the aquifer has been significantly altered. This alteration of the gradient has extended into the ground-water system beneath northwestern Mississippi, primarily in DeSoto and Marshall Counties. As a result of Memphis area pumpage, the most significant amount of which is attributed to Memphis Light, Gas and Water Division of the City of Memphis, Mississippi ground water is now, and has been, flowing northward out of Mississippi into Memphis. This report demonstrates this change in the aquifer flow gradient and the amount of ground water diverted annually from Mississippi into Memphis for the period of 1965 through 2006.

Based upon the Brahana Model, our own independent flow net analysis, potentiometric surface mapping, ground-water modeling, and our review of studies by other reputable scientists and water policy analysts (as discussed herein), it is our opinion that (1) Memphis area pumpage, primarily by MLGW, has altered the natural flow path and created a cone of depression in the Memphis Sand aquifer, resulting in the diversion of Mississippi's ground water; and (2) over the period of 1965 to 2006, an estimated 25 % to 35 % of Memphis area water supply has been derived from Mississippi. Further evaluation shows that 15 % to 22 % of MLGW's ground water withdrawals are obtained from ground water beneath Mississippi. For the year 2006, this diversion of Mississippi ground water equates to approximately 24 million gallons per day. It is created by MLGW pumpage extended into northern Mississippi. This large cone of depression occurs as a result of cumulative ground-water pumping (multiple wells) primarily from well fields operated by MLGW in the Memphis area. Essentially, many smaller individual well cones of depression overlap forming one, large cone of depression. **Figure 4** illustrates the area of the larger cone of depression that occurs from the cumulative well field pumpage. **Figure 5** is a three-dimensional illustration showing the larger cone of depression. The Arthur and Taylor model shows that flows have been diverted from their natural westerly direction northward by the cone of depression in Memphis. As a result, the pumpage that has been occurring from the Memphis, Tennessee area is capturing ground water from the aquifer beneath Mississippi. The model also shows that the natural discharge of flow to shallower aquifers has been reversed, and flow from the surface has the potential to contaminate the aquifer. These conditions were recognized by David Feldman from the University of Tennessee prompting the publishing of a report titled "Water Supply Challenges Facing Tennessee: Case Study Analyses and the Need for Long-Term Planning (June 2000), David Lewis Feldman, Ph.D., and Julia O. Elmendorf, J.D." In this report the author states that, at a ground-water pumping rate of approximately 145 million gallons per day (mgd) from the Memphis area a cone of depression is formed and 20-40 mgd is derived from beneath DeSoto County which is located in northwestern Mississippi. The cone of depression of the Memphis Sand can also be seen in potentiometric surface contour maps presented by Moore, 1960; Criner and Parks, 1976; and Parks, 1990. **Appendix A** contains the maps from these three reports.

3.0 HYDROGEOLOGY

The hydrogeology of the Memphis and northern Mississippi area has been described by others over the years. There are a number of principal aquifers and confining units delineated in this area. The major hydrogeologic units are: Surficial aquifer of Quaternary age consisting of the Fluvial deposits and the Alluvium; the Jackson-upper Claiborne Formation; the Memphis Sand; the Flour Island Formation; and the Fort Pillow Sand, all of Tertiary age (Outlaw, 1994). **Figure 6** is a generalized hydrogeologic cross section showing these units. Following are descriptions of each of these hydrogeologic units as delineated by Graham and Parks in 1986.

5.0 HYDROLOGIC EVALUATIONS

Ground-water conditions can be affected by a number of things that include climatic conditions and hydrogeologic characteristics. But, in many instances ground-water conditions are impacted by pumpage from wells. Impacts due to well pumpage can be significant should the quantities withdrawn be significant, such as the MLGW well field operation in the Memphis, Tennessee area. In order to achieve our objective of determining the effects on ground-water flows in relation to the Memphis Sand or Sparta aquifer underlying northwestern Mississippi as a result of pumpage or ground-water withdrawals in the Memphis area of Tennessee, evaluation of hydrologic data is necessary.

As mentioned earlier in this report in the **BACKGROUND** section, Memphis began using the Memphis Sand aquifer, which is the principal aquifer in the region, as a municipal water supply in 1886. Since that time, Memphis area pumpage has risen to a rate of approximately 200 mgd (Brahana & Broshears, 2001). The continual increase in ground-water withdrawals in the Memphis area has caused a long-term decline in ground-water levels in the Memphis Sand aquifer. This ground-water level condition is observed in hydrographs for observation wells monitored by the Tennessee USGS. Hydrographs are developed from actual water level measurements collected in the field by USGS personnel. **Figures 9 through 13** show that water levels have declined from approximately 20 to 50 in these area observation wells since 1958.

The USGS has also prepared ground-water elevation maps of the potentiometric surface for the Memphis Sand aquifer that show the declining water-level conditions across the southwest Tennessee and northwest Mississippi area. Potentiometric surface is the ground-water level that water in an aquifer will rise to in a tightly cased well. Potentiometric surface maps illustrate the ground-water gradient across a given area. These potentiometric surface maps (**Figures 14 – 21**) have been prepared for the following years; 1960, 1970, 1980, 1988, 1990, 1995, 2000 and 2005. As with the hydrographs, the potentiometric surface maps are based on actual water-level measurements. Water levels in the Memphis Sand aquifer have declined by approximately 100 feet since 1886 forming a large cone of depression. Water levels in the Sparta aquifer (the equivalent in Mississippi to the Memphis Sand) under northern DeSoto County, Mississippi have been estimated from a USGS model developed by Arthur and Taylor, 1990, to have declined by up to 90 feet.

