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.)

July 31, 2017

Signed: ______________

Brian Waldron, Ph.D.

SECTION 1. Qualifications and Background

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1. I am currently an Associate Professor in the Department of Civil Engineering at the University of Memphis. My research focuses on groundwater, including numerical modeling of groundwater flow. I am also the Director of the Center for Applied Earth Science and Engineering Research at the University of Memphis, an interdisciplinary research center that combines the resources of two previous University of Memphis research centers, the Center for Partnerships in GIS and the Ground Water Institute. I previously served as interim director of the Ground Water Institute and director of the Center for Partnerships in GIS.

2. I obtained my B.A. and M.A. in Civil Engineering from the University of Memphis (formerly known as Memphis State University) and my Ph.D. in Civil Engineering from Colorado State University. I have published articles in a variety of peer-reviewed journals, including specifically about groundwater modeling and the Middle Claiborne aquifer. My full CV is attached as Appendix A to my opening report, and it includes all my publications from the last ten years. I have not testified as an expert in any proceeding in the past four years.

3. I prepared this report at the request of the State of Tennessee for use in the original Supreme Court proceeding, *Mississippi v. Tennessee et al.*, No. 143, Original (U.S.). Specifically, I have been asked to respond to the two expert reports submitted by the State of Mississippi on June 30, 2017. In doing so, I remain focused on the question that I understand is at issue at this stage of the proceedings, which is whether the Middle Claiborne aquifer and the water within it constitute an interstate water resource. My opinions are based on my training as an engineer specializing in the study of groundwater and on the sources and data identified in this report. I reserve the right to revise or amend this report as necessary based on new information that may become available.

4. I am not being compensated for my expert services in this proceeding other than my ordinary compensation for my full-time positions at the University of Memphis. My compensation does not depend in any way on my opinions or on the outcome of this proceeding. The Office of the Tennessee Attorney General has an agreement to compensate the University of Memphis for my time at the rate of $275 per hour, in addition to paying the University for reasonable expenses I incur that are related to serving as an expert.

SECTION 2. Opinions

5. The majority of both expert reports (Wiley and Spruill) is not responsive to the question of whether the Middle Claiborne is an interstate resource. Both Wiley and Spruill appear to agree that the Middle Claiborne is aerially extensive and underlies parts of Mississippi and Tennessee, as well as other states. The only portion of either expert report that bears directly on the question of interstate versus intrastate is Spruill's discussion of groundwater flow in two hypothetical aquifers.

6. Spruill's review of Waldron and Larsen's (2015) report did not have enough substantive justification to determine the reason for his criticism, making it impossible to address or refute his reasoning.

7. Similarly, Spruill states in his summary that, in his opinion, pumping by the Memphis Light, Gas & Water Division ("MLGW") "is not consistent with good groundwater management practices." (Spruill, p. 3) However, Spruill offers no explanation of what good groundwater management practices are, or how MLGW's practices fall short, in the body of his report. This lack of explanation makes it impossible to address or refute Spruill's statement. I reserve the right to respond fully should Spruill provide an explanation of the criticism noted herein, or in paragraph 6.

8. Commenting on Wiley's numerical model is not intended to imply that the model is relevant to the legal issue here, which is the interstate nature of the aquifer. In the event that such modeling becomes relevant, the right to offer a more comprehensive response is reserved.

<u>Spruill's Hypotheticals Are Inapplicable</u>

9. Spruill provides two hypothetical cases for groundwater flow: (1) interstate conditions (Figure 1, Spruill *Figure 14*) representing a regional aquifer system without a river and (2) the impact of a river that traverses across state lines resulting in intrastate flow (Figure 2, Spruill *Figure 15*). Spruill argues that the intrastate case is analogous to predevelopment conditions within the Middle Claiborne aquifer and concludes that, because of the intrastate flow patterns, the groundwater in the aquifer is an intrastate resource.

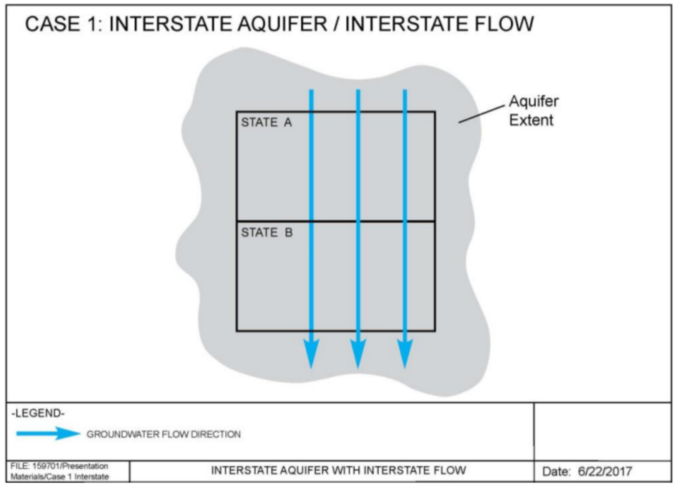


Figure 1 (Spruill *Figure 14*). Spruill's Case 1 hypothetical for interstate flow for a regional extensive aquifer without surface water impact.

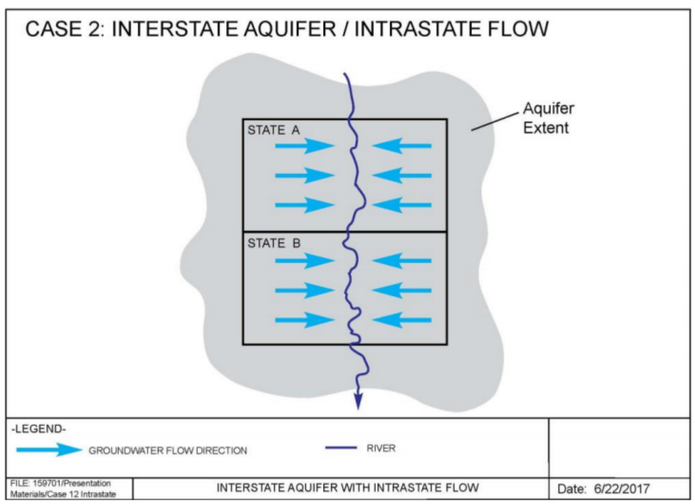


Figure 2 (Spruill *Figure 15*). Spruill's Case 2 hypothetical for intrastate flow for a regional extensive aquifer with surface water impact.

10. Spruill's Case 2 hypothetical uses a regionally extensive aquifer (implied to be analogous to the Middle Claiborne) bisected by a river (implied to be analogous to the Mississippi River) that, "[b]ecause of the geologic conditions, the natural groundwater flow within this aquifer is directed toward the river from both the east and the west" (Spruill, p. 33, sentence 3) under predevelopment conditions.

11. Leaving aside whether, in fact, the groundwater in Case 2 would be an "intrastate" resource because of its flow pattern, Case 2 is simply not descriptive of, or analogous to, the Middle Claiborne under predevelopment conditions. For groundwater to move as shown in Case 2, the river should incise the aquifer, thus creating a hydrologic barrier to flow from one side of the river to the other. Without incision, groundwater in the aquifer can flow beneath the river (even if there

is some discharge through overlying formations into the river). Without expressly saying so, Spruill and Wiley appear to imply that, in fact, the Mississippi River incises into the Middle Claiborne (see Figure 3, Wiley *Figure 6*) (Figure 2, Spruill *Figure 15*) and that the Mississippi River therefore serves as a point of natural discharge for the Middle Claiborne that could be a barrier to interstate flow.

