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 Exceptions to Report of the Special Master

REPLY OF DEFENDANT STATE OF TENNESSEE TO EXCEPTIONS OF PLAINTIFF STATE OF MISSISSIPPI TO REPORT OF THE SPECIAL MASTER

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QUESTIONS PRESENTED

The State of Tennessee supports the Special Master's recommendation that Mississippi's Complaint be dismissed. As explained in Defendants' Exception in Part, the Court should dismiss Mississippi's Complaint with prejudice. The State of Mississippi's Exceptions to the Report of the Special Master present the following questions:

1. Whether the Special Master correctly concluded that Mississippi's Complaint should be dismissed because any claim to the interstate Middle Claiborne Aquifer is governed by the equitable-apportionment doctrine, which bars Mississippi's tort-based claims and request for damages.

2. Whether, alternatively, the Court should dismiss Mississippi's Complaint as barred by issue preclusion because Mississippi's claims depend on it having an enforceable right to the Aquifer outside the purview of an equitable apportionment or interstate compact, an issue Mississippi litigated and lost in *Hood ex rel. Mississippi v. City of Memphis*, 533 F. Supp. 2d 646 (N.D. Miss. 2008), *aff'd*, 570 F.3d 625 (5th Cir. 2009), *cert. denied*, 559 U.S. 904 (2010).

TABLE OF CONTENTS

TABLE OF AUTHORITIES

STATUTES AND RULES

OTHER MATERIALS

GLOSSARY

2014 Compl.	Compl., *Mississippi v. Tennessee, et al.*, No. 143, Orig. (U.S. June 6, 2014)
2016 Op.	Memorandum of Decision on Motions To Dismiss and Motion To Exclude, *Mississippi v. Tennessee, et al.*, No. 143, Orig. (U.S. Aug. 12, 2016) (Special Master's Dkt. #55)
2018 Op.	Memorandum of Decision on Defendants' Motion for Summary Judgment, *Mississippi v. Tennessee, et al.*, No. 143, Orig. (U.S. Nov. 29, 2018) (Special Master's Dkt. #93)
App.	Appendix bound together with Brief in Support of Exception in Part of Defendants State of Tennessee, City of Memphis, and Memphis Light, Gas & Water Division to Report of the Special Master, *Mississippi v. Tennessee, et al.*, No. 143, Orig. (U.S. Feb. 22, 2021)
Aquifer	Middle Claiborne Aquifer
Defs. Exception Br.	Brief in Support of Exception in Part of Defendants State of Tennessee, City of Memphis, and Memphis Light, Gas & Water Division to Report of the Special Master, *Mississippi v. Tennessee, et al.*, No. 143, Orig. (U.S. Feb. 22, 2021)

DFOF	Defendants' Proposed Findings of Fact, *Mississippi v. Tennessee, et al.*, No. 143, Orig. (U.S. Sept. 19, 2019) (Special Master's Dkt. #115) (reproduced at App. 65a-140a)
Ex. D-___	Exhibit filed by Defendants in the evidentiary hearing before the Special Master in May 2019
Hood 2005 Compl.	Compl., *Hood ex rel. Mississippi v. City of Memphis, et al.*, No. 2:05CV32-GHD, Dkt. #2 (N.D. Miss. Feb. 1, 2005) (reproduced at App. 1a-29a)
Hr'g Tr.	Transcript of Evidentiary Hearing Before Special Master, *Mississippi v. Tennessee, et al.*, No. 143, Orig. (May 20-24, 2019) (Special Master's Dkts. #105-#109)
Joint Exhibit	Exhibit filed jointly by the parties in the evidentiary hearing before the Special Master in May 2019
Miss. Cert. Pet.	Petition for Writ of Certiorari, *Mississippi v. City of Memphis, et al.*, No. 09-289 (U.S. Sept. 2, 2009)
Miss. Exceptions Br.	Brief in Support of Exceptions to Report of the Special Master by Plaintiff State of Mississippi, *Mississippi v. Tennessee, et al.*, No. 143, Orig. (U.S. Feb. 22, 2021)
Mississippi Embayment	Mississippi Embayment Regional Aquifer System

Pl.'s Opp. to MJOP	State of Mississippi's Response in Opposition to Defendants' Motions for Judgment on the Pleadings, *Mississippi v. Tennessee, et al.*, No. 143, Orig. (U.S. Apr. 6, 2016) (Special Master's Dkt. #42)
Pl.'s Resp. to SJ	Plaintiff's Response to Defendants' Motion for Summary Judgment, *Mississippi v. Tennessee, et al.*, No. 143, Orig. (U.S. July 6, 2018) (Special Master's Dkt. #71)
Rep. or Report	Report of the Special Master, *Mississippi v. Tennessee, et al.*, No. 143, Orig. (U.S. Nov. 5, 2020) (Special Master's Dkts. #135 & #136)
Special Master	Honorable Eugene E. Siler, Jr.
Stip. Fact	Plaintiff's and Defendants' Joint Statement of Stipulated and Contested Facts, *Mississippi v. Tennessee, et al.*, No. 143, Orig. (U.S. Feb. 27, 2018) (Special Master's Dkt. #64)
Tenn. Reply App.	Appendix bound together with this brief
USGS	U.S. Geological Survey

INTRODUCTION

Mississippi seeks at least $615 million in damages for state tort-law claims involving groundwater in the shared Middle Claiborne Aquifer. The Special Master agreed with Tennessee that, if the Middle Claiborne Aquifer is an interstate water resource, this Court's equitable-apportionment doctrine – not Mississippi's tort theories – governs this action. Under this Court's precedents, an equitable-apportionment action would not yield monetary damages; instead, it would lead to the Court determining each State's fair share of the resource. And Mississippi could obtain such an apportionment only after showing that Tennessee's use of the resource caused Mississippi substantial injury. But Mississippi wants damages, not an equitable allocation, and it has suffered no injury at all. For those reasons, it disavows equitable apportionment and instead claims that Mississippi state tort law governs the Middle Claiborne Aquifer.

After a five-day evidentiary hearing following years of discovery, the Special Master agreed with Tennessee that the Middle Claiborne Aquifer is an interstate resource. He further held that the equitable-apportionment doctrine preempts state-law claims based on a State's use of such a resource. He thus recommended that the Court dismiss Mississippi's Complaint because Mississippi had disclaimed the only remedy available to it – an equitable apportionment.

This Court should adopt the Special Master's sound recommendation. Mississippi largely concedes that the Aquifer is interstate and instead argues that the equitable-apportionment doctrine should not apply to *this* interstate resource. But this Court's

precedents establish that equitable apportionment applies broadly to all different kinds of resources, whenever actions taken entirely within one State negatively affect a resource in another State. That is the case here: Mississippi alleges that Memphis's pumping, which occurs entirely in Tennessee through pumps that never cross state lines, affects water conditions in Mississippi through the laws of hydrology. Mississippi is incorrect that state tort law (rather than equitable apportionment) governs interstate groundwater.

Alternatively, this Court should dismiss Mississippi's claims on issue-preclusion grounds because Mississippi seeks to relitigate the same issue it lost in *Hood*: whether it has an enforceable right to the Aquifer outside the purview of an equitable-apportionment action.

The Court should overrule Mississippi's Exceptions to the Report of the Special Master, sustain Defendants' Exception in Part, and dismiss Mississippi's Complaint with prejudice.

STATEMENT

A. The Middle Claiborne Aquifer[1]

The Middle Claiborne Aquifer is a large hydrogeological unit located beneath portions of eight different States: Tennessee, Mississippi, Arkansas, Louisiana, Alabama, Kentucky, Missouri, and the southernmost tip of Illinois. DFOF ¶¶ 64, 97 (App. 88a, 94a); Rep. 17; Defs. Exception Br. 3 (excerpting

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[1] Defendants provided the Court with much of the pertinent background about the Middle Claiborne Aquifer in their Exception in Part to the Special Master's Report. Defs. Exception Br. 2-9. Here, Tennessee focuses on the facts most relevant to the Special Master's conclusion that equitable apportionment forecloses Mississippi's claims.

Joint Exhibit 71). It is one aquifer within the Mississippi Embayment Regional Aquifer System ("Mississippi Embayment"), which underlies the Mississippi River Valley and contains multiple laterally extensive aquifers separated by intervening confining units.[2] DFOF ¶¶ 64, 97 (App. 88a, 94a); Rep. 17. Like many large aquifers, the Middle Claiborne's hydrological properties – for example, its composition, hydraulic conductivity, and water levels – vary somewhat throughout its reach. DFOF ¶¶ 22, 64, 68-69 (App. 75a, 88a-89a). The Middle Claiborne Aquifer is also known by a variety of different names in different areas, including the Sparta Sand in Mississippi and the Memphis Sand in Tennessee. *Id.* ¶¶ 193-194 (App. 115a). But naming conventions aside, the Aquifer remains a single hydrogeological unit – in which there are no barriers to the lateral flow of water – throughout its eight-state footprint. Rep. 15-17, 20. The U.S. Geological Survey refers to the Aquifer as the Middle Claiborne. Rep. 15; DFOF ¶ 59 (App. 84a).

Humans access groundwater by installing wells and pumping from those wells. Pumping lowers the potentiometric level[3] in the area surrounding a well,

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[2] An aquifer contains sufficient saturated, permeable materials to yield usable quantities of water to wells and springs. DFOF ¶¶ 9-10 (App. 72a). A confining unit consists of less permeable materials and can separate aquifers. *Id.* ¶ 11 (App. 72a). Confining units restrict but do not eliminate the vertical flow of water between aquifers. *Id.* ¶¶ 11, 52 (App. 72a-73a, 82a).

[3] The potentiometric level in an aquifer is the elevation to which water rises inside a tightly cased – or sealed – and properly screened well. DFOF ¶ 26 (App. 76a). The potentiometric level reflects the elevation of the well screen and the pressure in the aquifer at the well screen. *Id.* In a confined

and hydrogeologists call this area of lowered potentiometric level a "cone of depression." *See* Rep. 13; DFOF ¶ 39 (App. 78a). Because all groundwater is constantly moving from areas of higher potentiometric level to areas of lower potentiometric level, a cone of depression causes water to flow from surrounding areas towards the well. DFOF ¶¶ 34, 39 (App. 77a-78a); Rep. 13. It is impossible to remove water from an aquifer for human use without creating a cone of depression. DFOF ¶¶ 41, 220 (App. 78a, 122a).

Pumping began in the Memphis area of the Middle Claiborne Aquifer in 1886. Memphis,[4] which is the largest urban area overlying the Middle Claiborne, relies on the Aquifer's groundwater as its primary public water source and has developed several well fields throughout Shelby County, Tennessee – the county that includes Memphis. *Id.* ¶¶ 257-259 (App. 128a-129a). Mississippi also pumps water from the Aquifer in DeSoto County, Mississippi – just on the other side of the state border. *Id.* ¶ 231 (App. 123a-124a). In recent years, Mississippi has significantly increased its pumping in DeSoto County. *Id.* All of the wells on both sides of the state border are

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aquifer, such as the Middle Claiborne Aquifer in the Memphis area, the potentiometric level is above the bottom of the overlying confining layer. *Id.* ¶ 23 (App. 75a). The diagrams at pdf pages 11 and 35 of Joint Exhibit 40 depict the potentiometric levels and cones of depression in confined and unconfined aquifers. The diagrams are reproduced in the Appendix to this brief (at 40a). Joint Exhibit 40, which was submitted in its entirety to the Special Master, is available at https://pubs.usgs.gov/wsp/2220/report.pdf.

[4] For simplicity, Tennessee refers to the City of Memphis and the Memphis Light, Gas & Water Division collectively as "Memphis."

drilled straight down into the Middle Claiborne, and none crosses any state boundary. *Id.* ¶¶ 117-118 (App. 98a). Other States, including Arkansas and Louisiana, also pump water from the Middle Claiborne Aquifer and other aquifers in the Mississippi Embayment. *Id.* ¶ 257 (App. 128a-129a).

Political borders do not affect cones of depression; a cone of depression will propagate outward from the well for a given distance unless it meets a physical or hydrogeological barrier. *Id.* ¶¶ 69-70, 72-73, 76, 114 (App. 89a-90a, 98a). Because there are no such barriers within the Middle Claiborne Aquifer, cones of depression can and often do extend across state borders. *Id.* ¶¶ 73, 126-130 (App. 89a, 100a-101a). This case centers on the regional cone of depression in the Memphis area of the Aquifer, which extends beneath Tennessee, Mississippi, and Arkansas. *Id.* ¶ 122 (App. 99a). That cone of depression is caused by pumping in all three States in the area. *Id.* ¶¶ 119-120 (App. 98a). As of 2007, there were many other cones of depression in the Aquifer that crossed state borders. At least three of these cones of depression involve larger areas and greater water-level declines than the cone of depression centered on Memphis: a cone of depression near Jackson, Mississippi, extending into Louisiana; a cone of depression near Stuttgart, Arkansas, extending into Mississippi; and a series of overlapping cones of depression in Union County, Arkansas, and nearby Louisiana, each extending across the Arkansas-Louisiana border. *Id.* ¶¶ 126, 128-130, 254-257 (App. 100a-101a, 128a-129a); Defs. Exception Br. 8 (reproducing Figure 14 from Joint Exhibit 19 at pdf p. 34.)

Although pumping within the Middle Claiborne Aquifer has altered the natural (or pre-development)

flow of water, groundwater was constantly moving within the Aquifer before any pumping. DFOF ¶ 19 (App. 74a). Under natural conditions, water in the Memphis area generally entered the Middle Claiborne in its eastern outcrop region – an area where the Middle Claiborne has no overlying confining layer and comes to the earth's surface (or close to the surface). *Id.* ¶ 25 (App. 75a). Water then migrated laterally through the Aquifer, before traveling upward through the overlying confining units and discharging[5] into the alluvial aquifer[6] near the Mississippi River. *Id.* ¶ 53 (App. 82a). During this migration, groundwater in the Aquifer slowly flowed across state lines. *Id.* ¶¶ 135-136 (App. 102a).