These potentiometric surface maps also provide information regarding ground-water gradient or flow direction which is always perpendicular to contours. The potentiometric maps in **Figures 14 – 21** all show that the ground-water flow direction in southwest Tennessee and northwest Mississippi is radial toward the center of Memphis where the lowest water levels are observed in the Memphis Sand. This rather large cone of depression seen on these figures occurs as a result of cumulative ground-water pumping (multiple wells) primarily from well fields operated by MLGW in the Memphis area. Ground-water gradient or flow direction will be discussed in the following section on **FLOW NET METHODOLOGY**.

5.1 Flow Net Methodology

A regional ground-water flow system is defined by a set of equipotential lines, boundary conditions, and corresponding flow lines. Equipotential lines are contour lines of the potentiometric surface elevations in an aquifer, as defined by water levels in wells open to a specific aquifer. Boundary conditions can be physical geologic features that define the extent of an aquifer, or hydraulic boundaries such as recharge and discharge boundaries. Flow lines define the direction of ground-water flow based on the configuration of the equipotential lines and boundary conditions. A flow net is a graphical representation of the ground-water flow system consisting of a set of equipotential lines and corresponding flow lines (Freeze and Cherry, 1979). It should be noted that the flow net method of analysis is a standard application utilized by hydrologists to calculate ground-water flow volumes driven by a gradient and is a relatively simple and straight forward process.

Flow nets are constructed from existing potentiometric surface contour maps, such as those published by the U.S. Geological Survey (USGS), or from ground-water model-derived potentiometric surface contour maps. Flow lines define the direction of ground-water from high potentiometric head to low potentiometric head using four basic rules: 1) flow lines and equipotential lines must intersect at right angles; 2) equipotential lines must meet impermeable boundaries at right angles; 3) equipotential lines must parallel constant head boundaries; and 4) if the flow net is constructed such that squares are created between two equipotential lines in one portion of the flow field, then squares must exist between these equipotential lines across the flow field (Freeze and Cherry, 1979). Rules 1 and 4 are the basis for construction of a flow net of the Ground Water Institute at the University of Memphis. Of particular interest was a flow net analysis performed by Dr. Gentry in the 1999 to 2000 time frame. Dr. Gentry indicated that he estimated that about 25 % to 1/3 of the pumpage occurring in the Memphis, Tennessee area is derived from the ground-water system in Mississippi. He based his analysis on a potentiometric surface map prepared by the USGS for the 1988 period

Ground-water modeling was utilized to assist in calculating the ground-water flow contributions from Mississippi as a result of pumpage from the Memphis area and is described in the following section.

5.2 Ground-Water Modeling

Ground-water flow models are tools utilized by hydrogeologists and engineers to simulate a ground-water flow system. Assuming that hydrogeologic data is available for the area of concern, the hydrogeologist or engineer will first develop a conceptual model that is a simplified framework of the hydrogeologic system and is used to develop a ground-water flow model. Next, a model code is selected, such as MODFLOW to set up the model. A model grid is created to define the horizontal and vertical dimensions of the aquifer system. Boundary conditions are assigned to define the regional flow system. Aquifer characteristics are assigned to the model grid system of nodes or cells to define the hydraulic properties of the aquifer and confining layers. Recharge (rainfall), discharge (evapotranspiration and ground-water pumpage), and in some cases, streams, are included in the model to simulate the natural hydrologic cycle. The model is then run and the results are compared to observed ground-water level data from the area being evaluated. The input data are then adjusted until an acceptable match between observed and modeled water levels are obtained. This adjustment process is referred to as model calibration. The calibrated model is then used to perform predictive simulations.

In order to conduct our analysis for calculating the flow of ground water captured from Mississippi, as a result of pumpage from the Memphis area, it was determined that ground-water modeling was a necessary tool to utilize. After reviewing the literature, several candidate ground-water models were identified for potential use on this project. They were all calibrated at the time of their development. Those models are discussed below.

5.2.1 Ground-Water Model Review

Three separate existing ground-water flow models were provided for review. The three models were:

1. Hydrogeology and Ground-Water Flow in the Memphis and Fort Pillow Aquifers in the Memphis Area, Tennessee, Water-Resources Investigations Report 89-4131 by J.V. Brahana and R.E. Broshears. U.S. Geological Survey. 2001.
2. A Ground Water Flow Model of the Northern Mississippi Embayment by David Kenley of Ground Water Institute, The University of Memphis, 1993.
3. A Ground Water Flow Analysis of the Memphis Sand Aquifer in the Memphis, Tennessee Area by Jamie Outlaw of Ground Water Institute, The University of Memphis, 1994.