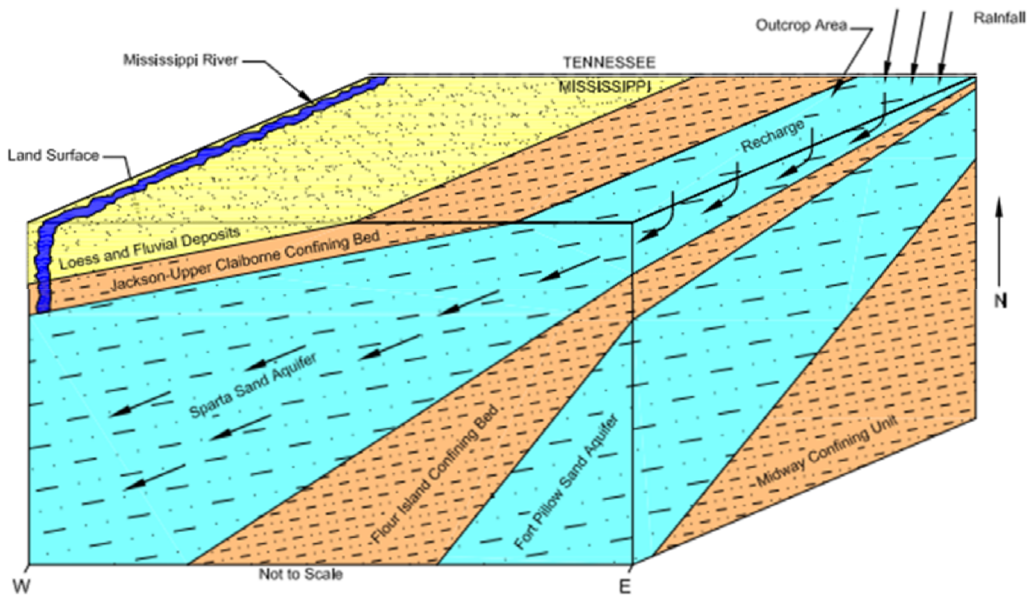


Figure 3 (Wiley *Figure 6*). Depiction of Mississippi River incision through the loess/fluvial deposits and Upper Claiborne confining unit into the Middle Claiborne.

12. As depicted in Figure 2, predevelopment conditions would result in groundwater in the Middle Claiborne beneath the State of Mississippi moving from east to west toward the Mississippi River. And following Spruill's Case 2 conceptualization, groundwater within the Middle Claiborne in Arkansas should follow the same pattern whereby groundwater would flow from west to east, discharging to the Mississippi River. Spruill states: "Groundwater in the SMS discharges upward to streams (local flow paths) and the Mississippi River (regional flow paths)." (Spruill, p. 9, para. 1, sentence 2) Under predevelopment conditions, Spruill states: "In the case of both states [Tennessee and Mississippi], that groundwater originates in, resides in, travels in, and ultimately discharges from the aquifer system within each state." (Spruill, p. 35, para. 1, sentence 5).

13. Spruill's apparent contention that the Mississippi River penetrates into the Middle Claiborne is erroneous. Saucier (1964) developed cross-sectional profiles that transected the Mississippi River based on geotechnical borings drilled by the U.S. Army Corps of Engineers. A subset of cross-sections is provided that range from 150 miles north of Shelby County, Tennessee, to 150 miles south (see Figures 6-12; scanned images of plates are provided). Figure 4 (Saucier (1964) *Figure 2*) is a geologic description. Of importance is the differentiation of the Upper, Middle, and Lower Claiborne units as Tertiary for purposes of their label on the cross-sections. As can be seen in Figures 6-11, the Mississippi never penetrates into the Tertiary except touching it once in a narrow section of the river (ref Figure 9(b)), remaining mostly within the Quaternary that overlies it (see Figure 4; the Quaternary is described by Spruill as loess and fluvial deposits; see Figure 3). Hence, the Mississippi River does not incise the Middle Claiborne.

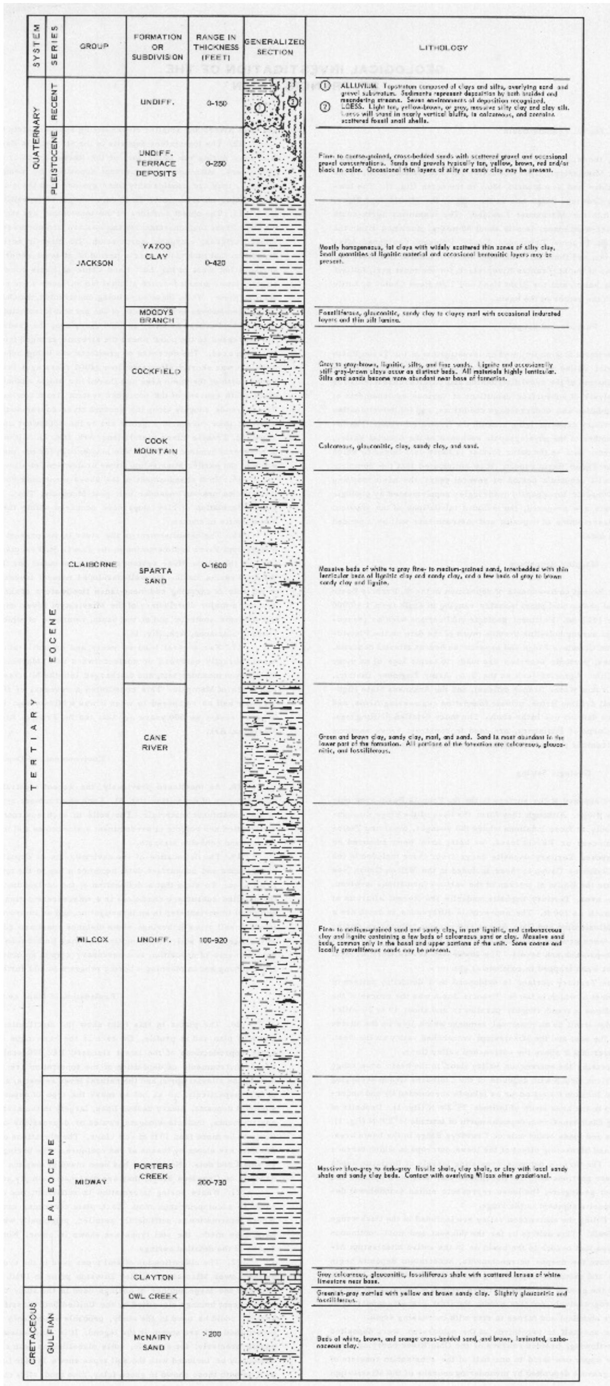


Fig. 2. Stratigraphic column, St. Francis Basin

Figure 4. Definition of geologic stratum that references two primary systems shown on Figures 6-12: Quaternary and Tertiary. The Tertiary section includes the Middle Claiborne, labeled as the Sparta Sand in *Figure 2* (Saucier, 1964).