Although there are a variety of maps attempting to recreate the historical pre-development flow, it is undisputed that water flowed across state borders, including from Mississippi into Tennessee, during pre-development conditions. *Id.* The most accurate map was from a 2015 peer-reviewed article, Ex. D-174,[7] *see* Tenn. Reply App. 28a, which was based in part on USGS data from 1886 to 1906 and on manual site surveys of pre-development well sites. *See id.* at 24a-26a; DFOF ¶ 160 (App. 108a). The

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[5] "Discharge" is water leaving an Aquifer, whether naturally or through pumping. "Recharge" refers to water entering an aquifer, whether in an outcrop area or as a result of seepage through a confining layer. Stip. Facts 21, 28.

[6] The alluvial aquifer is the shallow, unconfined aquifer located above the Middle Claiborne Aquifer at or near the land's surface. It is separated from the Middle Claiborne by a confining layer, and it is directly connected to the Mississippi River. DFOF ¶ 181 (App. 113a).

[7] The article, which was submitted in its entirety as Defendants Exhibit 174, is reproduced in the Appendix to this brief.

resulting map showed that, under pre-development conditions, water in the Memphis area predominantly flowed in a southeast-to-northwest direction, from Mississippi into Tennessee. DFOF ¶¶ 142, 151 (App. 103a-104a, 106a). In fact, that map showed that more water was flowing from Mississippi into Tennessee under pre-development conditions than in 2007. *Id.* ¶ 154 (App. 106a-107a).

B. Procedural History

1. This litigation began more than 15 years ago when Mississippi filed a complaint in district court alleging common-law tort claims against Memphis. Mississippi claimed that Memphis was "taking massive quantities of Mississippi's portion of the groundwater" in the Middle Claiborne and sought "several hundreds of millions of dollars" in monetary damages. *Hood* 2005 Compl. ¶¶ 12, 17 (App. 5a-7a).

After extensive discovery, the district court dismissed Mississippi's claims. The court held that the federal doctrine of equitable apportionment governed Mississippi's claims because Mississippi sought ownership of an interstate resource when "it has not yet been determined which portion of the aquifer's water is the property of which State." *Hood ex rel. Mississippi v. City of Memphis*, 533 F. Supp. 2d 646, 648 (N.D. Miss. 2008). The court further held that Tennessee (which Mississippi had not sued) was a necessary participant in any equitable apportionment. The court thus dismissed the case without prejudice under Federal Rule of Civil Procedure 19, concluding that Tennessee was a necessary and indispensable party and that the case fell within this Court's "original and exclusive jurisdiction." *Id.*

On appeal, Mississippi argued that the equitable-apportionment doctrine did not govern the dispute

because Mississippi "owns the groundwater" from the Aquifer "as a self-evident attribute of statehood, and thus there is no interstate water to be equitably apportioned." *Hood ex rel. Mississippi v. City of Memphis*, 570 F.3d 625, 629 (5th Cir. 2009). The Fifth Circuit rejected Mississippi's argument and affirmed that "[t]he Aquifer is an interstate water source" subject to "equitable allocation." *Id.* at 630, 631. In 2010, this Court denied certiorari in *Hood*. *See Mississippi v. City of Memphis*, 559 U.S. 904 (2010). It also denied without prejudice Mississippi's contemporaneous motion for leave to file a bill of complaint against Tennessee and Memphis. *See Mississippi v. City of Memphis*, 559 U.S. 901 (2010).

2. Four years later, Mississippi sought leave to file a bill of complaint against Tennessee and Memphis. *See* 2014 Compl. In 2015, the Court granted leave, *Mississippi v. Tennessee*, 135 S. Ct. 2916 (2015), and referred the case to the Special Master, *Mississippi v. Tennessee*, 136 S. Ct. 499 (2015).

Tennessee then moved to dismiss Mississippi's Complaint. The Special Master concluded that equitable apportionment applies to groundwater, just as it "has been applied to a variety of interstate water disputes." 2016 Op. 20. The Special Master reasoned that "equitable apportionment applies when 'the action of one State reaches through the agency of natural laws into the territory of another State'" and that groundwater pumping, like surface water pumping, can affect "water in another state through the operation of natural laws." *Id.* (quoting *Idaho ex rel. Evans v. Oregon*, 462 U.S. 1017, 1024-25 & n.8 (1983)). Recognizing that the equitable-apportionment doctrine would require dismissal of Mississippi's Complaint if the Aquifer were an

interstate resource, the Special Master ordered "an evidentiary hearing on the limited – and potentially dispositive – issue of whether the Aquifer is, indeed, an interstate resource." *Id.* at 1.

Following nearly two years of discovery, Defendants sought summary judgment. The Special Master reaffirmed his earlier conclusion that "equitable apportionment is appropriate if this case involves an interstate resource." 2018 Op. 10. He rejected Mississippi's argument that it possesses inherent property rights to a portion of the Aquifer, explaining that, "when a resource is interstate in nature, equitable apportionment supplies the proper method for determining rights." *Id.* at 21. And, although the Special Master recognized that the evidence showing the interstate nature of the Aquifer was "strong," he reaffirmed the need for an evidentiary hearing on whether "the Aquifer and water are interstate" in order to create a "robust record." *Id.* at 27.

In May 2019, the Special Master conducted a five-day evidentiary hearing. Evidence at the hearing conclusively showed the Aquifer is an interstate resource. Five expert witnesses testified, and the parties submitted thousands of pages of documentary evidence. Following the hearing, the parties filed post-trial briefs and proposed findings of fact and conclusions of law, and the Special Master later heard closing arguments. Based on this record, the Special Master concluded that the Middle Claiborne Aquifer is an interstate resource and that the equitable-apportionment doctrine bars Mississippi's claims. *See* Rep. 2. He therefore recommended that Mississippi's Complaint be dismissed. *Id.*

SUMMARY OF ARGUMENT

I.A. The Special Master correctly concluded that the equitable-apportionment doctrine governs any claim Mississippi can assert for rights to contested water in the interstate Middle Claiborne Aquifer. This Court previously has applied equitable apportionment to a variety of interstate resources including rivers, groundwater connected to interstate surface water, and even migratory fish. The doctrine can be invoked when actions taken entirely within one State adversely affect another State's ability to use the same resource.

B. Mississippi does not meaningfully dispute the Special Master's presumptively correct factual determination that the Aquifer is interstate in nature for four different reasons. *First*, Mississippi's claims concern a single aquifer underlying eight States. *Second*, the effects of pumping cross state borders. *Third*, groundwater flowed across state borders, including from Mississippi into Tennessee, under pre-development conditions. *Fourth*, the Middle Claiborne is hydrologically connected with interstate surface waters. Because the Aquifer is an interstate resource under all four explanations adopted by the Special Master, any claims that one State is depriving another State of its ability to use the resource would fall squarely within this Court's equitable-apportionment doctrine.

C. Should the requisites of the equitable-apportionment doctrine be satisfied, applying that doctrine to the Middle Claiborne would promote the goal of allocating shared resources in a just and equitable manner. Equitable apportionment recognizes that Mississippi and Tennessee each have sovereignty within their own borders. The doctrine

also accounts for both States' uses of the water and gives due weight to the importance of established uses, such as Memphis's longstanding public water system.

D. The equitable-apportionment doctrine preempts Mississippi's tort-based claims to the Middle Claiborne because the doctrine provides the exclusive litigation remedy for a State injured by another State's use of an interstate water resource. And equitable apportionment does not permit Mississippi to recover damages. Because Mississippi has disclaimed equitable apportionment – and could not state an equitable-apportionment claim in any event – Mississippi's Complaint should be dismissed with prejudice.

II.A. Mississippi's arguments against the equitable-apportionment doctrine fail. Mississippi's contention that the doctrine does not extend to groundwater relies on legally insignificant distinctions between groundwater and surface water. It further ignores the practical difficulties of applying a different doctrinal framework to groundwater. Mississippi's property-rights theory would be difficult to administer, and it would destabilize water policy throughout the country. Applying that theory to the Aquifer also would allow Mississippi to avoid scrutiny into its own, significant pumping.

B. Mississippi cannot avoid the equitable-apportionment doctrine by artificially restricting its claims to a portion of the Aquifer. The evidence at trial demonstrated that *all* of the water in the Aquifer would have flowed out of Mississippi under pre-development conditions at some point, and much of it would have flowed into Tennessee. Such cross-border flow is the hallmark of an interstate

resource. The Special Master also correctly rejected Mississippi's attempt to claim only the water within a subsection of the Aquifer – named the "Sparta Sand" on the Mississippi side – recognizing the scientific consensus that the Aquifer is a single hydrogeological unit. All of the groundwater within it forms part of the same interstate resource subject to the equitable-apportionment doctrine.

C. Mississippi's claim of sovereign authority over any portion of the Aquifer misconstrues this Court's precedents. This Court has recognized that each State has full jurisdiction over the lands within its borders. By contrast, a State cannot claim an ownership interest in a shared, interstate resource that overlies – or underlies – its lands, unless and until such interest is established by an equitable-apportionment decree or interstate compact. This Court's decision in *Tarrant Regional Water District v. Herrmann*, 569 U.S. 614 (2013), prevents one State from physically entering another State's territory. It does not apply here, where Memphis's pumps are located entirely within Tennessee.

D. The equal-footing and public-trust doctrines also do not apply to disputes over interstate resources. Similarly, Mississippi cannot rely on either State's statutory law, which merely codifies the public-trust doctrine. In fact, Mississippi's statute recognizes that interstate groundwater, like surface water, is subject to equitable apportionment.

III. In the alternative, the Court should dismiss Mississippi's claims as barred by issue preclusion. Mississippi's claims depend on it having an enforceable right to the Aquifer outside the purview of an equitable apportionment or interstate compact. Mississippi had a full and fair opportunity to litigate

that issue in *Hood*, and the Fifth Circuit squarely rejected that position. Having failed to prevail in that case, Mississippi cannot collaterally attack that final judgment here. This Court's exclusive jurisdiction in this interstate dispute does not change the analysis; an earlier forum's inability to hear a later suit does not deprive its judgment of issue-preclusive force. Applying issue preclusion to this action not only promotes issue preclusion's core purposes, but also comports with the principles that underpin this Court's original jurisdiction.

ARGUMENT

I. THE SPECIAL MASTER CORRECTLY CONCLUDED THAT THE EQUITABLE-APPORTIONMENT DOCTRINE BARS MISSISSIPPI'S CLAIMS

A. The Equitable-Apportionment Doctrine Governs All Interstate Natural Resources, Including Groundwater

The Special Master correctly concluded (at 26-32) that the equitable-apportionment doctrine governs Mississippi's claims. "Where, as here, the Court is asked to resolve an interstate water dispute raising questions beyond the interpretation of specific language of an interstate compact, the doctrine of equitable apportionment governs [the Court's] inquiry." *Florida v. Georgia*, 138 S. Ct. 2502, 2513 (2018); *see also Virginia v. Maryland*, 540 U.S. 56, 74 n.9 (2003) ("[f]ederal common law governs interstate bodies of water, ensuring that the water is equitably apportioned between the States"). In those circumstances, a State acquires an ownership share of an interstate resource not by mere virtue of sovereignty, but by seeking a "just and equitable allocation" from this Court. *Colorado v. New Mexico*, 459 U.S. 176, 183

(1982). The equitable-apportionment doctrine recognizes the fundamental principle that "a State may not preserve solely for its own inhabitants natural resources located within its borders." *Idaho ex rel. Evans v. Oregon*, 462 U.S. 1017, 1025 (1983).

This Court has applied the doctrine broadly to a wide array of interstate resources, including rivers, *see, e.g.*, *Nebraska v. Wyoming*, 325 U.S. 589, 617-19 (1945); river basins, *see, e.g.*, *Florida*, 138 S. Ct. at 2512; groundwater connected to interstate surface water, *see, e.g.*, *Nebraska v. Wyoming*, 515 U.S. 1, 14 (1995); *Washington v. Oregon*, 297 U.S. 517, 522-23 (1936); and even migratory fish, *see Idaho ex rel. Evans*, 462 U.S. at 1024-25. What matters is not whether the water is groundwater or surface water – or even whether the resource is fish rather than water. The doctrine applies whenever, as a "simple consequence of geography," *Kansas v. Nebraska*, 135 S. Ct. 1042, 1052 (2015), one State's use of a shared interstate resource causes injury to another State "through the agency of natural laws," *Kansas v. Colorado*, 206 U.S. 46, 97 (1907). This case fits that description. Mississippi alleges that Memphis's groundwater pumping in one State affects water conditions in the Aquifer beneath another State through the laws of hydrology. *See infra* pp. 15-16.

As the Special Master correctly concluded (at 26-32), Mississippi's dispute over the Aquifer's interstate groundwater would fall within the scope of the equitable-apportionment doctrine if Mississippi could establish the prerequisites for such a claim. Because Mississippi has not entered into an interstate compact and has explicitly disclaimed equitable apportionment of the Aquifer, its claims must be dismissed.

B. The Special Master Correctly Found That The Aquifer Is An Interstate Resource

The Special Master persuasively documented (at 11-26) that the Middle Claiborne Aquifer is an interstate resource. Mississippi agrees with the Special Master's factual findings supporting that conclusion, but it claims that the Special Master committed "legal error" by applying the equitable-apportionment doctrine to *this* interstate water resource. Miss. Exceptions Br. 26. The Special Master's factual findings – which are entitled to "a tacit presumption of correctness," *Colorado v. New Mexico*, 467 U.S. 310, 317 (1984) – bring the Aquifer within the equitable-apportionment doctrine's purview.