5.2.2 Description of the Models

The following is a general description of each of the three ground-water flow models reviewed as part of our preliminary analysis:

1. ***Hydrogeology and Ground-Water Flow in the Memphis and Fort Pillow Aquifers in the Memphis Area, Tennessee, Water-Resources Investigations Report 89-4131 by J.V. Brahana and R.E. Broshears. U.S. Geological Survey. 2001.***

This is a regional ground-water model constructed by Brahana and Broshears to determine changes in regional flow from pre-development time to 1980 due to changes in pumpage in Memphis Sand and Fort Pillow aquifers. The geographic extent of the model grid area is shown in **Figure 29** included in this report. The report includes the hydrogeology of the Memphis Sand and the Fort Pillow aquifers in the Memphis, Tennessee area. The model grid consists of three-layers, which are, from top to bottom: a) Fluvial Deposits; b) Memphis Sand Aquifer; and c) Fort Pillow Aquifer. A brief summary of a description by Brahana and Broshears of the three aquifers (layers) is as follows:

a) <u>Fluvial Deposits</u>

Fluvial deposit occurs at land surface and it ranges in thickness from 0 to 100 feet. Thickness is highly variable, because of surfaces at both top and base (Graham and Parks, 1986).

Locally, the fluvial deposits may be absent (Brahana and Broshears, 2001). The lithology of the fluvial deposits is primarily sand and gravel, with minor layers of ferruginous sandstone (Brahana and Broshears, 2001). Fluvial deposits are separated from the Memphis Sand aquifer by sediments of the Jackson Formation and the upper part of the Claiborne Group. There are no measurements of the hydraulic characteristics of the fluvial deposits in the Memphis area. However, based on the lithology, saturated thickness, and mode of occurrence, transmissivity is probably within the range of 5,000 to 10,000 ft2/d, and storage coefficient probably is in the range of 0.1 to 0.2 (Freeze and Cherry, 1979). The reported seasonal water-level fluctuations in the fluvial deposits range from 2 to 10 feet (Wells, 1933, Graham, 1982, and Graham and Parks, 1986). However, long-term declines of water levels within the fluvial deposits have not been documented, except in the southern part of the Sheahan well field (Brahana and Broshears, 2001). The fluvial deposit within the model was represented as a constant head boundary layer.

b) Memphis Sand Aquifer

It is the most productive aquifer in the area and it contributed 98 percent of total pumpage (188 mgd) to the city of Memphis in 1980 (Graham, 1982; Brahana and Broshears, 2001). The lithology of the Memphis Sand aquifer varies from fine- to coarse grained sand interbedded with layers of clay and minor amounts of lignite (Brahana and Broshears, 2001). The Memphis Sand aquifer occurs at a depth from 0 to 600 feet and varies in thickness from 500 to 890 feet. The underlying aquifer below the Memphis Sand aquifer is the Fort Pillow aquifer, and it is separated by 140 to 310 feet of clay layer of the Flour Island Formation. The Memphis Sand aquifer is confined and overlying the aquifer is 0 to 370 feet clay and sandy clay of the Jackson Formation and the upper part of the Claiborne Group. As the thickness of the Jackson Formation and the upper part of the Claiborne Group varies, at places the Fluvial deposits aquifer sits directly above the Memphis Sand aquifer. Thus, leakage to the Memphis Sand aquifer from the surface Fluvial deposits is pronounced in many places.

The Memphis Sand aquifer in the Memphis area is reported to have a range of transmissivity from 6,700 to 54,000 ft^2/d, and range of storage coefficients from 1×10^{-4} to 2×10^{-1} (Criner et. al., 1964; Moore, 1965; Hosman et. al., 1968; Brahana, 1982a; Arthur and Taylor, 1990; Parks and Carmichael, 1989a).

wells were assigned within the constant heads near the eastern and southern part of the model boundaries. Ground-water withdrawals from the wells within the constant head will have no effect to the potentiometric surface or drawdown, and the model will not simulate those wells. Calibration was concentrated on stress periods from 1961 to 1980. Calibration was conducted by adjusting the global multiplier of transmissivity, vertical conductance, and storage coefficients for the Memphis Sand and Fort Pillow aquifers, until the sum of the squared differences between observed and calculated heads were minimized (Brahana and Broshears, 2001). Pumpage was variable and increased with time in both the Memphis Sand and Fort Pillow aquifers.

2. ***A Ground Water Flow Model of the Northern Mississippi Embayment by David Kenley of Ground Water Institute, The University of Memphis, 1993.***

We reviewed the model data sets and performed model simulations to determine potentiometric surfaces within the model domain at the end of each stress period. A brief description of the model is provided below.

This is a three-dimensional ground-water flow model simulated using the USGS MODFLOW code. The model is based on Brahana and Broshears (2001) model, however, the time period of the model is extended from 1980 to 1993, with much finer grid-spacing in the Shelby County, Tennessee area. The model grid consists of 86 rows and 72 columns with grid spacing of the model varying between 3 to 100,000 feet in the east-west direction and 1600 to 100,000 feet in the north-south direction. The model had only two layers, the fluvial deposit aquifer and the Memphis Sand aquifer. It did not include the Fort Pillow aquifer. The conceptual model was altered for the Memphis Sand aquifer and it is represented as an unconfined aquifer (LAYCON 3), whereas in the Brahana and Broshears (2001) model it is represented as a confined layer (LAYCON 0). The purpose of the model was to determine impact to the potentiometric surface due to ground-water withdrawals in the Shelby County, Tennessee area.