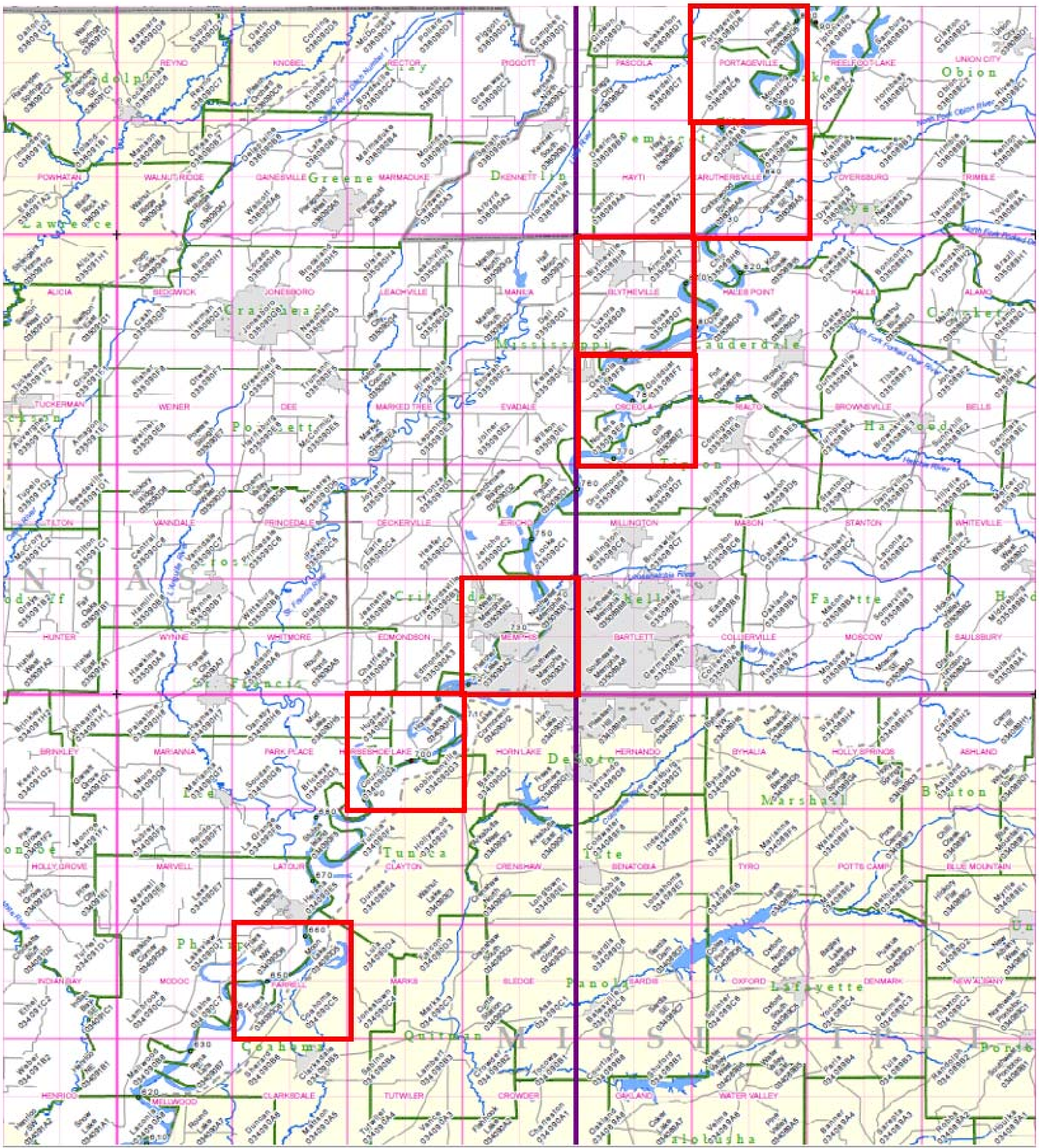


Figure 5. U.S. Army Corps of Engineers quads around the Tennessee-Mississippi-Arkansas area. Red boxes indicate quads with geologic cross-sections that show the depth of incision of the Mississippi River (see Figures 6-12). Quads between the red boxes did not have cross-sections that crossed the Mississippi River.

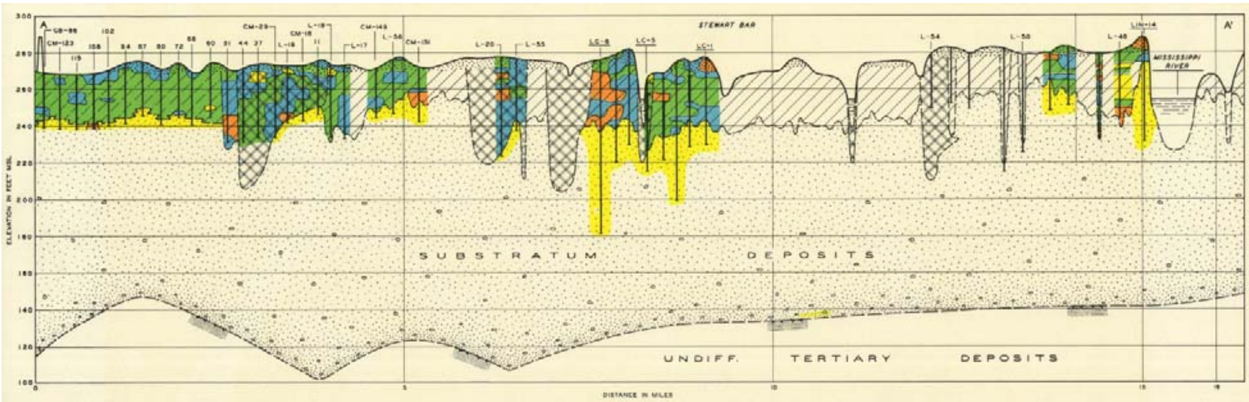


Figure 6. Cross-section within Portageville quad, showing the Mississippi River incised only within the Quaternary, approximately 80 ft above the Tertiary units that comprise the Middle Claiborne aquifer. (Saucier, 1964).

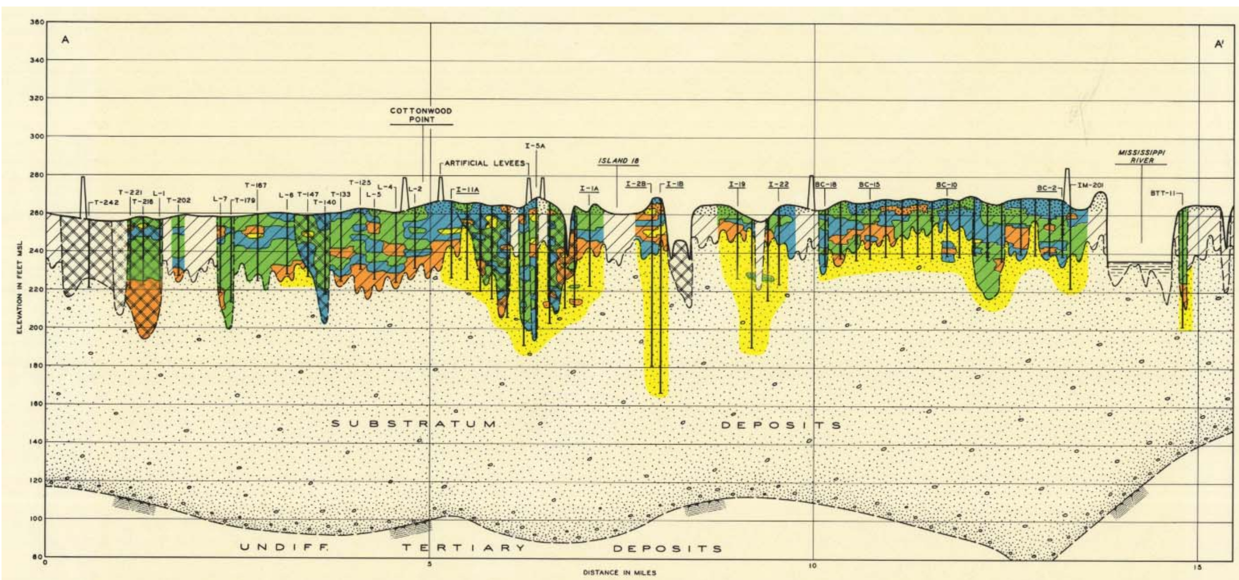


Figure 7. Cross-section within Caruthersville quad, showing the Mississippi River incised only within the Quaternary, approximately 100 ft above the Tertiary units that comprise the Middle Claiborne aquifer. (Saucier, 1964).