First, the Special Master correctly determined that the Aquifer is an interstate resource because it "is a continuous, interconnected hydrogeological unit beneath several states." Rep. 25. The Aquifer extends beneath portions of Tennessee, Mississippi, Arkansas, Louisiana, Alabama, Kentucky, Missouri, and Illinois. DFOF ¶¶ 64, 97 (App. 88a, 94a); Rep. 17. And it is a single hydrogeological unit because its hydrogeological properties – for example, its composition, hydraulic conductivity, and water levels – are continuous beneath those eight States. DFOF ¶¶ 65-73 (App. 88a-89a); Rep. 20. As Mississippi concedes (at 8), groundwater in the Aquifer is not "stationary." Water is able to flow freely throughout the Aquifer, which confirms that the Aquifer is a single multi-state hydrogeological unit. DFOF ¶¶ 76-77 (App. 90a).

Second, the Special Master properly found that effects of pumping in the Aquifer "cross[] the Mississippi-Tennessee border." Rep. 21. Groundwater in the Aquifer flows continuously across politi-

cal boundaries, and all experts agreed that there is no barrier at the Mississippi-Tennessee border. DFOF ¶¶ 75-77 (App. 90a). Consequently, pumping from the Aquifer in one State can and does affect water levels in the Aquifer in neighboring States. *Id.* ¶¶ 74, 112-125 (App. 89a-90a, 97a-101a). Mississippi does not dispute that these cross-border effects occur. In fact, its claims depend on those effects. *See, e.g.*, Miss. Exceptions Br. 11 (arguing that Memphis's "pumping is pulling groundwater from Mississippi into Shelby County"). The cross-border effects of which Mississippi complains provide a textbook example of one State "reach[ing], through the agency of natural laws, into the territory of another state." *Kansas*, 206 U.S. at 97.

Third, the Special Master correctly found (at 24) – and Mississippi agrees (at 8) – that groundwater flowed between Mississippi and Tennessee "[u]nder natural conditions." Indeed, every study of pre-development conditions in the Aquifer found groundwater flowed naturally across state lines. DFOF ¶¶ 135-150 (App. 102a-106a). Moreover, Mississippi's expert admitted that the area from which groundwater in the Aquifer flowed from Mississippi into Tennessee during pre-development times is larger than Mississippi initially alleged. *Id.* ¶ 141 (App. 103a). And Tennessee's unrebutted expert testimony established that the single most reliable study, Ex. D-174, found very substantial pre-development flow from Mississippi into Tennessee. DFOF ¶ 154 (App. 106a-107a). According to that study, in fact, the Mississippi-to-Tennessee interstate

flow was *greater* under pre-development conditions than it was in 2007. *Id.*[8]

Fourth, the Aquifer is an interstate resource because it is hydrologically interconnected "to interstate surface waters." Rep. 25. In the outcrop areas, the Aquifer is connected directly to the Wolf River (which flows from Mississippi into Tennessee). DFOF ¶¶ 177-180 (App. 112a-113a). And it is connected indirectly, through the alluvial aquifer, to the Mississippi River. *Id.* ¶¶ 181-185 (App. 113a). Mississippi does not dispute that factual finding either. This Court repeatedly has applied the equitable-apportionment doctrine to such surface-connected groundwater. *See, e.g.*, *Nebraska v. Wyoming*, 534 U.S. 40, 42 (2001) (Appendix); *Nebraska v. Wyoming*, 515 U.S. at 11; *Texas v. New Mexico*, 462 U.S. 554, 557 n.2, 567-69 (1983); *Washington v. Oregon*, 297 U.S. 517 (1936); *Kansas v. Colorado*, 206 U.S. at 114-15. As the Special Master thus explained (at 25), the Aquifer's connections to interstate surface water support a finding that it is interstate in nature.[9]

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[8] For this lawsuit, that fact confirms the error of Mississippi's core theory. In fact, *Mississippi's* pumping after development has *slowed* the natural flow of groundwater from Mississippi into Tennessee. *See infra* pp. 27-28. Tennessee's pumping, therefore, cannot be depriving Mississippi of any water as a matter of fact. This fact negates Mississippi's property-rights claims, which are predicated on Memphis supposedly "taking" groundwater from Mississippi. 2014 Compl. ¶¶ 22, 23.

[9] Mississippi's suggestion (at 29-30) that equitable apportionment does not control this dispute because Mississippi is not "independently" challenging the use of the Aquifer's interconnected surface waters lacks merit. The Special Master correctly concluded (at 25), and Mississippi does not dispute, that the Middle Claiborne is hydrologically connected to interstate surface waters. Mississippi cannot avoid equitable apportion-

C. The Special Master's Recommendation Serves Equitable Apportionment's Core Principles

The equitable-apportionment doctrine is well-suited to allocate rights to the groundwater in the eight-state Middle Claiborne Aquifer, if any State should establish that another State is causing substantial injury. The Special Master's recommendation promotes equitable apportionment's fundamental principles. The primary goal of an equitable apportionment is to allocate an interstate source among coequal sovereigns in a "just and equitable" manner. *South Carolina v. North Carolina*, 558 U.S. 256, 271 (2010). To achieve that goal, this Court has long employed a "flexible" balancing approach that considers "all relevant factors," including "climatic conditions," "established uses," and "the harms and benefits to competing States." *Colorado*, 459 U.S. at 183, 186. And, in light of the competing sovereign interests, this Court requires a State requesting an equitable apportionment to demonstrate a "real or substantial injury," *id.* at 187 n.13, that represents a "'threatened invasion of rights' that is 'of serious magnitude,'" *Florida*, 138 S. Ct. at 2514 (quoting *Washington*, 297 U.S. at 522). Applying that flexible doctrine to the Aquifer promotes the principles of justice, equity, and stability underpinning the doctrine.

First, the equitable-apportionment doctrine safeguards Tennessee's territorial sovereignty. It is undisputed that Memphis never physically entered Mississippi to capture water; the wells in Tennessee are all drilled straight down, and any cross-border effects are merely the natural consequence of devel-

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ment by merely limiting its challenge to a portion of the interconnected waters. *See also infra* pp. 26-29.

oping the Aquifer. DFOF ¶¶ 117-118 (App. 98a). Mississippi's claims thus seek to regulate activities that take place exclusively within Tennessee. Such cross-border regulation – which Mississippi demands as a matter of sovereignty – flouts the precept that "neither state can enforce its own policy upon the other." *Kansas*, 206 U.S. at 95. Indeed, the equitable-apportionment doctrine's "'guiding principle' . . . is that both States have 'an equal right to make a reasonable use' of" a shared interstate resource. *Florida v. Georgia*, 141 S. Ct. 1175, 1180 (2021) (quoting *Florida*, 138 S. Ct. at 2513). Mississippi cannot square its claims with that core principle.

Second, an equitable apportionment would give due consideration to both States' competing uses of the Aquifer. "At the root of the [equitable-apportionment] doctrine is the same principle that animates many of the Court's Commerce Clause cases: a State may not preserve solely for its own inhabitants natural resources located within its borders." *Idaho ex rel. Evans*, 462 U.S. at 1025. The doctrine therefore "require[s] the reasonably efficient use of water" and "impose[s] on States an affirmative duty to take reasonable steps to conserve and augment the water supply of an interstate [resource]." *Colorado*, 459 U.S. at 185. Given the interstate character of groundwater management, "the relative rights of contending States" must be adjudicated within a framework that serves the broader national interest, rather than the parochial "considerations . . . applied in such States for the solution of similar questions of private right." *Connecticut v. Massachusetts*, 282 U.S. 660, 670 (1931). Applying the equitable-apportionment doctrine would promote these principles and foster water conservation. *See*

Sporhase v. Nebraska ex rel. Douglas, 458 U.S. 941, 952-53 (1982) (because "water, unlike other natural resources, is essential for human survival[,] . . . there is a significant federal interest in conservation as well as in fair allocation").

Third, the equitable-apportionment doctrine would give due consideration to the "compelling" equities underpinning Memphis's established water system. *Colorado*, 459 U.S. at 187. The doctrine recognizes that "[t]he harm that may result from disrupting established uses is typically certain and immediate, whereas the potential benefits from a proposed diversion may be speculative and remote." *Colorado*, 467 U.S. at 316. To balance these competing interests and promote "the stability of property rights," the doctrine requires only "conservation measures that are 'financially and physically feasible' and 'within practicable limits.'" *Id.* at 316, 319 (quoting *Wyoming v. Colorado*, 259 U.S. 419, 484 (1922)).

Memphis has pumped water from the Aquifer since 1886, and the Aquifer is the City's primary public water source. DFOF ¶ 259 (App. 129a); *see* Miss. Exceptions Br. 9-10 (noting Memphis's water system consists "of more than 160 wells in 10 well fields"). Repositioning Memphis's wells to eliminate the cone of depression extending into Mississippi – if that were even possible – would impose "enormous" expense. DFOF ¶ 252 (App. 127a-128a).

Conversely, Mississippi has not demonstrated any injury. Memphis's pumping has not prevented Mississippi from increasing its own pumping to obtain the water it wants. *Id.* ¶¶ 231, 243 (App. 123a-124a, 126a). The Aquifer has remained fully saturated at all times, *id.* ¶¶ 243, 267 (App. 126a, 130a), and Mississippi's own expert testified that the volume of

water beneath DeSoto County, Mississippi, has changed very little since pumping began, *id.* ¶ 241 (App. 125a). In fact, water levels in the Middle Claiborne have stabilized in the area around Memphis in recent years, demonstrating that the amount of water discharging from the Aquifer – naturally and through pumping – is approximately equal to the amount of water naturally recharging into the Aquifer. *Id.* ¶¶ 229-230, 256 (App. 123a, 128a).

The Special Master did not reach Mississippi's claims of injury from having to drill wells to greater depths. *See* Rep. 5 (citing 2014 Compl. ¶ 54(b)). But any incremental inconvenience to Mississippi from additional electricity or construction costs as a result of lowered potentiometric levels, DFOF ¶¶ 244-245 (App. 126a), cannot justify upsetting Defendants' decades-long practices. If an equitable-apportionment decree were ever necessary for this Aquifer, it would properly balance all of these "harms and benefits" to the States in light of the existing uses. *Colorado*, 459 U.S. at 186.

The equitable-apportionment doctrine is the proper lens through which the Court should evaluate any claim Mississippi can assert against Tennessee. In light of the doctrine's core purposes of equity, justice, and stability, the Court should adopt the Special Master's recommendation and overrule Mississippi's exceptions.

D. The Equitable-Apportionment Doctrine Precludes Mississippi's Claims

The equitable-apportionment doctrine preempts Mississippi's tort-law claims centered on its alleged sovereign ownership of the moving groundwater in the interstate Aquifer. Equitable apportionment – not Mississippi's tort-law concepts – "is the doctrine

of federal common law" that supplies the exclusive remedy for Mississippi's claims. *Colorado*, 459 U.S. at 183; *see American Elec. Power Co. v. Connecticut*, 564 U.S. 410, 421 (2011) ("'When we deal with air and water in their ambient or interstate aspects, there is a federal common law.'") (quoting *Illinois v. City of Milwaukee*, 406 U.S. 91, 103 (1972)). And, as the Special Master correctly concluded (at 31), federal common law preempts Mississippi's state-law claims, which are all premised on its flawed assertion of an ownership interest in an unapportioned interstate resource. *See* 2014 Compl. ¶ 56.

If Mississippi has any remedy at all, it is to seek an equitable apportionment in this Court. But this Court's equitable-apportionment doctrine bars Mississippi from seeking at least "$615 million" in damages for the alleged "wrongful taking" of groundwater. *Id.* ¶¶ 55, 57. An equitable-apportionment decree is "directed at ameliorating present harm and preventing future injuries to the complaining State, not at compensating that State for prior injury." *Idaho ex rel. Evans*, 462 U.S. at 1028. This Court thus has permitted recovery of damages only after the Court has entered an equitable-apportionment decree or the States have agreed to a compact. *See, e.g.*, *Texas v. New Mexico*, 482 U.S. 124, 128 (1987) (permitting damages for violation of compact). Because Mississippi has disclaimed an equitable apportionment – and does not qualify for one in any event – the Complaint should be dismissed with prejudice. *See* 2014 Compl. ¶ 38; Defs. Exception Br. 15-27.

II. MISSISSIPPI'S ARGUMENTS AGAINST APPLYING EQUITABLE APPORTIONMENT ARE UNPERSUASIVE

A. The Equitable-Apportionment Doctrine Applies To Groundwater

Mississippi's argument (at 26-31) that groundwater is exempt from the equitable-apportionment doctrine lacks merit. Mississippi identifies no compelling reason to treat the Aquifer differently from the variety of interstate resources to which this Court has applied the doctrine. *See supra* p. 14. It points (at 6-8) to groundwater's existence in "pore spaces" and "slow" flow speed, but those features are not "legally meaningful." Rep. 27-28. "The Aquifer flows, if slowly, under several states, and it is indistinguishable from a lake bordered by multiple states or from a river bordering several states depending upon it for water." *Hood*, 570 F.3d at 630. Flow speed aside, the Aquifer's groundwater possesses the key characteristic of an interstate resource: actions in one State can and do affect the resource in a different State through "'the agency of natural laws.'" Rep. 28 (quoting *Idaho ex rel. Evans*, 462 U.S. at 1024 n.8); *see supra* p. 14. This Court never has established a different doctrinal framework for evaluating the use of interstate groundwater. Inventing a new regime for the Aquifer here would have adverse consequences that conflict with this Court's water-rights precedents.