Table 1 - Water Budget Flows From Desoto & Marshall Counties

Year	Marshall. MS (MGD)	Desoto, MS (MGD)
1886-1924	0.0023	4.18
1924-1941	0.004	9.22
1941-1955	0.007	13.55
1955-1960	0.2	19.946
1960-1965	0.17	22.66
1965-1970	0.133	28.21
1970-1975	0.147	32.22
1975-1980	0.16	33.32
1980-1983	0.161	34.35
1983-1991	0.17	35.38
1991-1993	0.17	35.4
1993-1995	0.168	32.1
1995-2000	0.169	33
2000-2005	0.17	33.1

Table 2 - Pumpage Amounts From Each County

Year	Marshall, MS (MGD)	Tate, MS (MGD)	Tunica, MS (MGD)	Desoto, MS--Pumpage From Model (MGD)
1886-1924	0.1	0.284	0.3553	0
1924-1941	0.232	0.63	0.775	0
1941-1955	0.375	0.94	1.105	0
1955-1960	1.07	2.47	1.99	0.497
1960-1965	1.105	2.65	2.26	0.898
1965-1970	1.221	2.836	2.69	1.23
1970-1975	1.4212	3.44	3.25	4.18
1975-1980	1.47	3.58	3.37	4.18
1980-1983	1.58	3.6	3.28	3.6
1983-1991	1.63	3.65	3.36	3.6
1991-1993	1.62	3.695	3.388	3.6
1993-1995	1.78	4.86	4.031	13.05
1995-2000	1.815	4.97	4.14	13.4
2000-2005	1.822	5.07	4.22	14

Exhibit 8

Excerpts from Update Report on Diversion and Withdrawal of Groundwater from Northern Mississippi into the State of Tennessee Addendum #1 (Expert Report of David Wiley)

(July 31, 2017)

UPDATE REPORT ON DIVERSION AND WITHDRAWAL OF GROUNDWATER FROM NORTHERN MISSISSIPPI INTO THE STATE OF TENNESSEE ADDENDUM # 1

Prepared For:

Jim Hood, Attorney General of the State of Mississippi

July 31, 2017

Prepared By:

LEGGETTE, BRASHEARS & GRAHAM, INC.
Professional Groundwater and Environmental Engineering Consultants
10014 North Dale Mabry Highway, Suite 205
Tampa, FL 33618

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INTRODUCTION

This report was prepared by David, A. Wiley, Professional Geologist and Sr. Vice President of Leggette, Brashears & Graham, Inc. (LBG) at the request of the Attorney General of the State of Mississippi. It amends the report dated June 30, 2017 that updated and confirmed previous work performed for the Attorney General to determine the effect of Memphis Light, Gas & Water's (MLGW's) consistent, significant expansion of the commercial water well pumping operations between 1965 and our previous report dated April 14, 2014 on Mississippi's natural groundwater flow and storage. This report addendum focuses solely on the review of and critique of the June 27, 2017 Expert Report on the Interstate Nature of the Memphis/Sparta Sand Aquifer prepared by Gradient Corporation Gradient) for City of Memphis, Tennessee and Memphis Light, Gas & Water Division (MLGW). Our review is presented in a concise manner addressing each section of the Gradient report in order as appropriate.

Exhibit 9

Excerpts from Deposition of David Wiley

(September 26, 2017)

In the Matter Of:

STATE OF MISSISSIPPI vs

STATE OF TENNESSEE

OF TENNESSEE,

DAVID WILEY

September 26, 2017

BEFORE THE SUPREME COURT
OF THE UNITED STATES

STATE OF MISSISSIPPI,
Plaintiff,
Vs. NO.
STATE OF TENNESSEE,
CITY OF MEMPHIS and
MEMPHIS LIGHT, GAS & WATER,
Defendants.

DEPOSITION
OF
DAVID WILEY
September 26th, 2017

ALPHA REPORTING CORPORATION
236 Adams Avenue
Memphis, TN 38103
901-523-8974
www.alphareporting.com

The deposition of DAVID WILEY is taken on this, the 26th day of September, 2017, on behalf of the Defendants City of Memphis and MLGW Division, pursuant to notice and consent of counsel, beginning at approximately 8:31 a.m., in the offices of Baker, Donelson, Bearman, Caldwell & Berkowitz, 165 Madison Avenue, Memphis, Tennessee

This deposition is taken pursuant to the terms and provisions of the Federal Rules of Civil Procedure.

All forms and formalities are waived. Objections are reserved, except as to form of the question, to be disposed of at or before the hearing.

The signature of the witness is not waived.