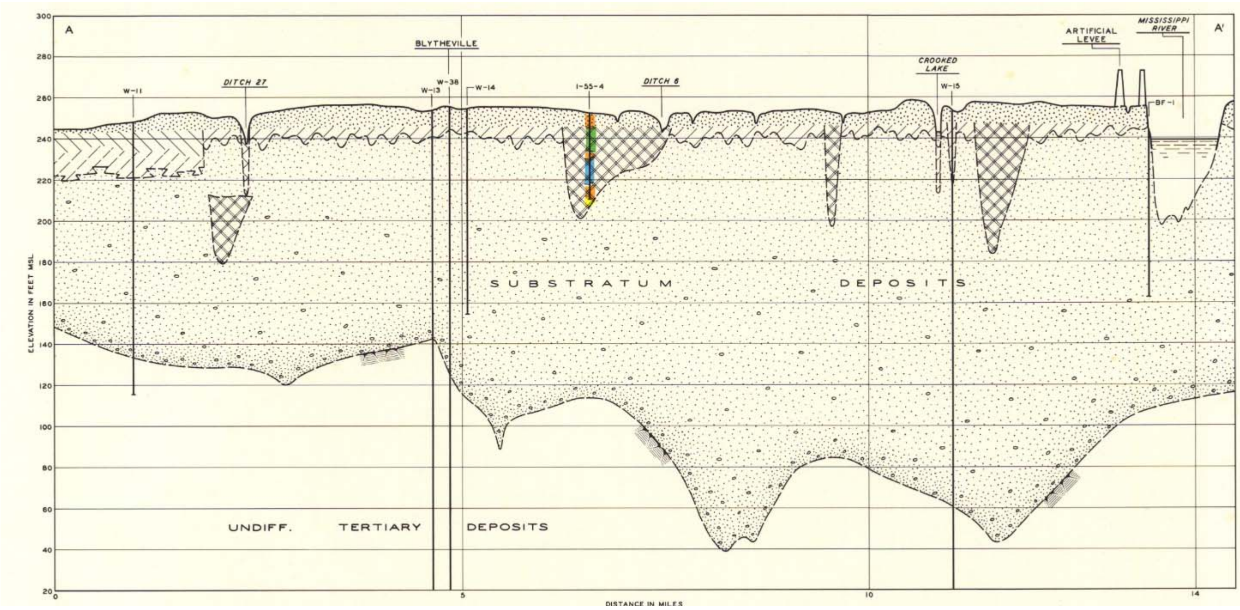
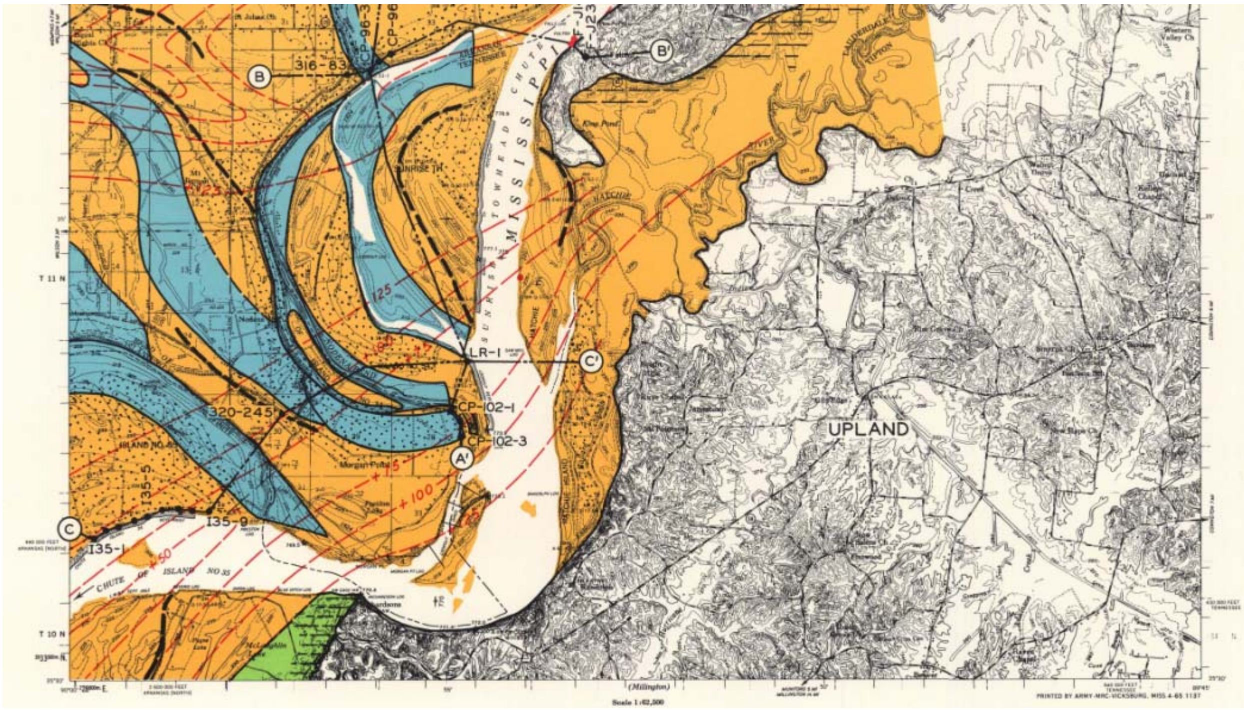


Figure 8. Cross-section within Blytheville quad, showing the Mississippi River incised only within the Quaternary, approximately 80 ft above the Tertiary units that comprise the Middle Claiborne aquifer. (Saucier, 1964).



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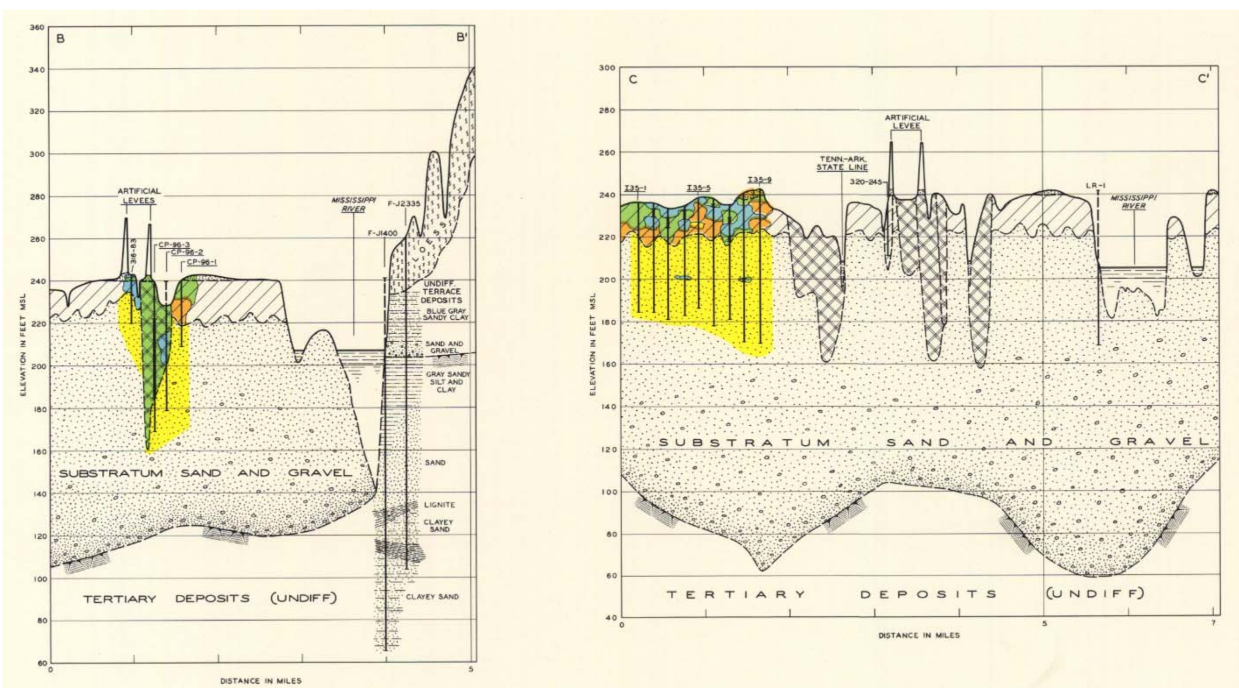


(b)

Figure 9. (a) Location of cross-sections within Osceola quad. (b) Cross-sections within Osceola quad showing incision of Mississippi River to the Tertiary at a narrow section of the river (B-B') and incision of the Mississippi River just into the Holocene and Quaternary units immediately downstream of section B-B' (C-C') (Saucier, 1964).