First, applying a new rule to the Aquifer would be difficult to administer because of the hydrological connections between groundwater and surface water. Groundwater in *all* aquifers is constantly moving between the aquifers and surface waters through natural recharge and discharge. DFOF ¶¶ 19, 34, 264

(App. 74a, 77a, 129a-130a). And the Special Master properly concluded that the Middle Claiborne in particular was hydrologically connected to surface water. Rep. 25. This Court's equitable-apportionment precedents already recognize such inextricable connections. In *Washington v. Oregon*, for example, the Court applied the equitable-apportionment doctrine when addressing a claim – similar to Mississippi's – that Oregon farmers should be enjoined from pumping "subsurface water" because of the effect on water in Washington. 297 U.S. at 523-26. Similarly, in *Kansas v. Colorado*, the Court declined to treat "subsurface water" as "separate" from a "surface stream" for purposes of equitable apportionment. 206 U.S. at 114-15. And, in *Nebraska v. Wyoming*, the Court applied the equitable-apportionment doctrine when addressing Nebraska's claim that "groundwater pumping in Wyoming" depleted "surface water flows." 515 U.S. at 14.

Second, applying Mississippi's property-rights theory to groundwater also would be impracticable because it is impossible to determine when particular groundwater molecules have crossed or will cross a State's border. Mississippi asks (at 18-20, 34-35) the Court to determine ownership of each molecule of water in the Aquifer by determining whether it "resided in Mississippi." But hydrologists work on the macroscopic level to draw conclusions about the average speed or direction of water movement within an aquifer; they cannot follow individual molecules of water in isolation. DFOF ¶¶ 269-271 (App. 130a-131a). Further, the expert testimony demonstrated that groundwater flow patterns are constantly changing – such as when new pumps create cones of depression – further complicating efforts to determine

which water molecules cross political boundaries. *Id.* ¶¶ 31, 39 (App. 76a-78a). The threat of hundreds of millions of dollars in retrospective damages based on the results of such uncertain analysis would thwart the principle of stability at the heart of federal common law in this area. *See Colorado*, 459 U.S. at 183, 186.

Third, Mississippi's sovereignty-based framework would destabilize state water policy across the United States and frustrate the public interest. For decades, States have formulated water policy with the knowledge that the federal equitable-apportionment doctrine protects "existing economies" and looks unfavorably on legal claims that threaten to "disrupt[] established uses." *Id.* at 187. Mississippi's theory seeks to cast that regime aside in favor of a rule allowing States to use their own tort laws to upend the longstanding policies of neighboring States. Were the Court to accept Mississippi's proposed paradigm shift, States throughout the Nation would be affected. Many States extract water from interstate aquifers. DFOF ¶¶ 110-111 (App. 96a-97a). Under Mississippi's theory, those States could be forced to defend themselves against lawsuits threatening ruinous liability and disruption of existing water uses. *See* 2014 Compl. ¶ 55 (seeking at least $615 million in damages). And, because cones of depression are an inevitable effect of pumping, adopting Mississippi's theory functionally would preclude States from developing the resource in close proximity to the state border. Given the paramount importance of doctrinal "stability" in the area of water rights, *Colorado*, 467 U.S. at 316, the damage caused by such upheaval could be substantial.

Fourth, applying a new rule to the Aquifer would allow Mississippi to avoid scrutiny into its own pumping. In recent years, Mississippi's groundwater withdrawals in DeSoto County have increased to approximately 20 million gallons per day, and the volume of groundwater in the Aquifer flowing from Mississippi into Tennessee has decreased. DFOF ¶ 231 (App. 124a). Mississippi's pumping near Jackson has caused one of the largest cones of depression in the Aquifer. *Id.* ¶¶ 255-257 (App. 128a-129a). The Court should not incentivize States to seek a financial windfall while avoiding cooperation with other States and bypassing the balancing of interests that an equitable apportionment would require.

For those reasons, the Special Master correctly declined to craft a new legal regime for groundwater and recommended that the Court instead apply the equitable-apportionment doctrine to this interstate water dispute. Rep. 26-32. The Court should adopt that sound recommendation.

B. Mississippi Cannot Limit Its Claims To Only A Particular Subset Of Water Within The Middle Claiborne

The Special Master also correctly rejected Mississippi's attempt (at 31) to evade equitable apportionment by artificially limiting its claims to a subset of the Aquifer's groundwater. Rep. 29-30; 2016 Op. 29, 32. Mississippi's evolving position on this issue has not become more persuasive over time.

Mississippi initially claimed to own the groundwater in the Aquifer that "does not cross into Tennessee under natural predevelopment conditions." 2014 Compl. ¶ 46; *see also* Pl.'s Opp. to MJOP 18; Pl.'s Resp. to SJ 14. Mississippi now changes course and claims (at 21, 31) to own "all groundwater" in

the Middle Claiborne located "within its borders," regardless of how it would have flowed under pre-development conditions and how short its "residence" time in Mississippi might be. But Mississippi does not "own" any of the groundwater and cannot avoid an equitable apportionment "by limiting its claims to a specific portion of the water." 2018 Op. 13, 23.

Mississippi has shifted its focus for good reason – there is no "intrastate" water that would have remained underneath Mississippi under pre-development conditions. Mississippi concedes (at 8) that water in the Aquifer is constantly moving and would not have remained in Mississippi indefinitely even absent pumping. All groundwater in the Aquifer beneath Mississippi eventually would have left the State under natural conditions, as even Mississippi's expert conceded on cross-examination. DFOF ¶ 174 (App. 111a) (citing Hr'g Tr. 307:5-10 (Spruill) (May 21, 2019)). In fact, the single most reliable study of pre-development flow showed *more water* flowing from Mississippi into Tennessee under pre-development conditions than in 2007.[10] *Id.* ¶ 154 (App. 106a-107a). This is likely due in part to increased pumping in Mississippi "right along the border . . . intercepting that flow that would have naturally gone into Tennessee." Hr'g Tr. 853:16-854:6 (Waldron) (May 23, 2019). For that reason,

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[10] The study compared the pre-development water flow within the Middle Claiborne Aquifer to the flow in 2007 because the 2007 study – published by the U.S. Department of the Interior in 2008 and submitted to the Special Master as Joint Exhibit 71 – used the most recent data available about the Middle Claiborne and mapped water levels in the Aquifer in both the confined and the unconfined areas and across state borders. DFOF ¶ 153 (App. 106a). Joint Exhibit 71 can be found at https://pubs.usgs.gov/sim/3014/pdf/sim3014.pdf.

Mississippi's Complaint has it backwards. Mississippi's pumping is depriving Tennessee of water that, under natural conditions, would have flowed from Mississippi into Tennessee.

Mississippi's claim (at 35) that the Aquifer's groundwater is "intrastate" because it "existed" beneath Mississippi is equally unfounded. Mississippi's theory would mean that groundwater beneath its territory belongs to Mississippi until it passes beneath a political boundary and becomes another State's water. But a molecule that supposedly belongs to one State and then, the next moment, to a different State is the epitome of an interstate resource. Indeed, under Mississippi's theory, there would be no interstate rivers because surface water typically exists within one State before flowing into another State.

Mississippi's suggestion (*e.g.*, at 7) that water in the Sparta Sand is in a separate aquifer is also factually incorrect and legally irrelevant. The Middle Claiborne Aquifer and its various subsections go by a variety of names. The name Sparta Sand typically refers to a section of the Aquifer beginning just south of the border between Mississippi and Tennessee. DFOF ¶ 194 (App. 115a). As the Special Master correctly recognized, the Sparta Sand is not a separate aquifer: the "scientific consensus holds that the Middle Claiborne Aquifer is a single hydrogeological unit." Rep. 20.

Even if the units were separate, distinct water bodies may form a single interstate water resource. One of this Court's recent equitable-apportionment cases, *Florida v. Georgia*, 138 S. Ct. 2502 (2018), involved a single interstate water resource that consisted of three rivers with different names,

forming a "Y" shape where two of the rivers flowed into the third. *Id.* at 2508. Despite the presence of three arguably distinct rivers and a lake, the Court recognized the existence of one resource – "an interstate *river basin* known as the Apalachicola-Chattahoochee-Flint River Basin." *Id.* (emphasis added). Because the rivers were hydrologically connected, it made no difference that the Flint River flows exclusively in Georgia, while the Apalachicola River exists solely in Florida, *see id.* at 2528 (Appendix); *see also Florida*, 141 S. Ct. at 1178 ("This case concerns the Apalachicola-Chattahoochee-Flint River Basin, an area spanning more than 20,000 square miles in Georgia, Florida, and Alabama. The Basin contains three rivers.").

Similarly, in *Kansas v. Colorado*, the Court considered an interstate river where the water periodically ran dry between the States. *See* 206 U.S. at 115. The lack of permanent flow across the state boundary did not transform part of the river into an "intrastate" resource exempt from equitable apportionment. Instead, the Court considered the river as a whole. Here, too, hydrological realities – not Mississippi's inapposite naming conventions – determine the interstate nature of the Aquifer.

C. This Court's Precedents Foreclose Mississippi's Competing Theory Of Territorial Sovereignty

Mississippi's claim of sovereign authority over parts of the Aquifer misapprehends the Court's precedents. This Court has recognized that each State "has full jurisdiction over the lands within its borders, including the *beds* of streams and other waters." *Kansas*, 206 U.S. at 93 (emphasis added). But a State cannot claim an ownership interest in

an interstate natural resource within its lands, unless and until such interest is established under an equitable-apportionment decree or interstate compact. In other words, each State has territorial sovereignty over the land that contains the interstate waters, not – as Mississippi maintains (at 27) – over the waters themselves. The States' ownership of the submerged lands creates the accompanying power to control public uses of water within that State. *See* Rep. 29 (citing *Kansas*, 206 U.S. at 93). But this Court's equitable-apportionment cases have "consistently denied" the proposition that a State may exercise exclusive "ownership or control" over all "waters flowing within [its] boundaries." *Hinderlider v. La Plata River & Cherry Creek Ditch Co.*, 304 U.S. 92, 102 (1938). In fact, the Court explicitly rejected "the legal fiction of state ownership" of "ground water" in *Sporhase v. Nebraska ex rel. Douglas*, 458 U.S. at 951, which Mississippi does not address.

In arguing for sovereign control over groundwater, Mississippi relies heavily on *Tarrant Regional Water District v. Herrmann*, 569 U.S. 614 (2013), but that decision involved one State physically *entering another State's territory* to access a water resource. Specifically, a Texas water utility sought to obtain extra water under an interstate compact by entering Oklahoma and "divert[ing]" a "tributary of the Red River located in Oklahoma." *Id.* at 625. This Court concluded that the Texas utility did not have "the right to cross state lines and divert water from Oklahoma" because the relevant compact did not grant Texas a "cross-border" right. *Id.* at 626, 632. In that context, the Court observed that States are presumed not to cede their prerogative "to control water within their own boundaries." *Id.* at 632. Unlike the Texas

utility, Memphis here never has sought to cross into Mississippi's territory to access its water. As the Special Master correctly observed, *Tarrant* is therefore inapplicable because it "only protects a state against physical intrusion." Rep. 29-30.

Mississippi's claim (at 41) that Memphis is nevertheless "reach[ing] into Mississippi" is incorrect. Memphis's pumps are in Tennessee, and it is pumping groundwater that, when extracted, undisputedly lies beneath Tennessee's territory. Rep. 21. Any cross-border effects on water in Mississippi are the natural consequence of the laws of hydraulics. DFOF ¶¶ 41, 123-124 (App. 78a, 99a). All wells create cones of depression, and it is impossible to remove any water from an aquifer without causing water in the surrounding area to flow towards the well. *Id.* ¶ 41 (App. 78a). That Memphis's pumping "reaches, through the agency of natural laws, into the territory of another state" underscores why an equitable apportionment is Mississippi's exclusive remedy. *Kansas*, 206 U.S. at 97.

Ultimately, Mississippi's ownership claim fails because it ignores Tennessee's equal rights to develop the Aquifer within *Tennessee's* own borders. By challenging actions within Tennessee, Mississippi reaches beyond its borders while simultaneously arguing that "'neither state can have any right beyond its territorial boundary.'" Miss. Exceptions Br. 23 (quoting *Rhode Island v. Massachusetts*, 37 U.S. (12 Pet.) 657, 733 (1838)) (emphasis omitted). Equitable apportionment is the Court's solution to this very problem: both States have "control over waters within their own territories," *Tarrant*, 569 U.S. at 631, and neither State "can legislate for[] or impose its own policy upon the other," *Kansas*, 206

U.S. at 95. The States' competing interests "must be reconciled as best they may." *New Jersey v. New York*, 283 U.S. 336, 342-43 (1931). As the Special Master previously explained, Mississippi has not "lost rights to the water" in the Aquifer; instead, "equitable apportionment supplies the proper method for determining rights." 2018 Op. 21.

D. Mississippi Cannot Rely On The Equal-Footing And Public-Trust Doctrines Or State Statutory Law

The equal-footing and public-trust doctrines do not support Mississippi's claims, as the Special Master correctly concluded. *See* Rep. 29-31; 2016 Op. 21. The equal-footing doctrine merely ensures that Mississippi has the same rights as all other States. *See Puerto Rico v. Sanchez Valle*, 136 S. Ct. 1863, 1871 (2016). It does not supplant the well-established principle that no State owns interstate water resources within its borders. *See, e.g.*, *Hinderlider*, 304 U.S. at 102. Similarly, the public-trust doctrine establishes only that Mississippi holds in trust the waters and submerged lands confined within its own territorial borders, subject to fiduciary duties to preserve those resources for the public's benefit. *See Cinque Bambini P'ship v. State*, 491 So. 2d 508, 516-17 (Miss. 1986), *aff'd sub nom. Phillips Petroleum Co. v. Mississippi*, 484 U.S. 469 (1988). Thus, as Mississippi recognizes (at 22, 31), the public-trust doctrine defines the relationship between a State and "its citizens." That doctrine does not apply to disputes among States over the use of interstate water resources, which implicate the coequal rights of neighboring sovereigns and would be subject to an equitable allocation by this Court. *See Kansas*, 206 U.S. at 97-98. Neither the equal-

footing doctrine nor the public-trust doctrine displaces the equitable-apportionment doctrine in the context of an interstate-water dispute.