A P P E A R A N C E S

FOR THE PLAINTIFF:

DANIEL COKER HORTON & BELL
C. MICHAEL ELLINGBURG, ESQ.
4400 Old Canton Road
Suite 400
Jackson, Mississippi 38655
(662) 232-8979
Mellingburg@danielcoker.com

FOR THE DEFENDANTS CITY OF

MEMPHIS and MLGW:

BAKER DONELSON BEARMAN CALDWELL &
BERKOWITZ, PC
LEO BEARMAN, ESQ.
DAVID BEARMAN, ESQ.
MS. CHRISTINE ROBERTS
165 Madison Avenue
Suite 2000
Memphis, Tennessee 38103
(901) 577-2214

FOR THE STATE OF TENNESSEE

KELLOGG, HANSEN, TODD, FIGEL &
FREDERICK
JOSHUA BRANSON, ESQ.
T. DIETRICH HILL, ESQ
1615 M. Street NW
Washington, DC, 20036
jbranson@kellogghansen.com

STATE OF TENNESSEE ATTORNEY GENERAL
BARRY TURNER, ESQ.
425 5th Avenue North
2nd Floor
Nashville, Tennessee 37202
(615) 532-2541

COURT REPORTING FIRM:

ALPHA REPORTING CORPORATION
BRIAN DOMINSKI, LCR #114
236 Adams Avenue
Memphis, Tennessee 38103
(901) 523-8974
www.alphareporting.com

ALSO PRESENT: MS. CHARLOTTE KNIGHT

Q. (BY MR. DAVID BEARMAN) The final document that I've handed you is your CV that was included with your expert disclosure from the State of Mississippi. Have you looked at that document?

A. Yes. It has been a while, but, yes, I've looked at it.

Q. Is this your current CV?

A. Yes.

MR. DAVID BEARMAN: Let's mark that Exhibit 3.

(The above-mentioned document was marked as Exhibit 3.)

Q. (BY MR. DAVID BEARMAN) Mr. Wiley in your report you use the term "Sparta Sand" and you also use the term "Sparta/Memphis Sand." I want to make sure that we're talking about the same aquifer. Is that right?

A. Yes, we are.

Q. I think on one of your diagrams it is labeled "Middle Claiborne Aquifer." That's the same aquifer also, right?

A. Yes, the Memphis Sparta Sand is in the Middle Claiborne Aquifer.

Q. And you've read the report by David Langseth, and he used the term "Memphis Sparta Sand Aquifer" or "MSSA." Do you remember that?

A. Yes.

Q. That is the same aquifer?

A. Yes.

Q. I think Dr. Spruill wrote a report. Have you read that?

A. Yes.

Q. He used the term "Sparta Memphis Sand." That's the same aquifer also, right?

A. Yes.

Q. During the deposition today, if we talk about the aquifer, can we assume that we're talking about the Memphis Sand Sparta Aquifer or the Sparta Sand, the Sparta Memphis Sand, unless we specify otherwise?

A. Yes, I can agree to that because we're primarily talking about a couple of aquifers here in the area.

Q. One of the other aquifers, for example, would be the Fort Pillow?

A. Fort Pillow.

Q. So for purposes of the deposition we'll assume that the term "aquifer" is the Memphis Sand Sparta Aquifer. Okay?

A. Okay. If I have a question about that to clarify, I'll ask.

Q. Okay. We agree, I think, that the extent of the aquifer is pretty well agreed upon by scientists, don't we?

A. Yes.

Q. And the aquifer is I'll use the term "bell shaped," that starts up around Illinois and coming down east includes a little part of Kentucky, Tennessee and Mississippi. Is that right?

A. The Mississippi Embayment is bell -shaped. The aquifer may not match that perfectly, but it extends in those states.

Q. Let me hand you a diagram here. This is Figure 17 from USGS report authored by Clark and Hart. Is the area that is colored in, I guess you would say here, a different shade of blue and green and a little orange, that is the aquifer, correct?

A. This map is a potentiometric surface simulated water-level map of the Middle

Claiborne Aquifer, as it states at the bottom, and it shows the boundaries of the Middle Claiborne Aquifer in different colors.

Q. There is a black line that kind of outlines the extent of the aquifer, correct?

A. Yes.

Q. Okay. That is not really disputed?

A. No.

MR. DAVID BEARMAN: Let's make that Exhibit 4.

(The above-mentioned document was marked as Exhibit 4.)

Q. (BY MR. DAVID BEARMAN) You agree that the Memphis Sparta Aquifer is a primary source of fresh water for Northwest Mississippi and Shelby County, right?

A. Yes.

Q. And you agree that the Memphis Sparta Aquifer lies beneath several states, right?

A. Yes.

Q. It lies beneath Tennessee?

A. Yes, it does.

Q. Portions lie beneath Mississippi?

A. Yes.

Q. Portions lie beneath Arkansas?
A. Yes.
Q. Portions lie beneath Kentucky?
A. Yes.
Q. Among other, right?
A. The other -- I believe there are several others.
Q. Missouri?
A. Missouri.
Q. I can't remember if I said Louisiana.
MR. ELLINGBURG: Alabama and Louisiana.
A. Louisiana.
Q. (BY MR. DAVID BEARMAN) The Memphis Sparta Aquifer is recharged from outcrop areas in both Tennessee and Mississippi, right?
A. That's right.
Q. And the outcrop area is where the aquifer comes close to the surface or comes to the surface with no confining layer above it, right?
A. That's right.
Q. The outcrop area is sometimes called the recharge area?
A. In this case it is called the recharge

area.
Q. And the outcrop area is unconfined, correct?
A. That's correct.
Q. Because there is no confining layer above it?
A. That's correct.
Q. And in the outcrop area precipitation falling infiltrates directly into the aquifer without having to go through a confining layer, correct?
MR. ELLINGBURG: Objection to form.
Q. (BY MR. DAVID BEARMAN) Do you understand my question?
A. Yes.
Q. Is that correct?
A. Yes, it does.
Q. You agree that before pumping began in the Memphis Sparta Aquifer, that there was some water that recharged into the aquifer in Mississippi and naturally flowed into that part of the aquifer beneath Tennessee, right?
A. There is -- yes, there is a small -- was a small part of the recharge that came in

the outcrop in Mississippi that flowed into Tennessee.