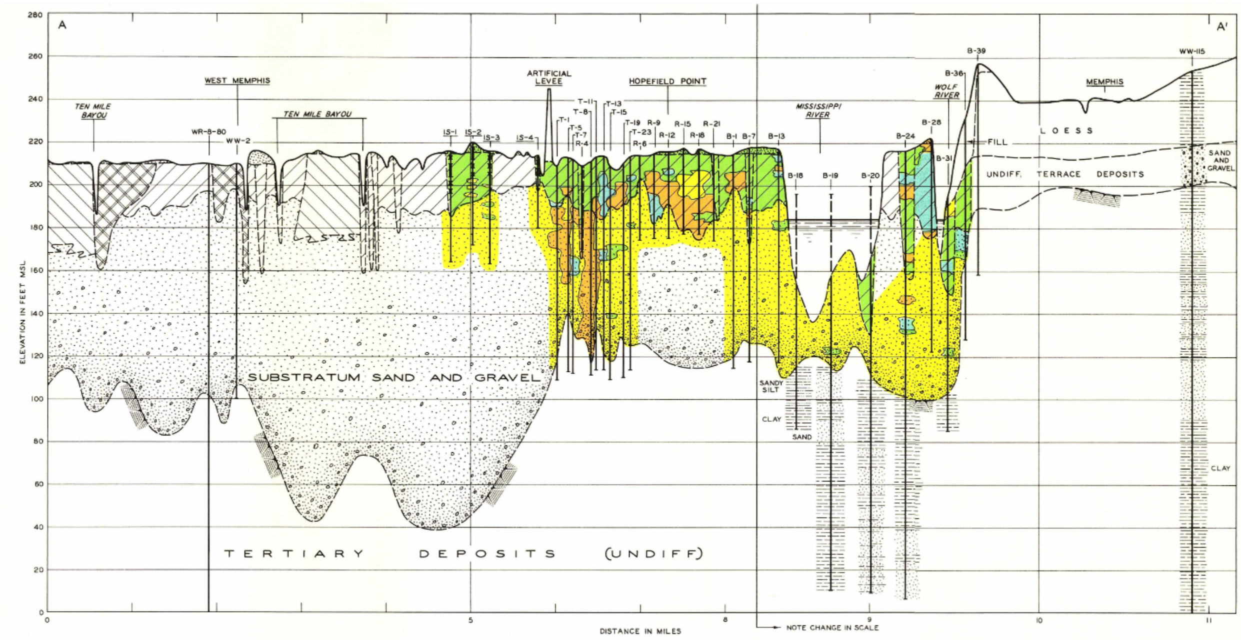


Figure 10. Cross-section within Memphis quad, showing the Mississippi River incised only within the Quaternary, approximately 20 ft above the Tertiary units that comprise the Middle Claiborne aquifer. (Saucier, 1964).

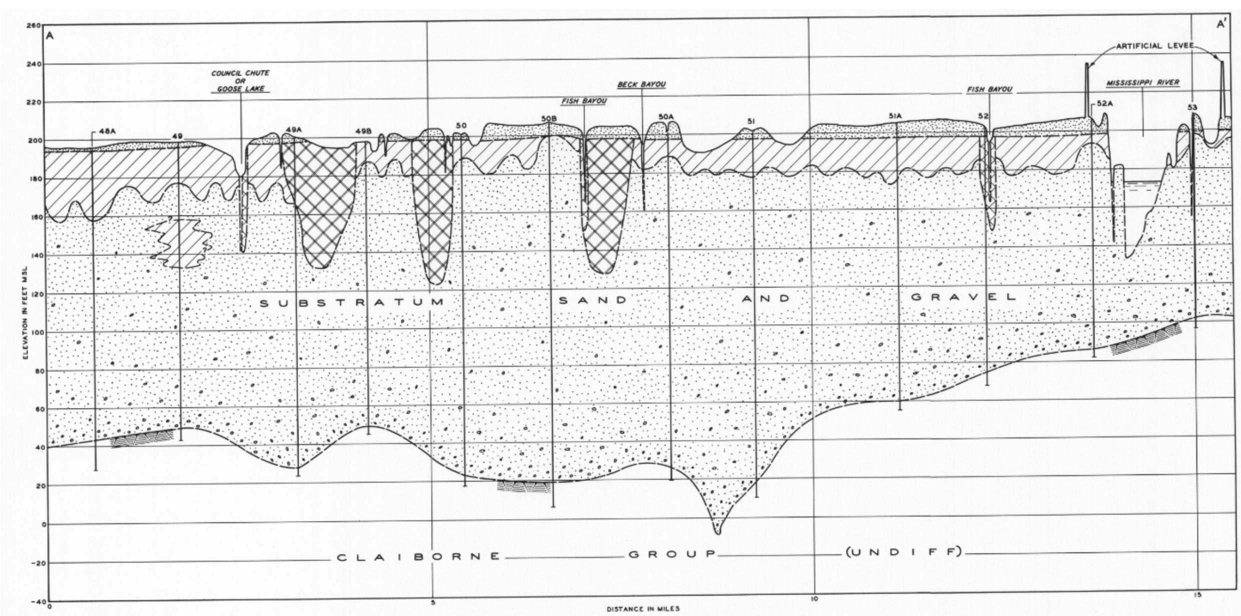


Figure 11. Cross-section within Horseshoe Lake quad, showing the Mississippi River incised only within the Quaternary, approximately 40 ft above the Tertiary units that comprise the Middle Claiborne aquifer. (Saucier, 1964).

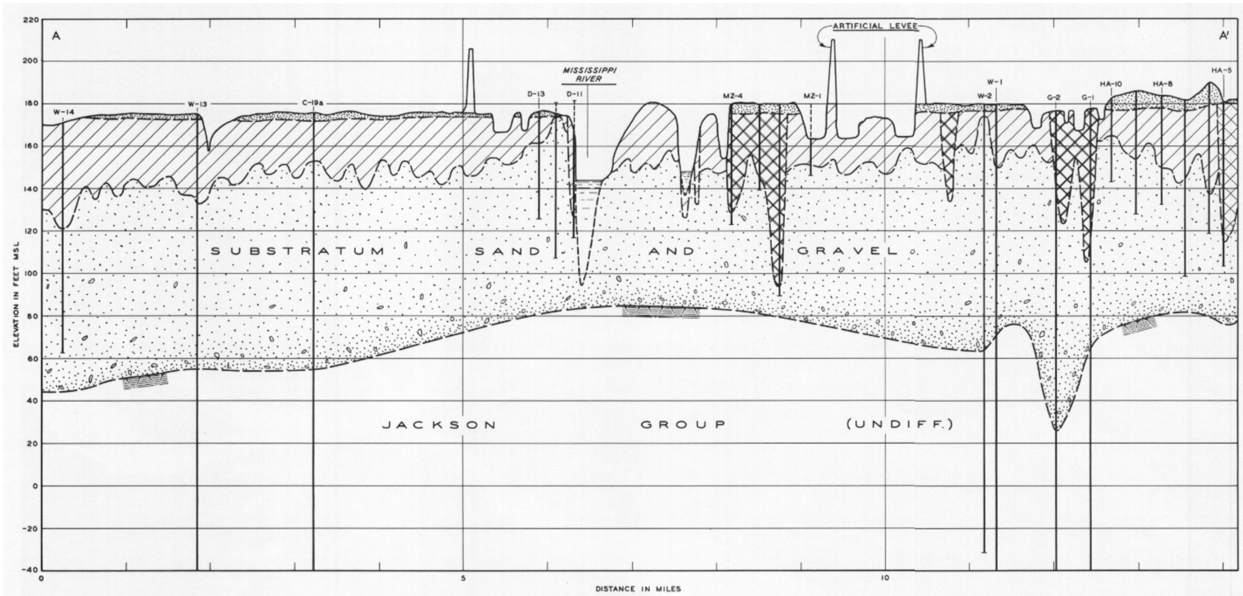


Figure 12. Cross-section within Farrell Lake quad, showing the Mississippi River incised only within the Quaternary, approximately 20 ft above the Tertiary units that comprise the Middle Claiborne aquifer. (Kolb et al., 1968).