State statutory law does not support Mississippi's position, either. The Tennessee and Mississippi statutes on which Mississippi relies (at 41-43) codify the public-trust doctrine. *See* Tenn. Code Ann. § 68-221-702 (recognizing that "the waters of the state are the property of the state and are held in public trust for the benefit of its citizens"); Miss. Code Ann. § 51-3-1 (similar). But the public-trust doctrine governs *intrastate* water located within a State's borders. *See supra* p. 32. These statutory provisions thus do not resolve this *interstate* dispute. *See Colorado*, 459 U.S. at 183-84 ("The laws of the contending States concerning intrastate water disputes are an important consideration governing equitable apportionment. . . . But state law is not controlling. Rather, the just apportionment of interstate waters is a question of federal law[.]"); *see also* 2014 Compl. ¶ 37 (recognizing that "[n]either State's legal regime provides any effective mechanism for resolving this dispute").

If anything, Mississippi's statutory law undermines its position. The very chapter Mississippi cites (at 42-43) groups interstate groundwater together with surface water and recognizes that both are subject to equitable allocation. *See* Miss. Code Ann. § 51-3-41. Specifically, Mississippi law authorizes the Commission on Environmental Quality to negotiate "compacts and agreements concerning [Mississippi's] *share of ground water* and waters flowing in watercourses where a portion of those waters are contained within the territorial limits of a neighbor-

ing state." *Id.* (emphasis added).[11] Mississippi law reveals the State's own awareness that, under longstanding equitable-apportionment principles, an interstate compact could be necessary to establish its rights to an interstate groundwater resource like the Aquifer.

Were Mississippi's legal theory correct, no such authority would be necessary: Mississippi's "share" of such groundwater already would be fixed as a matter of sovereignty. And were Mississippi correct that groundwater is so unlike surface water as to demand a different legal regime, its own legislature would not have treated the two identically in contemplating interstate negotiations over Mississippi's "share" of such waters. *Id.* Mississippi identifies no provision of Mississippi law asserting exclusive ownership of groundwater resources "where a portion of those waters are contained within the territorial limits of a neighboring state." *Id.* The absence of any such provision undermines Mississippi's attempt to exempt groundwater from ordinary equitable-apportionment principles.

III. IN THE ALTERNATIVE, THE COMPLAINT SHOULD BE DISMISSED BECAUSE MISSISSIPPI'S CLAIMS ARE BARRED BY ISSUE PRECLUSION

This Court also should dismiss the Complaint on the alternative ground that Mississippi's claims are barred by issue preclusion. Issue preclusion "foreclos[es] successive litigation of an issue of fact or law actually litigated and resolved in a valid court

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[11] In 1995, Mississippi's legislature amended the interstate-compact provision to include "ground water." *See* 1995 Miss. Laws ch. 505, § 4.

determination essential to the prior judgment." *New Hampshire v. Maine*, 532 U.S. 742, 748-49 (2001). Because Mississippi's claims depend on the very same property-rights theory that it advanced and lost in *Hood*, issue preclusion bars Mississippi's claims as a matter of law.

A. Mississippi Seeks To Relitigate The Same Issue *Hood* Already Decided Against It

Mississippi's claims rise and fall on one core issue: whether, in the absence of an equitable apportionment, Mississippi has an enforceable right to the groundwater in the Aquifer. *Hood* squarely held that it does not. *See Hood*, 570 F.3d at 630 ("The Aquifer is an interstate water source, and the amount of water to which each state is entitled from a disputed interstate water source must be allocated before one state may sue an entity for invading its share."); 2014 Compl. ¶ 35 ("Prior attempts to litigate these issues [in *Hood*] have been unsuccessful."). The ruling in *Hood* was "a valid court determination essential to [a] prior judgment." *New Hampshire*, 532 U.S. at 748-49; *see* 2016 Op. 26.

Mississippi had "a full and fair opportunity to litigate" the issue that *Hood* resolved against it. *Montana v. United States*, 440 U.S. 147, 153 (1979). That opportunity included Mississippi's unsuccessful efforts – based on the same arguments it advances here again – to convince this Court that the courts below erred in resolving that issue against Mississippi. *See Mississippi v. City of Memphis*, 559 U.S. 904 (2010).[12] Mississippi thus is precluded from

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[12] *Compare* Miss. Cert. Pet. 12 (Mississippi "owns the surface water and ground water resources within the geographical confines of its boundaries as a function of statehood") *with* 2014 Compl. ¶ 38 (Mississippi has "sovereign prerogative[]"

challenging *Hood* in this action. *See Montana*, 440 U.S. at 153 (final "determination" of previously litigated issue "is conclusive in subsequent suits based on a different cause of action").[13]

B. Issue Preclusion Applies In This Original Action

This Court's original jurisdiction does not lessen *Hood*'s issue-preclusive effect. This Court has held that once "a [f]ederal court has decided" a jurisdictional issue – even where the court doing so lacks power to rule on the merits – a later court "in which the plea of res judicata is made has not the power to inquire again into that jurisdictional fact." *Stoll v. Gottlieb*, 305 U.S. 165, 172 (1938). That conclusion holds true even when the later court has exclusive jurisdiction. For example, "a state court judgment

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over "waters naturally residing within its boundaries"); *compare* Miss. Cert. Pet. 16-17 (invoking "public trust doctrine"; citing *Cinque Bambini*) *with* 2014 Compl. ¶¶ 11-12 (same); *compare* Miss. Cert. Pet. 12 (distinguishing "equitable apportionment cases" as "involv[ing] disputes between states over surface water flowing through both states in a river, its tributaries or water sheds") *with* 2014 Compl. ¶ 48 (equitable apportionment applies only to water "such as rivers and other surface waters, and the watersheds supplying them").

[13] Although the *Hood* dismissal was under Federal Rule of Civil Procedure 19(b), the judgment remains binding as a matter of issue preclusion. *See* 18A Charles A. Wright, Arthur R. Miller & Edward H. Cooper, *Federal Practice and Procedure* § 4436, at 147 (3d ed. 2017 & 2019 Supp.) (non-merits dismissal "preclude[s] relitigation of the issues determined"). By contrast, because a non-merits dismissal "does not bar a second action as a matter of claim preclusion," *id.*, *Hood* would not foreclose Mississippi from bringing a proper equitable-apportionment action. *Hood*, however, does preclude Mississippi from relitigating the *issue* of whether disputes over the Aquifer are governed by the equitable-apportionment doctrine.

may in some circumstances have preclusive effect in a subsequent action within the exclusive jurisdiction of the federal courts." *Marrese v. American Acad. of Orthopaedic Surgeons*, 470 U.S. 373, 380 (1985); *see Becher v. Contoure Labs., Inc.*, 279 U.S. 388, 391-92 (1929) (reaching that conclusion in a patent suit). The same principle applies here. Just as state-court judgments may bar subsequent cases within the exclusive jurisdiction of federal courts, *Hood* retains issue-preclusive force here. In both contexts, the earlier forum's inability to hear the later suit does not deprive its judgment of issue-preclusive effect.

Affording issue-preclusive effect to *Hood* is consistent with this Court's prerogative to resolve "all controversies between two or more States." 28 U.S.C. § 1251(a). *Hood* itself did not dispose of any claims that Mississippi might bring against Tennessee in an original action, and Tennessee does not contend that *Hood* has *claim*-preclusive effect here. It remains for this Court alone – assisted by the Special Master – to resolve this action. But the Court can and should apply issue-preclusion principles and bar Mississippi from relitigating the issue it already lost. That would represent not an abdication of the Court's original jurisdiction, but rather a prudent exercise of it. *See Arizona v. California*, 530 U.S. 392, 410, 413-18 (2000) (applying issue-preclusion "'principles'" in an original action even when "'the technical rules of preclusion [we]re not strictly applicable'") (quoting *Arizona v. California*, 460 U.S. 605, 619 (1983)).

C. Applying Issue Preclusion In This Water-Rights Dispute Advances That Principle's Core Purposes

Issue preclusion "is central to the purpose" of civil litigation. *Montana*, 440 U.S. at 153. By preventing "parties from contesting matters that they have had a full and fair opportunity to litigate," issue preclusion avoids "the expense and vexation attending multiple lawsuits, conserves judicial resources, and fosters reliance on judicial action." *Id.* at 153-54. Those principles assume particular importance "with respect to rights in real property," including "the holding and use of water rights." *Arizona*, 460 U.S. at 619-20.

Mississippi's attempt to relitigate the issue it lost in *Hood* offends those core principles. Allowing Mississippi to relitigate the central contention that it lost in *Hood* – that the Aquifer water is an interstate resource governed by equitable-apportionment principles – has imposed significant added expense on Tennessee and this Court. And Mississippi's efforts threaten to upend Tennessee's settled expectations in an area where this Court has recognized a "compelling need for certainty." *Id.* at 620. After *Hood* was decided, Defendants continued to use water in the Aquifer – which serves vital municipal needs – in reliance on the Fifth Circuit's holding that Mississippi may not "sue an entity for invading its share" of the Aquifer unless and until the Aquifer is equitably apportioned. *Hood*, 570 F.3d at 630. Mississippi's attempt to relitigate *Hood*'s holding now – and to seek damages for water pumped in direct reliance on *Hood* – undermines a "major purpose" of the rulings in *Hood*: to give Defendants "assurance" regarding "the amount of water they can anticipate to receive

from" the Aquifer. *Arizona*, 460 U.S. at 620. Future litigants should not have to experience what Tennessee has endured: multi-year relitigation of an issue that conclusively disposes of Mississippi's claim to own water within an unapportioned interstate resource.

CONCLUSION

The Court should overrule Mississippi's Exceptions to the Report of the Special Master, sustain Defendants' Exception in Part, and dismiss Mississippi's Complaint with prejudice.

Respectfully submitted,

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APPENDIX

TABLE OF CONTENTS

JOURNAL OF THE AMERICAN WATER RESOURCES ASSOCIATION

AMERICAN WATER RESOURCES ASSOCIATION

PRE-DEVELOPMENT GROUNDWATER CONDITIONS SURROUNDING MEMPHIS, TENNESSEE: CONTROVERSY AND UNEXPECTED OUTCOMES[1]

Brian Waldron and Daniel Larsen[2]

ABSTRACT: Reliance on groundwater resources by differing governing bodies can create transboundary disputes raising questions of ownership and apportionment as the resource becomes strained through overuse or threatened by contamination. Transboundary disputes exist at varying scales, from conflicts between countries to smaller disputes between intrastate jurisdictions. In 2005 within the United States, the State of Mississippi filed a lawsuit against its political neighbor and their utility, the City of Memphis and Memphis Light, Gas, and Water, for groundwater deemed owned by the State of Mississippi to be wrongfully diverted across the state line and into Tennessee by the defendants. The

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basis of the lawsuit was potentiometric maps of groundwater levels for the Memphis aquifer that showed under suggested pre-development conditions no flow occurring across the Mississippi-Tennessee state line, but subsequent historic potentiometric maps show a cone of depression under the City of Memphis with a clear northwesterly gradient from Mississippi into Tennessee. The suggested pre-development conditions were derived from limited groundwater level observations between 41 and 74 years post-development. A new pre-development map is constructed using historic records that range 0-17 years post-development that shows the natural flow is northwesterly from Mississippi into Tennessee and transboundary groundwater quantities have actually decreased since pre-development conditions.

(KEY TERMS: water allocation; water law; data management; water supply; Memphis aquifer.)

Waldron, Brian and Daniel Larsen, 2014. Pre-development Groundwater Conditions Surrounding Memphis, Tennessee: Controversy and Unexpected Outcomes. *Journal of the American Water Resources Association* (JAWRA) 1-21. DOI: 10.1111/jawr.12240

INTRODUCTION

Transboundary water disputes are occurring more commonly as freshwater resources become strained. Conflicts, arising when water usage by one party becomes restricted due to the actions of a second party, occur at varying scales, from large international scale to smaller, intrastate jurisdictional scales (Rowland, 2005). A chief concern in assessing solutions to transboundary water disputes is knowledge of not only the total resource availability and quality but also how those resources have been redistributed or

otherwise impacted due to human activity (Rowland, 2005). A common approach to water quantity or distribution disputes is to determine the water movement prior to water development, to use quantitative modeling to assess pre- and post-development groundwater budgets, and to apportion the resource according to sustainable yield (e.g., Rainwater *et al.*, 2005; Coes *et al.*, 2010). Significant challenges to establishing pre-development conditions are the lack or inconsistency of historic data and consistency of measurements made in the past as well as natural variability that may or may not be sampled by the available historic record (e.g., Meko *et al.*, 2007). Further complicating the picture is the legal presentation of water resource data that were never intended to be applied to establish pre-development conditions across jurisdictional boundaries. In this contribution, historic data acquisition and verification for rigorously determining pre-development water levels in a regional aquifer subject to a transboundary water dispute are discussed. The revised pre-development water level map is used to estimate pre-development water transfer across the boundary and demonstrate the importance of rigorously establishing pre-development hydrologic conditions in transboundary water disputes.

TRANSBOUNDARY WATER ISSUES AND THE CASE OF THE MEMPHIS AQUIFER

Examples of international transboundary groundwater disputes are numerous. In Western Europe, an inventory of transboundary groundwater conditions was conducted in 1999 by the Core Group Groundwater and the United Nations Economic Commission for Europe (UNECE). Of the 37 countries queried, 25 responded with a total of 89 transboundary aquifers

identified (Arnold and Buzas, 2005). The results from the questionnaire indicated that >85% of the transboundary aquifers had groundwater quantity monitoring programs and roughly 80% had groundwater quality monitoring programs. Recognition of transboundary waters between two parties has culminated into joint monitoring agreements, such is the case with the United States (U.S.) and Mexico (1988), Switzerland and France (1978), Germany and Austria (1987), and others (Eckstein and Eckstein, 2005). Yet, interestingly, a conflict between parties is not always recognized among those who utilize the same resource. For example, Arnold and Buzas (2005) point out that one of the discrepancies in the aforementioned survey was that a transboundary aquifer may have been identified by one country but not by its counterpart. Confusion regarding ownership of groundwater beneath one's land owing to the paucity of groundwater law also exacerbates transboundary groundwater conflicts; such is not so much the case with surface water (Matthews, 2005). Surface water, because of its visible passage across the landscape, has a long history of water conflict law and thus the laws are better defined (Arnold and Buzas, 2005). It would seem that at the international scale transboundary groundwater conflicts have had more exposure (U.S.-Mexico Water Treaty, 1994; UNECE Water Convention), yet resolutions are still rarely achieved (Fuentes, 1999; Eckstein and Eckstein, 2005).