Q. And that natural movement was without any influence from pumping, right?

A. That's right.

Q. When we talk about prepumping, what years do you understand that to be?

A. The late 1800's. 1885 I know was one of the years that was identified -- that people started evaluating from.

Q. The period of time referred to as prepumping is also sometimes referred to as predevelopment, right?

A. Yes. It is. By the way, I have acid reflux, and in the mornings my voice stays hoarse for awhile until it clears up. Hopefully you can understand me. It is always horse in the morning. I have to clear my throat a lot.

Q. If I do not understand you, I'll ask you to clarify.

You agree that the Memphis Sparta Aquifer is one of the most productive aquifers in both Shelby County, Tennessee, and DeSoto County, Mississippi, right?

A. Yes.
Q. You said that in your report, correct?
A. Yes.
Q. You agree that pumping groundwater from the Memphis Sparta Aquifer from wells in one state can impact the groundwater in that same aquifer in another state?
A. I agree with that, that's right.
Q. In fact, you say in your report that groundwater pumped from the Memphis Sparta Aquifer in Tennessee impacts that same aquifer in Mississippi, right?
A. That's right.
Q. And you also say in your report that pumping in DeSoto County impacts the groundwater that is available to Shelby County in that same aquifer, right?
A. I believe I said that pumping from DeSoto County has reduced the amount that is diverted into Shelby County due to MLG&W pumpage.
Q. So pumping from DeSoto County from the Memphis Sparta Aquifer is decreasing the amount of water in the aquifer flowing into Shelby

from MLG&W wells and to evaluate predevelopment groundwater flow conditions in the confined aquifer. I'm referring to the Memphis Sparta Sand Aquifer.

Q.   Were you asked to address anything else in your initial report, Exhibit 1?

A.   Those were the key things we were to address. In addressing those, we updated our groundwater flow model to see what the drawdown was and the potentiometric surface results were from pumping, but the goal was to address those two things.

Q.   Generally speaking, is that the same focus of your 2014 expert report?

A.   Yes.

Q.   And is it the same focus as the reports you authored back in 2006 and 2007?

A.   Pretty much so. That's ten years ago. I think it is about the same thing.

Q.   Are you going to opine on the issue identified by Special Master Siler in his memorandum of decision?

A.   I have not reviewed that.

Q.   You have not read the opinion?

A. No.

Q. You have not been asked, then, to opine on whether the Memphis Sparta Aquifer is an interstate water resource?

A. I don't know what an interstate aquifer resource is. I've seen no definition of that anywhere in the literature. I can't talk to that.

Q. So you are not going to offer an opinion one way or the other?

MR. ELLINGBURG: On that specific question.

Q. (BY MR. DAVID BEARMAN) Are you going to offer an opinion as to whether the Memphis Sparta Aquifer is an interstate resource?

A. No.

Q. Are you going to offer an opinion as to whether the groundwater in the Memphis Sparta Aquifer is an interstate resource?

A. No.

Q. Is there anything in your initial report or rebuttal report, Exhibits 1 and 2, that address or might be a factor in determining whether the Memphis Sparta Aquifer or the groundwater in it is an interstate or intrastate resource?

A. No.

MR. ELLINGBURG: I'm going to object to the form. He was pretty quick on that. The reality -- he is not going to address the legal question whether it is an interstate.

MR. DAVID BEARMAN: All right. You --

MR. ELLINGBURG: But he is going to address all the hydrological issues. So I don't mean there to be any misreading or misrepresentation or misunderstanding of that question.

MR. DAVID BEARMAN: I'll object to your objection.

Q. (BY MR. DAVID BEARMAN) Do you know if the test to determine whether an aquifer is interstate or intrastate is an objective test?

A. I know of no such test.

Q. Have you heard the term "transboundary aquifer"?

A. I've heard that term.

Q. What is a transboundary aquifer?

A. An aquifer that exists on two sides of

Q. So when we -- back in 2007 the model was updated with pumping through 2006, correct?

A. Through 2006 is correct.

Q. How did you update the model between 2007 up to the time you wrote your report in April of 2014?

A. We updated the model by adding the pumpage amounts from the MLG&W well fields from 2007 through -- I forgot the date. I believe it was through 2012. And we also updated DeSoto County pumping in the model through that same time period.

Q. When you say "updated," does that mean that you just added the pumping that occurred from 2007 to 2012 or did you go back and tweak any of the other pumping?

A. No. We just added additional pumping.

Q. So there was no change, then, in your DeSoto County or MLG&W pumping up through 2006?

A. I'm sorry. Could you ask that again.

Q. In the original -- let me start again. Sorry. In 2007, when you were deposed, the model, your model, was updated through 2006, correct?