14. The fact that the river does not incise the aquifer means that it cannot serve as a complete barrier to flow. It therefore invalidates the hypothetical flow directions of Spruill's Case 2 as an analogy for flow conditions in the Middle Claiborne. If the Mississippi River did, in fact, incise into the Middle Claiborne, that could result in groundwater during predevelopment conditions on the west side of the river (such as in Arkansas) moving eastward toward the Mississippi River. This scenario contradicts every reasonable study of predevelopment conditions, including those cited by Spruill. For example, Spruill uses Arthur and Taylor's (1998) predevelopment conditions, stating: "Figure 9 illustrates the natural pre-development potentiometric (pressure) surface for the confined Middle Claiborne Aquifer. Arrows show that the direction of natural groundwater flow in the SMS in the vicinity of Memphis was generally directed from east to west (Figure 9)." (Spruill, p. 19, para. 2, sentence 4) (Figure 13, Spruill *Figure 9*) Arthur and Taylor (1998) clearly shows groundwater moving from Mississippi into Tennessee, Arkansas, and Louisiana. These interstate flow conditions contrast with the hypothetical predevelopment flow conditions posed by Spruill's Case 2 (i.e., flow is not west to east toward the Mississippi River from Arkansas and Louisiana).

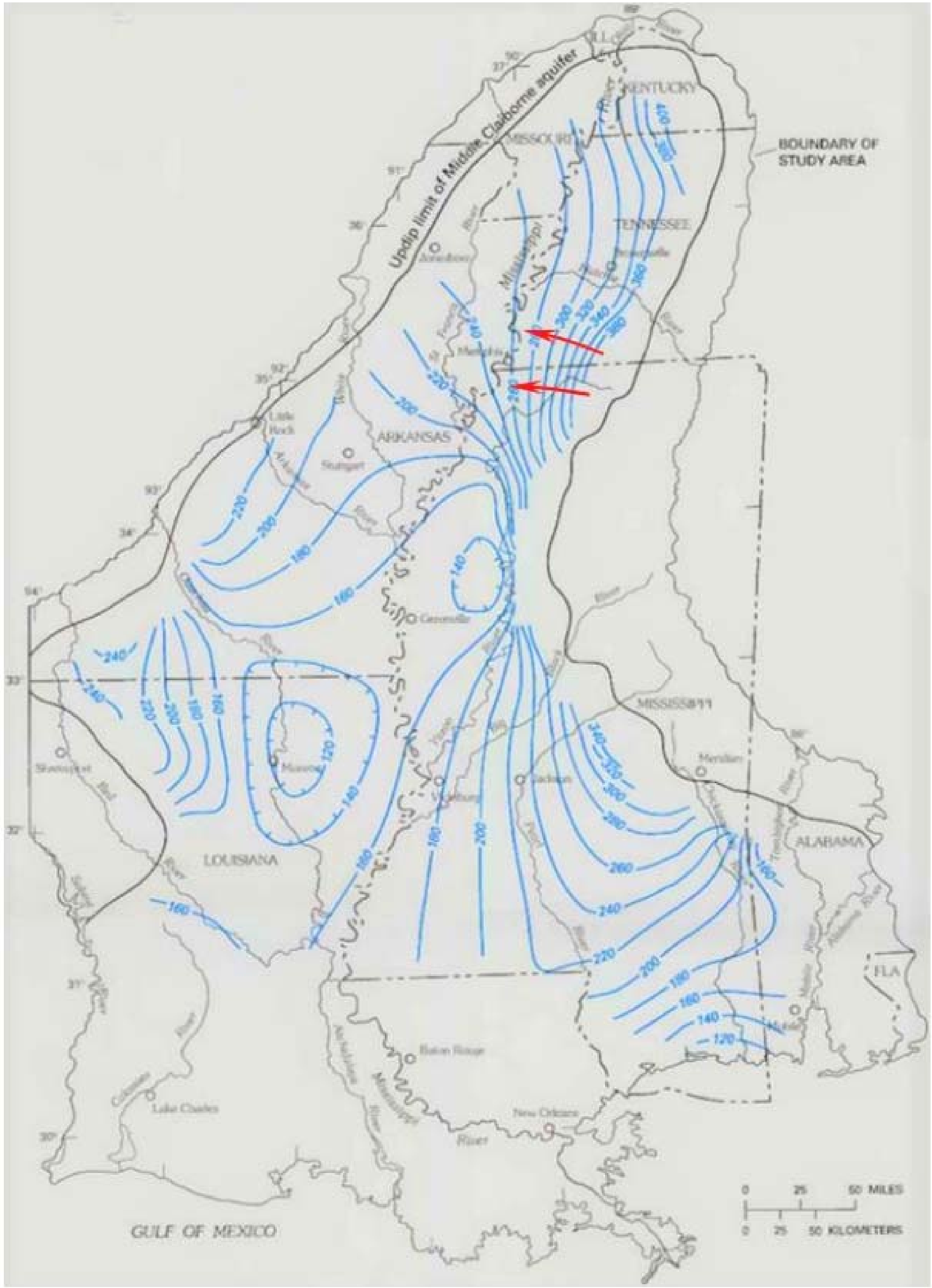


Figure 13 (Spruill *Figure 9*). Depiction of predevelopment conditions for the Middle Claiborne by Arthur and Taylor (1998) with red arrows drawn by Spruill showing movement of groundwater generally east to west, but with an obvious slant northward from Mississippi into Tennessee.

15. Moreover, the fact that groundwater is flowing from Mississippi into Tennessee, Arkansas, and Louisiana under predevelopment conditions shows why, even under Spruill's definition, the groundwater in the Middle Claiborne is not intrastate. Rather than traveling in the aquifer and discharging from the aquifer entirely within one state, the groundwater in the Middle Claiborne under Mississippi flowed out of the state.

Concerns with Wiley's Numerical Model

16. Wiley uses a groundwater flow model to justify his depiction of predevelopment groundwater flow conditions, as well as to analyze impacts of continued groundwater production from the Middle Claiborne beyond the years simulated by Brahana and Broshears (2001). Spruill relies on Wiley's numerical model for his determination of predevelopment conditions, as well.

17. Wiley states: "Pre-development simulation was conducted by turning off the well package of MODFLOW. Figure 12 included in this report, shows the model-computed potentiometric surface of the Sparta/Memphis Sand aquifer prior to 1886, which is considered to represent pre-development or pre-pumping conditions." (Wiley, p. 14, para. 2, sentences 1-2) (Figure 14, Wiley *Figure 12*). To begin with, Wiley is deriving predevelopment conditions for the Middle Claiborne by turning off pumping; hence, his predevelopment conditions are not based on published field observations. Additionally, Wiley states: "This pre-development potentiometric surface map was presented by Brahana, 2001 and has been published by others who have performed hydrologic analyses in the region." (Wiley. p. 14, para. 2, sentence 4) (see Figure 14, Wiley *Figure* 12). Wiley goes on to list Brahana and Broshears (2001) as the source of his *Figure 12*. However, Brahana and Broshears (2001) do not provide any such figure that depicts predevelopment conditions as shown in Wiley's report.