In the U.S., recognition of groundwater in transboundary water issues has found substantiation in surface water disputes, primarily in the mid-western and western states. Here, groundwater as early as the late 1800s was considered a tributary to surface water. The two systems have been treated as in-

separable such as in Colorado (McClennan v. Hurdle, 1893; Medano Ditch Co. v. Adams, 1902; Comstock v. Ramsay, 1913), New Mexico (Templeton v. Pecos Valley Artesian Conservancy District, 1958; City of Albuquerque v. Reynolds, 1963), Nebraska (Sporhase v. Nebraska, 1982), and Arizona (Maricopa Co. Municipal Water Conservation District v. Southwest Cotton Company, 1931 and 1932).

In the southeastern U.S., the humid-temperate climate and associated precipitation (mean annual precipitation in Memphis is 142 cm/yr) may account for the lack of clarity in water right's law in comparison to the more arid western part of the country, yet groundwater conflict in this water-rich environment does exist. In 2005, the State of Mississippi filed an action lawsuit against the City of Memphis and the major utility, Memphis Light, Gas, and Water (MLGW), in Tennessee, claiming that groundwater withdrawal from the Memphis aquifer by MLGW had caused diversion of groundwater from beneath Mississippi into Tennessee (Hood v. City of Memphis, 2009). The State of Mississippi claims that under pre-development pumping conditions, the groundwater gradient and, hence groundwater flow under homogeneous, isotropic conditions, was east to west (Criner and Parks, 1976) parallel to the Mississippi-Tennessee state boundary. They further contend that since the pre-development period, which is considered to have ended in 1886 with construction of the first commercial well in Memphis, groundwater withdrawals from the Memphis aquifer in Tennessee, primarily within Shelby County, have caused the gradient to reorient to a southeast-northwest direction (Criner and Parks, 1976; Graham and Parks, 1986; Parks and Carmichael, 1990; Kingsbury, 1996; Brahana and Broshears,

2001), thus causing groundwater claimed to be owned by the State of Mississippi to move northward into Tennessee.

The first well drilled and screened in the Memphis aquifer was constructed by R.C. Graves, owner of the Bohlen-Huse Machine and Lake Ice Company (Bohlen-Huse) well in downtown Memphis in 1886. Pumping from this well is considered to mark the beginning of groundwater development from the Memphis aquifer. Of note, the water that issued from the well was abundant and of great quality as described by Safford (1890).

> The water was clear and sparkling, tonic and palatable. People drank of it. Crowds soon collected about the flowing fountain. Policemen were in requisition. The news spread like wildfire. The elixir of life had been found. Memphians of all degrees, high and low, old and young, with buckets and jugs, coffeepots and tin cans, waited in long files to be served, each in turn, from the gushing, hygienic well. And so for days. In good weather there could be seen lines of baby carriages, each with its little occupant, reaching from the well a square or so away. Physicians gave prescriptions: "Let the baby drink artesian water."

Pumping of groundwater from the Memphis aquifer in Shelby County, Tennessee has continued to increase exponentially since 1886 (Criner and Parks, 1976; Hutson and Morris, 1992; Hutson, 1999; Webbers, 2003). With the current groundwater withdrawal at 712,000 m^3/day, pumping has undoubtedly caused changes in groundwater movement from regions in neighboring Mississippi and Arkansas into Tennessee. Of critical importance regarding apportionment, however, are the deviation in hydraulic head from pre-development to current development

conditions and availability of water to all potential users. A new pre-development potentiometric surface of the Memphis aquifer is presented based on the historical records between 1886 and 1904 that show the natural hydraulic gradient of groundwater was southeast to northwest, and thus flow was northwestward from Mississippi to Tennessee. The new potentiometric surface map indicates that calculations based on the pre-development conditions suggested by Criner and Parks (1976) would greatly underestimate the natural pre-development interstate water transfer. Determination of total interstate groundwater transfer is further complicated in this case by urban development and associated groundwater pumping in northwestern Mississippi, which was not addressed in the State of Mississippi lawsuit. This case study details the historical approach to determining pre-development conditions and some of the problems attendant to clarifying pre- to post-development changes in transboundary water transfer.

SITE DESCRIPTION

The Eocene Memphis aquifer underlies Shelby County, Tennessee, and the adjoining counties in Tennessee, Mississippi, and Arkansas (Figure 1). The Memphis aquifer is a thick, prolific freshwater aquifer that is part of the Mississippi embayment (ME) aquifer system (Hosman and Weiss, 1991). The ME is a shallow sedimentary basin that spans parts of nine states in the south-central U.S. with an axis that approximately follows the trace of the Mississippi River. The ME is filled with nearly 1,000 m of unconsolidated sand, silt, and clay in the study region (Cushing *et al.*, 1964).

The Memphis aquifer is 250 m thick in Shelby County and tapers to no thickness along the margins of the ME (Waldron *et al.*, 2010). South of the Tennessee-Mississippi state line, multiple thin clay-rich confining units separate the Memphis aquifer interval (the transition zone in Figure 1) into multiple aquifer systems (Brahana and Broshears, 2001), including the Sparta aquifer that is correlative to the upper section of the Memphis aquifer and the Meridian (Mississippi) or Carrizo (Arkansas) Sand that is correlative to the lower section of the Memphis aquifer (Waldron *et al.*, 2010).

The Memphis aquifer in Shelby County is confined above and below by the upper Claiborne confining unit and Flour Island confining unit, respectively. However, the upper Claiborne confining unit in Shelby County is leaky (Parks, 1990) and is known to provide an avenue of recharge from overlying water sources to the Memphis aquifer (e.g., Parks *et al.*, 1995; Brahana and Broshears, 2001; Larsen *et al.*, 2003). East of Shelby County, the Memphis aquifer is unconfined (Figure 1), but generally overlain by a thin (<5 m) veneer of Pleistocene loess. The aquifer comprised mainly of fine to very coarse sand with minor clay lenses, with estimated hydraulic conductivity values of 15-30 m/day (Parks and Carmichael, 1990). The quantity of clay increases and grain size of the sand decreases in the Memphis aquifer south of the Tennessee-Mississippi state line (Waldron *et al.*, 2010); however, the magnitude of the hydraulic impact of these textural changes is not known.

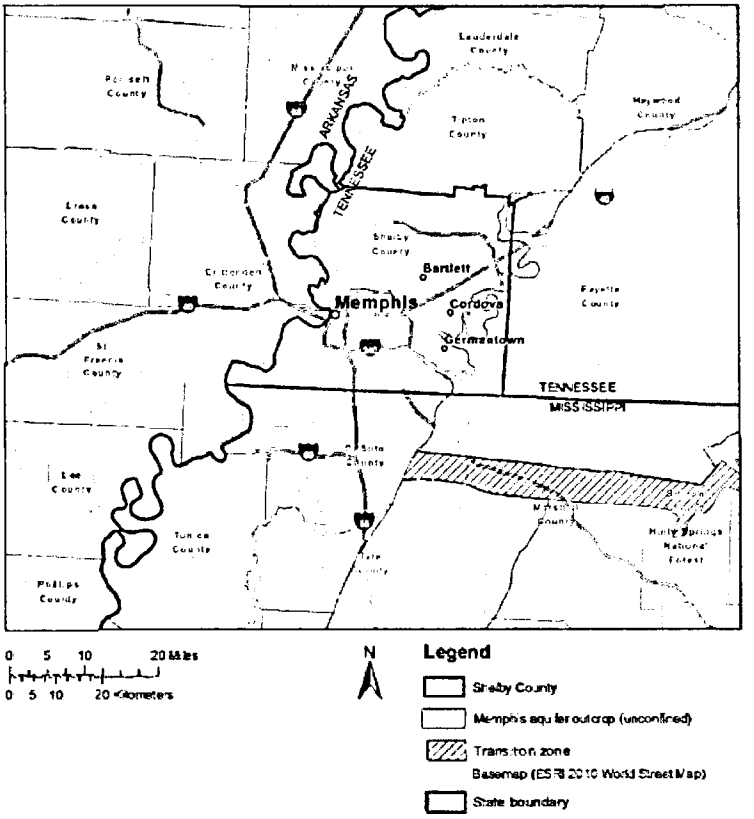

FIGURE 1. Map of the Memphis Area and Surrounding Region, Showing the Estimated Outcrop Zone for the Memphis Aquifer (from Brahana and Broshears, 2001). Transition is approximate southern extent of Memphis aquifer in northern Mississippi, where the regional middle Claiborne is divided into three or more distinct aquifers separated by regional confining units (Waldron *et al.*, 2010).

Criner and Parks (1976) developed a pre-development potentiometric map of the Memphis aquifer beneath Shelby County based on five well locations that depicted groundwater level conditions at the point of discovery of the prolific aquifer system in 1886. They indicate that groundwater generally flowed westward from Fayette County, Tennessee, across Shelby County and into Crittenden County,

Arkansas. Although no water level data were presented for locations in northern Mississippi, they showed perpendicular potentiometric contours along the Tennessee-Mississippi state line, suggesting that no flow occurred across the state line prior to groundwater development (Figure 2).

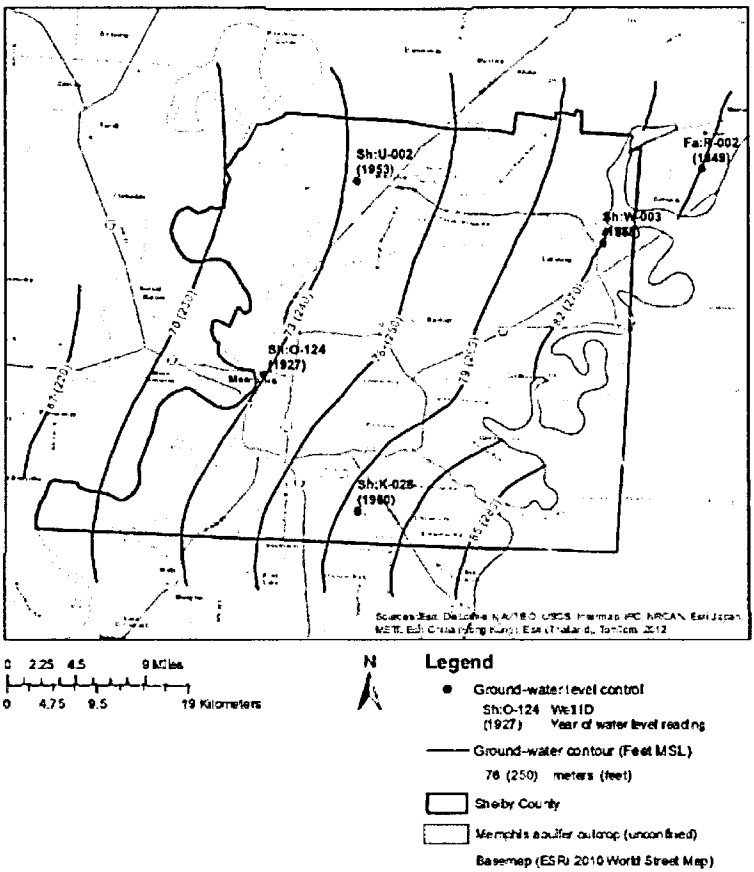

FIGURE 2. Pre-development Potentiometric Surface Map Prepared by Criner and Parks (1976) Showing Wells Used for Control and Dates of Recording Used for Map. Memphis aquifer outcrop pattern from Parks (1990) shown to illustrate region of unconfined conditions.

Since pre-development conditions, pumping in Shelby County has caused groundwater gradients to readjust; hence, the potentiometric contours suggest

flow along the Arkansas-Tennessee state line to be more eastward, flow from Fayette and Tipton counties has made a southerly turn and flow along the Tennessee-Mississippi state line is now toward the northwest (Figure 3). This trend has been apparent since the early 1960s (Criner and Parks, 1976; Graham, 1979; Parks and Carmichael, 1990; Kingsbury, 1992). The large cone of depression in western Shelby County centers on downtown where the oldest well fields exist.

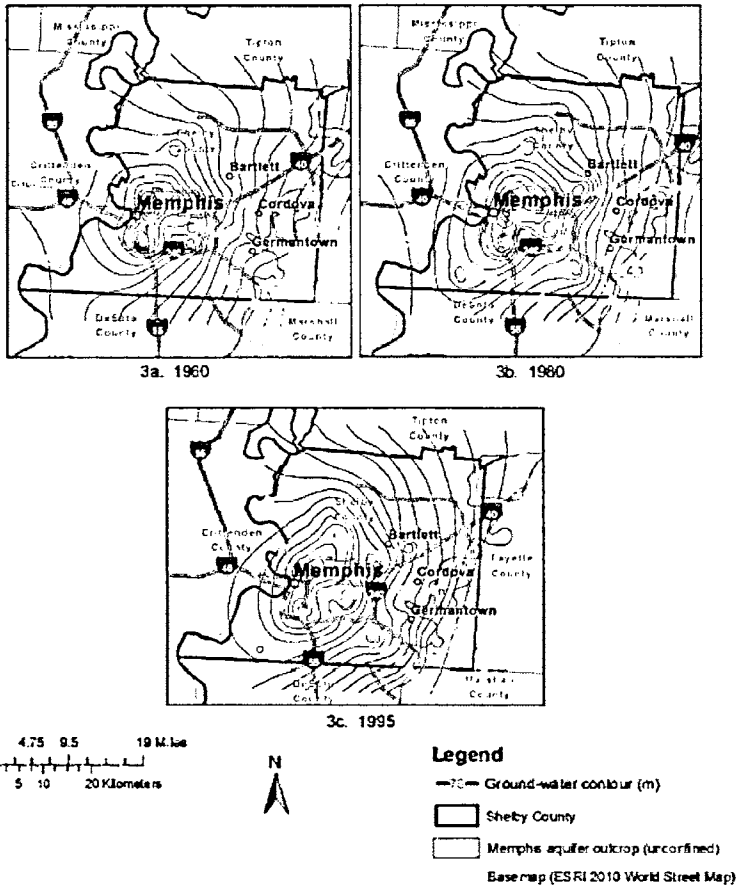

FIGURE 3. Potentiometric Surface Maps for Memphis Aquifer in 1960 (Criner and Parks, 1976), 1980 (Graham, 1982), and 1995 (Kingsbury, 1996). Illustrating changes in water levels in Shelby County, Tennessee as development proceeded during the past century.