A. Yes.
Q. And then you updated the model again in 2014?
A. Yes.
Q. When you updated it, you added the pumping from 2007 through 2012?
A. Yes.
Q. But you didn't make any changes to the pumping prior to 2007?
A. No.
Q. Between April of 2007, when you issued a report, and the writing of your expert report in June of 2017, what changes did you make to the model?
A. Pumping.
Q. And was that updating again?
A. Just adding pumping in.
Q. So the only changes you would have made would have been to add 2013, 2014, 2015 and 2016, correct?
A. From the 2014 report to the 2017 report, yes, we added those four years.
Q. You didn't go back and make any other changes to the previous years?

A. No, we didn't.
Q. All right. When you said that you got the pumping records from MDEQ, are those documents that you requested?
A. We requested pumping through the attorneys for DeSoto County.
Q. Do you remember what those reports were called?
A. No.
Q. Was it a single report that included all of the pumping from 1965 through 2016, or were they annual reports?
A. It was information based on the time period we requested.
Q. Was it in the form of a spreadsheet?
A. I believe they were on spreadsheets.
Q. Did you do anything to verify the pumping values that were provided by MDEQ?
A. I don't know what you mean by "verify."
Q. If they gave you a list of volume pumped from fifteen wells, is that just what you put into your model, or did you go back and look to see if those numbers were accurate, if they were screened in the right aquifer, that kind of

Q. This is the one we received. You are saying you have a revised table that should show from 1965 to 2016?
A. Yes.
MR. DAVID BEARMAN: All right. I'm going to request that.
MR. ELLINGBURG: Sure.
Q. (BY MR. DAVID BEARMAN) So as to 1965 through 2006, which is the table we received, that's where you got the values for pumping on MLG&W Table 2?
A. Yes.
Q. Take a look, if you will, at Table 1 for 1985. Look at the total pumped. What do you show there on Table 1?
A. It looks like 148 million gallons a day.
Q. For 1985?
A. Yes.
MR. ELLINGBURG: Are we looking at the same thing?
THE WITNESS: Total.
MR. ELLINGBURG: That's 1995. Do you have your glasses, Dave?

THE WITNESS: Oh, I can't see it. That is why I've got this paper out.
A. I've written 131 --
Q. (BY MR. DAVID BEARMAN) 131,655,274?
A. That looks right.
Q. 131.655 million gallons?
A. That's right.
Q. Look at 1985 on Table 2.
A. Yes.
Q. Do you agree that it says 131.9 MGD?
A. Yes.
Q. What is the difference and why is there a difference?
A. I don't know.
Q. Look at 2006 on Table 1.
A. 156.233.
Q. So that is 156.233 million gallons per day, right?
A. Yes.
Q. And on Table 2 it shows 149.8 MGD, correct?
A. Yes.
Q. So there is not agreement between Table 1 and Table 2?

MR. ELLINGBURG: In regard to those two or more?

A. Those two numbers are different.

Q. (BY MR. DAVID BEARMAN) You don't have any explanation as to why they are different?

A. Not as I sit here today.

Q. Don't you think that is an important part of your report to get this accurate, the amount of pumping accurate?

A. Yes.

Q. So Table 2, then, is not accurate?

A. I would have to go back and look to see which table is accurate and which one is not accurate.

Q. Either Table 1 or Table 2 is not accurate?

A. It appears that way.

Q. Take a look at page 6 of your report.

A. Okay.

Q. In the first full paragraph, about six lines down, it says "The Sparta Sand in Tennessee has been continuously pumped at a higher rate than it can be naturally recharged based on its geology." Do you see that?

A. Yes.
Q. Is that your opinion?
A. Yes.
Q. The Sparta Sand in Tennessee would be the Memphis Sparta Sand that we've been talking about, right?
A. Yes.
Q. Same aquifer?
A. That's correct.
Q. At the top of the next page you say "If pumping exceeds the rate of recharge, the depth to which a pump is lowered will have to be increased in the area drained by the cone of depression will continue to grow (sic)" Did I read that right?
A. I think you left something out. You might want to read it again.
Q. Why don't you read that sentence.
A. Okay: If pumping exceeds the rate of recharge, the depth to which a pump is lowered will have to be increased, and the area drained by the cone of depression will continue to grow."
Q. So as I understand what you are saying

is that if the aquifer is -- the pumping rate from the aquifer is greater than the natural recharge, the cone of depression will continue to grow?

A. Yes.

Q. Now, in your report you have potentiometric surface maps of the Memphis Sparta in what I'll call the Tri-State area, correct?

A. In the Shelby County/DeSoto County area, yes.

Q. And you know that the maps, the potentiometric maps, from 2013 to 2016 show that the cone of depression is actually getting smaller, correct?

A. Slightly smaller, yes.

Q. Take a look at Page 9.

A. Okay.

Q. In the first paragraph "The Sparta Sand is a distinct geological formation and primary source of groundwater in Northwest Mississippi and Shelby County, Tennessee." Do you see that?