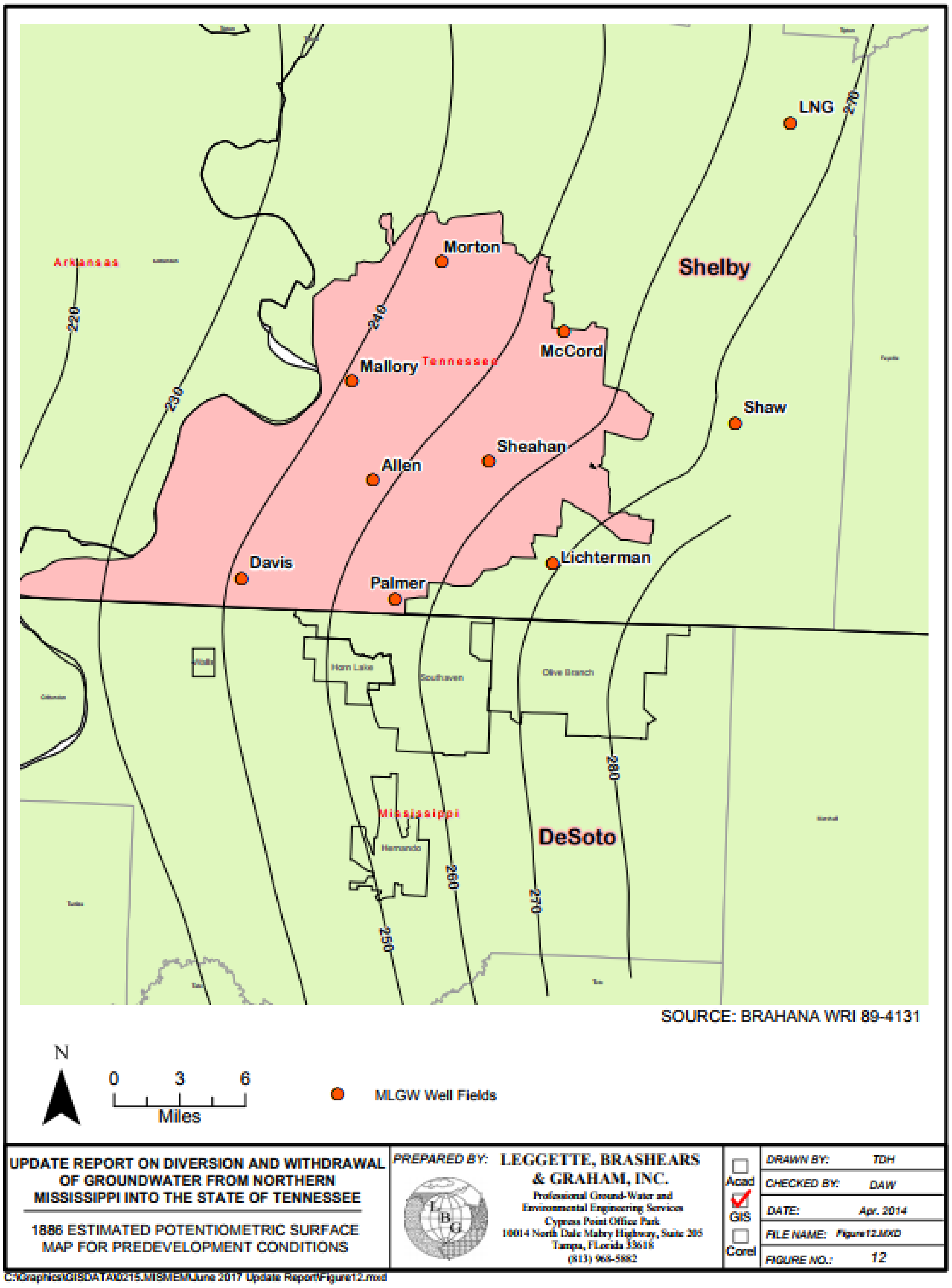
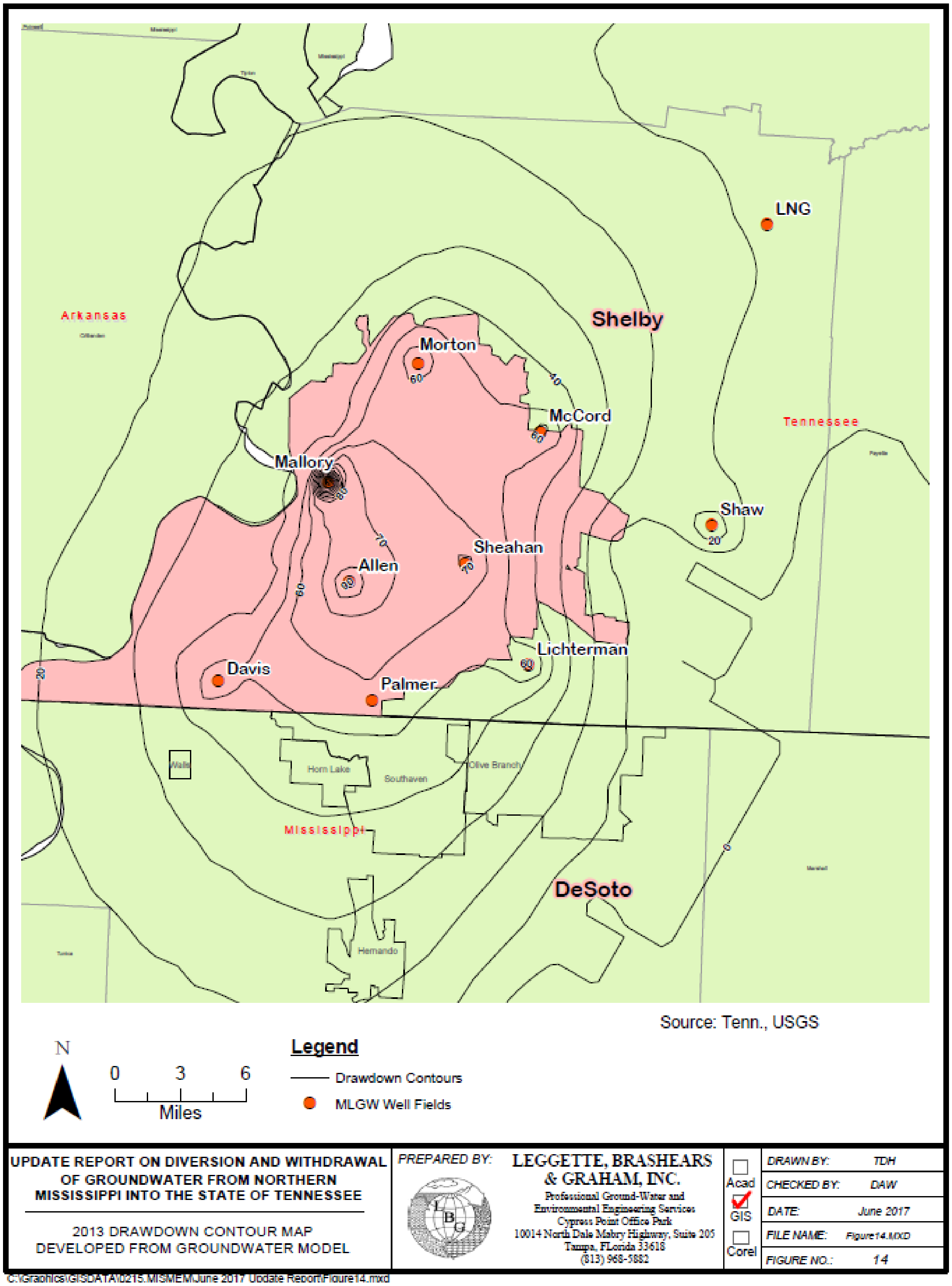


Figure 14 (Spruill *Figure 17*). Illustration of predevelopment conditions in the Middle Claiborne and sourced to Brahana and Broshears (2001).