In the unconfined regions of the Memphis aquifer, groundwater gradients are expected to be toward the river systems, similar to what is observed in the shallow aquifer beneath Shelby County (Graham and Parks, 1986; Konduru, 2007). Overall, the general flow within the tristate region is toward the embayment axis with a southward trend toward the Gulf of Mexico (Hosman *et al.*, 1968).

Groundwater withdrawal in Shelby has increased exponentially since pre-development. From 1886 to 1975, withdrawals increased from below 38,000 to over 681,000 m^3/day (Criner and Parks, 1976). Over the next 20 years, withdrawals plateaued, averaging 628,000 m^3/day (Hutson and Morris, 1992; Hutson, 1999) before increasing again to a new level of 710,000 m^3/day in 2005 (Webbers, 2003; Kenny *et al.*, 2009).

HISTORY

In 2005, the State of Mississippi filed a lawsuit against the City of Memphis and MLGW in Tennessee, seeking apportionment and compensation (1.3 billion U.S. dollars) for groundwater that has been artificially pulled across the state line between Desoto and Shelby counties due to extensive withdrawals by the defendants. Their claim is based on groundwater flow patterns inferred from the pre-development and post-development potentiometric surface maps of the Memphis aquifer described by Criner and Parks (1976).

In February 2008, Judge Davidson of the U.S. District Court for the Northern District of Mississippi Delta Division ruled that because the Memphis aquifer was an interstate body of water, Tennessee as a sovereign entity should be involved in the

lawsuit pursuant to Rule 19 of the U.S. Federal Rules of Civil Procedure (Hood Ex Rel. Mississippi v. City of Memphis, Tenn., 2008). Because Judge Davidson warranted Tennessee's involvement, lawsuits between states must be heard by the U.S. Supreme Court under 28 U.S.C. §1251(a).

The State of Mississippi appealed Judge Davidson's ruling to the Fifth Circuit Court of Appeals. The original ruling by the District Court was affirmed (Hood v. City of Memphis, 2009). The lawsuit was elevated to the U.S. Supreme Court who dismissed the case without opinion; however, by dismissing without prejudice the State of Mississippi can file the original action with the U.S. Supreme Court if the correct parties are involved and injury is quantified. It remains unknown if the State of Mississippi will pursue the lawsuit further. The pre-development map constructed from this research will have direct bearing on what injury, if any, can be substantiated.

PRE-DEVELOPMENT CONDITIONS

Criner and Parks (1976) constructed their depiction of pre-development conditions using five water level measurements as control. Two control points are in northern Shelby County, the third is in northwestern Fayette County, the fourth control is located in downtown Memphis (not the Bohlen-Huse well), and the remaining control point is located in the southern portion of Shelby County (Figure 2); however, no data from northern Mississippi were used. Criner and Parks (1976) state that the groundwater levels at these locations represent pre-development conditions in the Memphis aquifer before pumping began, which is considered to be 1886 (Criner and Parks, 1976; Brahana and Broshears, 2001; Clark

and Hart, 2009). Yet, the time between pre-development and the water levels used by Criner and Parks (1976) spans 41-74 years post-pre-development.

Earlier records of groundwater levels in the region by Glenn (1906), Crider and Johnson (1906), and Fuller (1903) tabulate locations of towns or persons and information about their wells including well depth, depth to groundwater, pump rate, and water quality. The earliest Memphis aquifer well is the famous R.C. Graves well in downtown Memphis, Tennessee, marking the 1886 pre-development date. As shown in Table 1, wells in Glenn (1906) place the latest well records only 17 years post-pre-development. Mapping these early, near pre-development period groundwater levels is essential to establishing rigorous control on pre-development groundwater conditions in the region, but required determining or, in some cases, reconstructing the locations, ground surface elevations, and screened intervals of each of these wells.

TABLE 1. Continued.

ID	Citation	Town	State	County	Published Ground-Surface Elevation (ft and m) (MSL)	Estimated Ground-Surface Elevation (m) (MSL)	Well Depth (ft and m)	Depth to Water (ft and m)	Calculated Water Elevation (m) (MSL)	Estimated Vertical Error (m)	Method of Location	Well Purpose	Year of Installation	Method of Withdrawal	Supplemental Information
9	Fuller (1903) p. 360	Ina	Tennessee	Fayette	N/A	152	110 ft (34 m)	102 ft (31 m)	121	3.8	F.W. Day; Omni Gazetteer of the United State of America, vol. 4 1991 (found on page 976)	N/A	1900	Valve bucket	F.W. Day from 1910 census lived on South Main so inside city limits; Day was the mail carrier
10	Glenn (1906) p. 71	LaGrange	Tennessee	Fayette	532 ft (162 m)	165	175 and 213 ft (53 and 65 m)	194 ft (59 m)	106	3.6	Placed along Main street and 4th and the railroad to the north	N/A	1906 pub	N/A	Town started on Samuel B. Harper's tract of 167 acres, Oct. 1827; 225 town lots laid off south of 4th street with lots 1-14 north of 4th street; Greenhigh Infirmary (Dr. James Nicholson Cocke) offered water cure baths (1855)
11	Glenn (1906) p. 72	Moorman	Tennessee	Fayette	N/A	116	103 ft (31 m)	53 ft (16 m)	100	2.5	Intersection of Hwy 222 and Winfrey	N/A	1897	Windmill	Issac Bowers (farmer listed in 1900 census; no location information)
12	Glenn (1906) p. 72	Moscow	Tennessee	Fayette	354 ft (108 m)	109	95 ft (29 m)	69 ft (21 m)	27	2.5	Placed at present town center	N/A	1906 pub	N/A	Established in 1826 as part of Daniel W. Head's 60.5 acres; D.W. Head appointed overseer to cut road from Head's Ferry (assumed to

(continued)

TABLE 1. Continued.

ID	Citation	Town	State	County	Published Ground-Surface Elevation (ft and m) (MSL)	Estimated Ground-Surface Elevation (m) (MSL)	Well Depth (ft and m)	Depth to Water (ft and m)	Calculated Water Elevation (m) (MSL)	Estimated Vertical Error (m)	Method of Location	Well Purpose	Year of Installation	Method of Withdrawal	Supplemental Information
															be Hwy 76) to Somerville; Railroad leaving town center toward Somerville on 1876 map; town center on 1876 map shown south of Wolf River in present town location
13	Fuller (1903) p. 360	Oakland	Tennessee	Fayette	N/A	116	125 ft (38 m)	75 ft (23 m)	93	2.5	Center of roads Church (west), Oak (north), Hathaway (east), and Yancy (south)	N/A	~1890	Pump	B.J. Flippin (age 58) is a miller and gin in 1900 census; no location information
14	Glenn (1906) p. 72	Rossville	Tennessee	Fayette	311 ft (95 m)	95	N/A	32 ft (10 m)	86	2.5	Placed at intersection of Main and the railroad	N/A	1906 pub	N/A	John F. Robertson had 200 acre plantation — sold 4 acres to railroad ~1837; Came into existence in 1853, built on 25 acres for building of a town at the depot at a place known as Lafett on the Memphis and Charleston railroad. No depth of well was given, but description stated that well screen was below

(continued)

TABLE 1. Continued.

ID	Citation	Town	State	County	Published Ground-Surface Elevation (ft and m) (MSL)	Estimated Ground-Surface Elevation (m) (MSL)	Well Depth (ft and m)	Depth to Water (ft and m)	Calculated Water Elevation (m) (MSL)	Estimated Vertical Error (m)	Method of Location	Well Purpose	Year of Installation	Method of Withdrawal	Supplemental Information
															clay and in white sand (consistent with description of Memphis Sand)
15	Glenn (1906) p. 72	Somerville	Tennessee	Fayette	356 ft (109 m)	117	136 ft (41 m)	50 ft (15 m)	102	2.7	C.W. Robertson; placed at courthouse where Main circles and heads north as Hwy 76	Domestic	1898	Hand pump	Well used for gardening
16	Fuller (1903) p. 360	Taylor's Chapel	Tennessee	Fayette	N/A	109	80 ft (24 m)	60 ft (18 m)	91	3.7	R.V. Taylor; Omni Gazetteer of the United State of America, vol. 4 1991 (found on page 1121); Cemetery on USGS Lacona quad (7.5 min)	N/A	1902	Valve bucket	
17	Fuller (1903) p. 362	Belle Eagle	Tennessee	Haywood	N/A	101	70 ft (21 m)	60 ft (18 m)	82	3.5	R.H. Taylor	N/A	1896	Bucket	Not in 1900 nor 1910 census
18	Glenn (1906) p. 82	Brownsville	Tennessee	Haywood	344 ft (105 m)	108	230 ft (70 m)	Avg. 47 ft (14 m)	94	5.5	Centroid of town limits in 1877	Municipal	1895	Compressed air	Water level taken from underground waters of TN and KY 1906 (p. 83 top)
19	Fuller (1903) p. 362	Forked Deer	Tennessee	Haywood	N/A	106	96 ft (29 m)	Artesian	106	3.9	H.A. Rainey	N/A	1900	Pump	Not in 1900 nor 1910 census

(continued)

TABLE 1. Continued.

ID	Citation	Town	State	County	Published Ground-Surface Elevation (ft and m) (MSL)	Estimated Ground-Surface Elevation (m) (MSL)	Well Depth (ft and m)	Depth to Water (ft and m)	Calculated Water Elevation (m) (MSL)	Estimated Vertical Error (m)	Method of Location	Well Purpose	Year of Installation	Method of Withdrawal	Supplemental Information
20	Glenn (1906) p. 84	Ged	Tennessee	Haywood	N/A	111	247 ft (75 m)	60 ft (18 m)	92	4.2	Triangulation of location from current road intersections to historic location	Domestic	1906 pub	N/A	TN post offices and postmaster appointments 1789-1984, Frazier, D.R. 1984; Ged was a post office from 5/22/1882 to 12/31/1903; post office map shows Ged south and west of Carolina post office on 1877 map; on 1877 map there is a home (Mrs. E.A. Davie) in the approximate location of Ged with a store located a very short distance west of her property; using the intersection of concentric circles from similar road intersections between the 1877 roads and those that exist presently (Jefferson and rail crossing and Old Highway 19 and Elm Tree) Ged was pinpointed

(continued)

TABLE 1. Continued.

ID	Citation	Town	State	County	Published Ground-Surface Elevation (ft and m) (MSL)	Estimated Ground-Surface Elevation (m) (MSL)	Well Depth (ft and m)	Depth to Water (ft and m)	Calculated Water Elevation (m) (MSL)	Estimated Vertical Error (m)	Method of Location	Well Purpose	Year of Installation	Method of Withdrawal	Supplemental Information
21	Glenn (1906) p. 85	Keeling	Tennessee	Haywood	N/A	110	96 ft (29 m)	46 ft (15 m)	95	2.5	Town existed just west of current intersection of Keeling Road and Fredonia Loop Road	N/A	1896	Valve bucket	
22	Glenn (1906) p. 85	Stanton Depot	Tennessee	Haywood	290 ft (88 m)	101	140 ft (43 m)	40 ft (12 m)	88	3.2	Centroid of small parcel north of Main along southwest-northeast dogleg	Railroad	1906 pub	N/A	Haywood County map (1877) included 3 detailed inserts one being Stanton Depot; a spur from the Memphis Division of Louisville-Nashville Great Southern Railroad ran between the north leg of Main Street to the east and Lafayette Street to the west
23	Fuller (1903) p. 362	Arlington	Tennessee	Shelby	N/A	83	228 ft (67 m)	8 ft (2 m)	25	3.3	Located within old section of town's present location	Railroad	1901	Pump	Water used for locomotives and was of fine quality; same depth to water found by Wells, 1932 pub
24	Glenn (1906) p. 107	Bleak	Tennessee	Shelby	N/A	113	176 ft (54 m)	47 ft (14 m)	98	3.5	Located from 1916 U.S. Soils Map	Stagecoach stop and post	1906 pub	N/A	Mail post to Olive Branch, Mississippi; 4 postmen between 1893 and 1905 from Post Office

(continued)

TABLE 1. Continued.

ID	Citation	Town	State	County	Published Ground-Surface Elevation (ft and m) (MSL)	Estimated Ground-Surface Elevation (m) (MSL)	Well Depth (ft and m)	Depth to Water (ft and m)	Calculated Water Elevation (m) (MSL)	Estimated Vertical Error (m)	Method of Location	Well Purpose	Year of Installation	Method of Withdrawal	Supplemental Information
															Department Library Collection of Historic Maps, 1550-1928; town location present on 1916 U.S. Soils Map
25	Glenn (1906) p. 107	Collierville	Tennessee	Shelby	377 ft (115 m)	119	239 and 248 ft (73 and 76 m)	95 ft (29 m)	27	0.6	Fire station on current town square	Municipal	1906 pub	Pump	Original well site was at same location as the fire station presently on the town square northeast corner
26	Fuller (1903) p. 362	Cordova	Tennessee	Shelby	N/A	110	125 and 128 ft (38 and 39 m)	50 ft (15 m)	95	2.5	Intersection of Macon Road and railroad	N/A & N/A	1900	N/A & boiler	J.W. Allen and W.G. Allen owned wells; Allen family identified on 1888 Shelby County map near Dexter railroad stop east of Cheatam Road
27	Fuller (1903) p. 364	Eads	Tennessee	Shelby	N/A	102	100 ft (30 m)	60 ft (18 m)	84	2.6	T.C. Owen; 1910 Census; lived on Front Street in Eads	Domestic	1898	Pump	Eads was a railroad stop on Tennessee Midland Railroad located 40 chains north of Eads

(continued)

TABLE 1. Continued.