A. I see that.

Q. Tell me what a distinct geological

Northwest Mississippi influences the shape of potentiometric surface contours and direction of groundwater flow, which is westward." Did I read that correct?
A. Yes.
Q. Is the structural geology in Northwest Mississippi the dip?
A. That's part of it.
Q. What is the other part?
A. The formations above.
Q. That would be the Jackson confining layer?
A. The Jackson confining layer, the Mississippi alluvium.
Q. The next sentence, "Figure 9 shows the predevelopment potentiometric surface under natural conditions generated from groundwater modeling and shows this generally east-to-west-southwest groundwater directional movement perpendicular to the contours in Northwest Mississippi consistent with information presented by Arthur and Taylor of the USGS."
A. Yes.
Q. Now, Figure 9 of your report is not

based on groundwater modeling, is it?
A. No.
Q. So your report is wrong on that point?
MR. ELLINGBURG: Objection to the form.
Go ahead.
A. This map was presented in the Brahana report to represent his predevelopment potentiometric surface map.
Q. (BY MR. DAVID BEARMAN) But in your report you say that Figure 9 shows the predevelopment potentiometric surface generated from groundwater modeling.
A. This map was prepared by Criner and Parks as a predevelopment map and used by Brahana with his groundwater model.
Q. It is your testimony that this map was produced by Brahana and Broshears from their model?
MR. ELLINGBURG: Objection to form. That's not what it says.
A. I'm sorry. Could you --
Q. (BY MR. DAVID BEARMAN) I'm trying to find out --
MR. ELLINGBURG: Could you read back

his answer.

(The prior answer was read by Mr. Dominski.)

Q. (BY MR. DAVID BEARMAN) Mr. Wiley, if it was prepared by Criner and Parks, then it couldn't have been a result of the Brahana map, right, I mean the Brahana model?

MR. ELLINGBURG: Objection to form.

A. As I said, Brahana utilizes a predevelopment map in his modeling report. When he calibrated his model, he compared it to this map.

Q. (BY MR. DAVID BEARMAN) I'm just trying to make sure we're on the same page. The contours on your Figure 9 were not generated by a groundwater model?

A. No.

Q. No, they were not?

A. No, they were not.

Q. In the last sentence of that paragraph on Page 11, you say "Only a small area in northeastern DeSoto County has groundwater flow entering Tennessee under predevelopment conditions as shown in green in Figure 9."

vertical exaggeration, that cube would be one foot wide and 600 feet deep, right?
A. That's what that would mean, yeah.
Q. So for every one foot or one mile laterally, you would go 600 feet or 600 miles vertically?
A. For 600-to-1 vertical exaggeration, that sounds right.
Q. On this figure toward the right side of the page it says T E N N, period, C O, period and M I S S, period, C O, period. Can you tell me what those terms are?
A. The "C O" evidently shouldn't be there. It is just the Tennessee and Mississippi state line.
Q. All right. So that's just an error there where it says "C O"?
A. Correct.
Q. Will you turn to Figure 6. This figure is entitled "Hydrogeologic Cross-Section Illustrating Recharge at Outcrop and Groundwater Flow." Is that correct?
A. I see that.
Q. Did Leggette-Broshears prepare this

280-foot contour that is not included in your figure. Is there a reason that was left out?

A. No.

Q. Isn't that important if the 280-foot contour continued further than where you have indicated here in East Shelby County?

A. It probably should have been on there, but I don't believe it would have affected any of the results. It probably should have been on there to be consistent.

Q. Your Figures 14 through 17 are drawdown contour maps, correct?

A. Yes.

Q. And the only pumping that is included on these drawdown maps or that was used to formulate these drawdown maps was MLG&W pumping and DeSoto County pumping, correct?

A. That's correct.

Q. On each of these figures, 14 through 17, there is a note at the bottom right that says "Source: Tennessee USGS." That is just an error?

A. It is carried over from whatever base map was used for something else.

Q. So that's just wrong?
A. Yes.
Q. Now, your potentiometric maps, 13, 14, 15 and 16, are based only on pumping in DeSoto County and MLG&W pumps, right
A. What figure numbers did you just say?
Q. 18, 19, 20 and 21.
A. Yes. Those are potentiometric surface maps with MLG&W and DeSoto County pumpage.
Q. So these potentiometric maps do not -- you can't say whether these potentiometric maps accurately represent conditions in the aquifer because you didn't include any other pumping in Shelby County, right?
A. That's right.
Q. Now, Figure 22 in your report, I think you described -- you say that Figure 22 is a graphic version of Table 3. Is that right?
A. Yes.
Q. Now, when we looked at Table 3, I asked you if it considered Marshall County, and you said no. Figure 22, the title of that figure says "Volume of Groundwater Contributed to Shelby County, Tennessee, from DeSoto and

Marshall Counties, Mississippi, Due to MLG&W Pumping, 1965 Through 2016." So my question is does it or does it not include Marshall County?

A. It does not include Marshall County.

Q. So this is an error in the title of Figure 22?

A. Yes.

Q. You can set that down. I'm going to ask you some questions about Exhibit 2, which is your update report on diversion and withdrawal of groundwater from Northern Mississippi into the State of Tennessee, Addendum 1, dated July 21, 2017. Is that right?

A. That's what I've got here.

Q. Okay. Does this report include all of your criticisms of Dr. Langseth's opinions?

A. Up until now, I would say yes.

Q. What do you mean "up until now"?

A. I don't know if I have any more or will have any more.

Q. The reason we're here today is so that we get to find out all the criticisms you have. So as of the time we're sitting here today, this

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STATE OF TENNESSEE

COUNTY OF SHELBY

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