18. Wiley's numerical groundwater model also appears not to represent observed groundwater conditions for the Middle Claiborne very well; therefore, the model's results cannot be trusted. Wiley's model of the Middle Claiborne extends pumping from predevelopment through 2016. Numerical models should be calibrated to observed values to ensure trust in model results (Reilly and Harbaugh, 2004). According to Wiley, the MLGW Mallory well field had a water level decline of 180 feet in 2013, double that of nearby well fields (Figure 15 a-b, Wiley *Figure 14* with inset). According to Wiley, the groundwater elevation at Mallory in 2013 was 60 feet mean sea level (Figure 16, Wiley *Figure 18*). The U.S. Geological Survey ("USGS") has been taking field measurements in Mallory since 1974. Observed drawdown and groundwater levels collected by the USGS between 2010 and 2017 are shown in Figure 17. The lowest groundwater level observed by the USGS in 2013 for a well in the Mallory well field (Sh:O-212; USGS 350914090010601) was about 130 feet, not 60 feet (70-foot error) as Wiley's model simulates. Similar errors persist for future year simulations. Due to the model's inability to represent observed conditions, any conclusions drawn from Wiley's model are speculative.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Legend
Drawdown Contours
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UPDATE REPORT ON DIVERSION AND WITHDRAWAL OF GROUNDWATER FROM NORTHERN MISSISSIPPI INTO THE STATE OF TENNESSEE
2013 DRAWDOWN CONTOUR MAP DEVELOPED FROM GROUNDWATER MODEL
PREPARED BY:
LEGGETTE, BRASHEARS & GRAHAM, INC.
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10014 North Dale Mabry Highway, Suite 205
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(a)

(b)

Figure 15 (Wiley *Figure 14*). (a) Drawdown of groundwater within the Middle Claiborne showing a large, erroneous depression at Mallory in 2013 and (b) zoomed in section of Shelby County showing MLGW's Mallory, Allen and Sheahan well fields, highlighting the erroneous simulation of Wiley's numerical groundwater model (values are feet of drawdown).

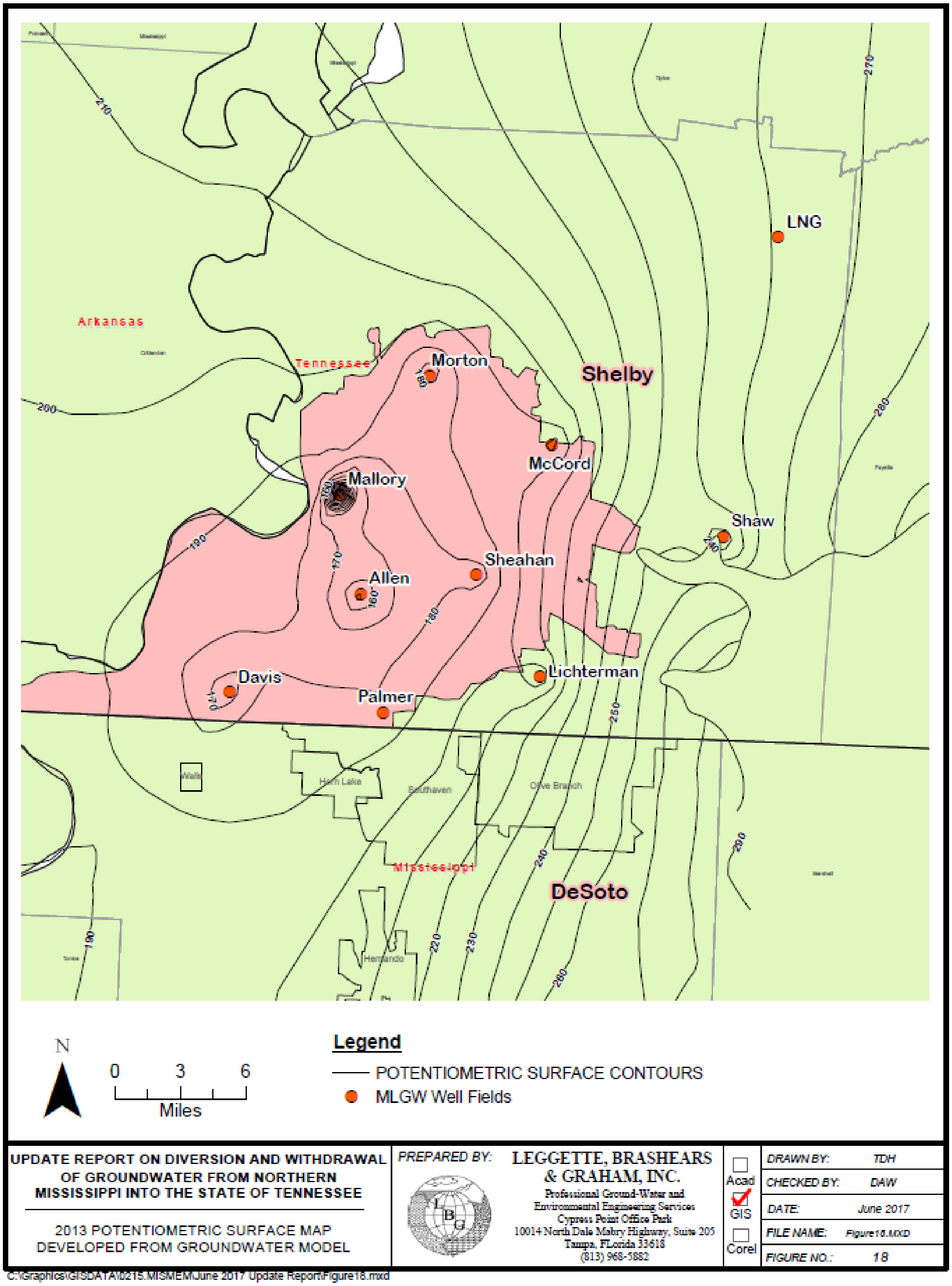

Figure 16. Numerically simulated groundwater levels of the Middle Claiborne in 2013 produced by Wiley and used for justification of intrastate condition changes by Spruill.

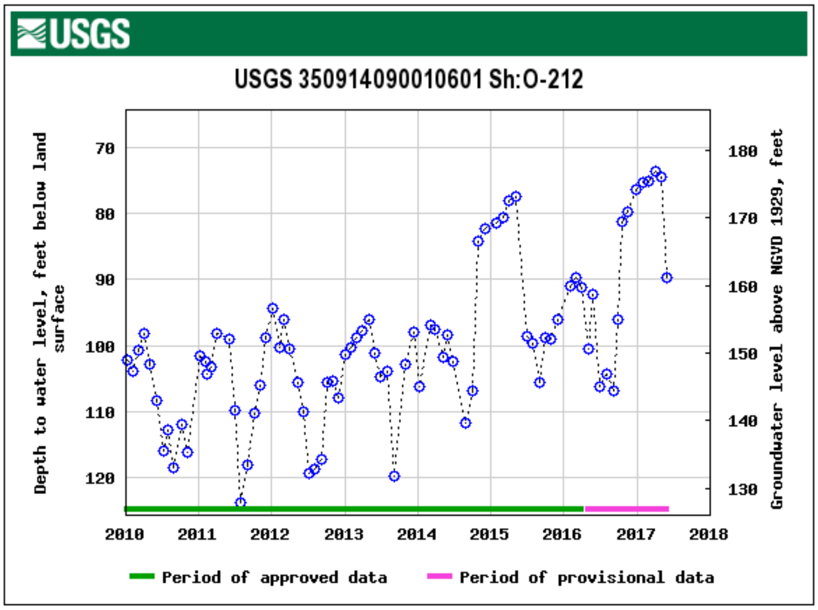

Figure 17. USGS observed groundwater level within the Mallory well field between January 2010 and July 2017.

Materials Considered

1. Arthur, J.K., and Taylor, R.E., 1998. Ground-water flow analysis of the Mississippi embayment aquifer system, south-central United States. *U.S. Geological Survey Professional Paper* 1416-I, 48 pp.
2. Brahana, J.V., and Broshears, R.E., 2001. Hydrogeology and Groundwater Flow in the Memphis and Fort Pillow Aquifers in the Memphis Area, Tennessee. *U.S. Geological Survey Water-Resources Investigation Report* 89-4131, 56 pp.
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6. Waldron, B., and Larsen, D., 2015. Pre-development Groundwater Conditions Surrounding Memphis, Tennessee: Controversy and Unexpected Outcomes. *Journal of the American Water Resources Association* 51:133-153.
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