ID	Citation	Town	State	County	Published Ground-Surface Elevation (ft and m) (MSL)	Estimated Ground-Surface Elevation (m) (MSL)	Well Depth (ft and m)	Depth to Water (ft and m)	Calculated Water Elevation (m) (MSL)	Estimated Vertical Error (m)	Method of Location	Well Purpose	Year of Installation	Method of Withdrawal	Supplemental Information
28	Fuller (1903) p. 364	Massey	Tennessee	Shelby	N/A	100	200 ft (61 m)	100 ft (30 m)	69	1.3	Original well site found on old Kirby farm	N/A	1899	Gasoline engine	J.A. Kirby; 1900 Tennessee Census (ED 45 Sheet 3 Line 34); north of Nonconnah Creek in 11th district
29	Glenn (1906) p. 110	Memphis	Tennessee	Shelby	N/A	71	354 ft (108 m)	Artesian	71	1.0	Located on R.C. Graves well house property using 1890 Sanborn maps	Municipal	1886	Artesian	1901 map of Memphis, TN; artesian water department shown south of Auction, north of Concord, between Fifth and Fourth just east of Bayou Gayoso Creek
30	Glenn (1906) p. 116	Covington	Tennessee	Tipton	316 ft (96 m)	87	533 ft (162 m)	31 ft (9 m)	77	2.5	ICRR rail depot	Railroad	1906 pub	Pump	On 1909 plate maps, the ICRR Depot is located in Block 8, sheet 8 between Liberty to the west, Pleasant to the south and between the 2nd and 3rd spurs from the west
31	Glenn (1906) p. 117	Tabernacle	Tennessee	Tipton	N/A	101	225 ft (69 m)	106 ft (32 m)	68	3.8	Intersection of Tabernacle and Hwy 179	N/A	1906 pub	N/A	Underground waters of TN KY 1906 (p. 117)

Note: MSL, mean sea level.

APPROACH AND METHODS

Finding Historic Well Locations

As these late 19th and early 20th Century wells no longer exist, determining their location required an extensive analysis of archive records available in county courthouses, libraries, and digital databases. Some well records mention only the town name. In these cases, historic maps were used to place the well in the approximate center of the road network for that town (see id's 1-5, 7, 10-13, 15-21, 24, and 31 in Table 1). In these instances, the spatial error would be at its largest covering multiple city blocks with the largest estimated error at just under 450 m. In many of these instances, the well was used to provide water to steam locomotives; in these cases, the well was placed near the rail yard (see id's 14, 22, 23, and 30 in Table 1). The remainder of the wells were located based on a well owner's name whose location could be determined from either 1900 or 1910 census records (i.e., an address) (see id's 6, 9, and 27), property descriptions, and blueprint drawings (see id's 8, 25, and 29) or their property boundary that was found on historic plats (see id's 18, 26, and 28). In these latter instances, the spatial error would be at its lowest with some well locations mapped direct atop the structure in which they were housed. Spatial error will be incorporated into the analysis of flow across the Tennessee-Mississippi state line in a later section.

Determining Ground Surface Elevations

The water level for each well was recorded as depth to water (Fuller, 1903; Crider and Johnson, 1906; Glenn, 1906). To standardize the water levels, the approximate ground surface elevation of the well was determined in reference to mean sea level (MSL)

using the vertical datum of 1988. The most accurate ground surface elevation came from surveying the well. The original well sites at Helena, Arkansas and Forrest City, Arkansas still exist. A survey traverse was performed from a benchmark to the well site and the measured ground surface elevation used.

The second most accurate elevation was from interpolation of elevation contours mapped by the U.S. Army Corps of Engineers (USACE) during the 1930s (USACE, 1932). Using these older elevation contours was critical in downtown Memphis, Tennessee, where growth and development have greatly altered the landscape. The only well located in downtown Memphis was the Bohlen-Huse well drilled by R.C. Graves in 1886. Glenn (1906) stated that the original water level in this well was 68.9 m MSL. Based on the location of the Bohlen-Huse facility from an 1897 Sanborn map, the ground surface elevation as interpolated from a 1932 USACE contour map was approximately 234 ft (71.0 m) MSL. Given that flowing artesian conditions originally existed at the well, the water level for this well was adjusted from 68.9 m to reflect the 71.0 m land surface elevation. Wells (1932, 1933) suggests that the original water level for this well was between 70.1 and 71.6 m MSL.

For the remainder of the wells, the lack of data for original land surface elevations, such as that available for wells mapped in downtown Memphis, required using more recent elevation data: 60-cm resolution LiDAR (2006) and the U.S. Geological Survey (USGS) national elevation dataset (NED) at 30-m spacing. As LiDAR existed only for Shelby County, Tennessee, ground surface elevation estimates for the wells in Shelby County with the exception of the Bohlen-Huse well were determined using this

dataset. The USGS NED dataset was used for the remainder of the wells. For wells mapped to a town center, an average ground surface elevation was calculated based on the elevations within the boundary of the town's outskirts as defined by its historic road network. When a town's boundary could not be determined, an elevation was calculated by averaging elevations within a square kilometer area centered on the well point. Fewer elevations were included in the average for those instances where the well was more accurately located to a rail yard or property boundary.

Vertical error is introduced when using the LiDAR and USGS NED with the latter having the largest error of approximately 2.44 m. An estimate of the vertical error was calculated based on comparing the average elevation plus one standard deviation to the NED error; the larger of the two was set as the vertical error. As an estimate of the vertical error for the LiDAR data was not available, those wells whose elevations were measured using LiDAR were assigned a vertical error estimate of 2.44 m. In those instances when the well location and elevation were surveyed, the vertical error was less than 1 cm. Vertical error (see Table 1) will be incorporated into the analysis of flow across the Tennessee-Mississippi state line in a later section.

Validating Well Screen Intervals in the Memphis Aquifer

The final step to assessing wells appropriate for determining pre-development conditions was to ascertain whether the well was screened within the Memphis aquifer. As none of the well records had screen information, it was assumed that the base of the well screen was equal to the well's total depth.

Using the total well depth as a guide, nearby geophysical logs to each well were used to validate proper emplacement in the Memphis aquifer.

Constructing Memphis Aquifer Pre-development Water Levels

The pre-development groundwater level condition for the Memphis aquifer shown in Figure 4 was developed using 27 control points over an 11-county footprint. Water level contouring was a two-part process. First, Delaunay triangulation was performed to obtain a preliminary representation of the water level contours. Using the triangulation results plus the distance measurements from the convex hull, water level contours were adjusted further by hand to smooth jagged contours often associated with this technique and more accurately represent the groundwater/surface water connection in the unconfined area of the Memphis aquifer.

In Fayette and Haywood County, Tennessee where the Memphis aquifer is unconfined, groundwater contours were drawn to depict gaining streams, crossing the streams where the ground surface equaled the groundwater contour elevation (Figure 4). The lack of data control in Mississippi prevented detailing water level conformation to stream valleys. Along the Tennessee-Mississippi border, groundwater gradients are not east to west as suggested by Criner and Parks (1976), but they have a northwest orientation across the state line before turning westward in northern Shelby County and Tipton County toward Arkansas. Once in Arkansas, the gradients turn south following the overall plunge of the ME toward the Gulf of Mexico (Hosman *et al.*, 1968).

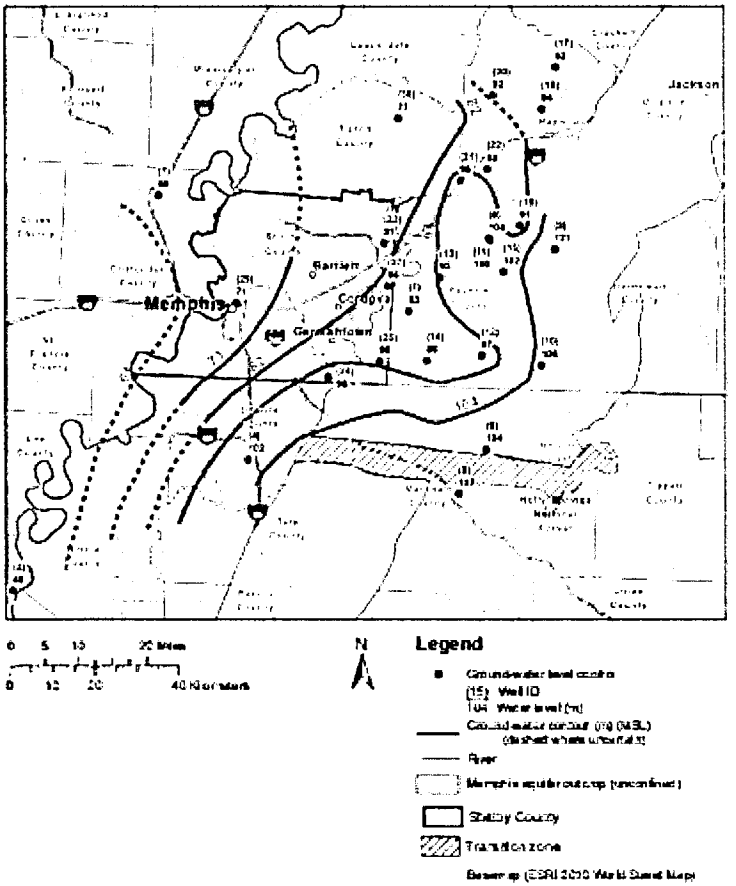

FIGURE 4. Pre-development Potentiometric Surface for the Memphis Aquifer from This Study.

A comparison of groundwater volumes crossing the Tennessee-Mississippi state line, specifically along the Shelby County-Desoto and Marshall County boundary, is made using our proposed pre-development conditions and more recent conditions as mapped by Schrader (2008). To estimate the volumes of flow crossing between Mississippi and Tennessee specifically along the Shelby County border, Darcy's law was employed using a range of

saturated thickness of 209-284 m (Gomberg *et al.*, 2003), a range of hydraulic conductivity of 13-18.6 m/day for the Memphis Sand (TN) or Sparta Sand (MS) (Waldron *et al.*, 2010), and calculated hydraulic gradients that vary in magnitude depending upon location along the Shelby County southern border.

For the pre-development condition as shown in Figure 4, volumetric water rates range from 156,292 to 294,378 m^3/day across the range of hydraulic conductivity and aquifer thickness with an average rate of 219,922 m^3/day. A range of hydraulic gradients across the Mississippi-Tennessee state line along Shelby County was derived from the contours where they vary between 0.00034 and 0.00138. Devlin (2003) offers an alternative quantitative method to deriving gradients from the observed point heads in a linear gradient field. Following Devlin's approach, the gradient across the state line is 0.00026, lower than that derived from the contours. As the gradient field, as interpolated from the water level, suggests a non-linear flow pattern across the state line, the gradients derived from the contours will be used. When considering the vertical error (see Table 1), the volumetric flow-rate range expands to be between approximately 139,000 and 331,000 m^3/day with an average rate of 221,000 m^3/day. The spatial location error is not considered as it does not impact the position of the contours.

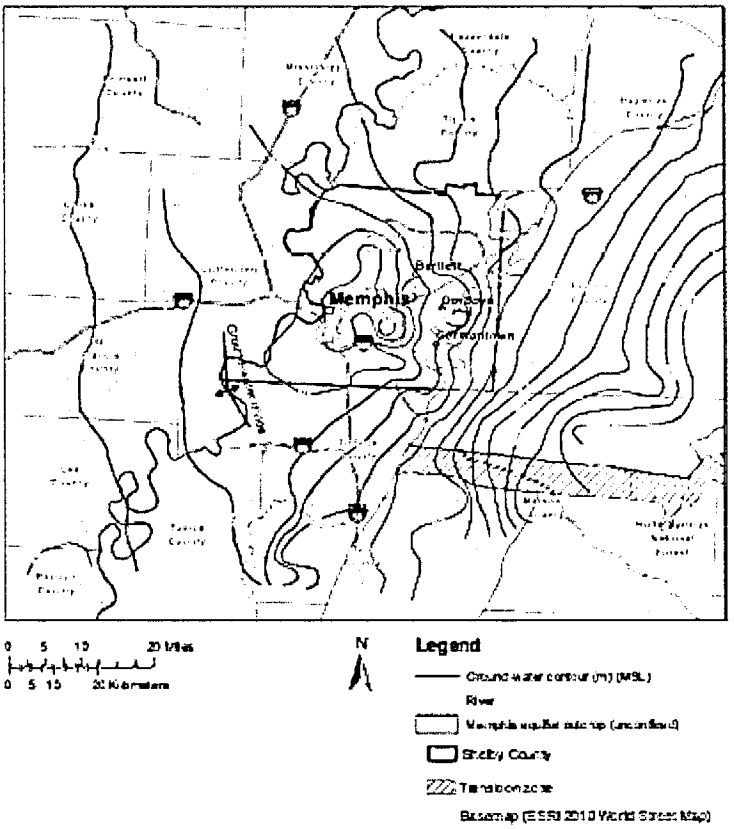

FIGURE 5. Regional Potentiometric Surface for the Memphis Aquifer and Middle Claiborne Aquifer (south of transition zone) Developed by Schrader (2008).

The same calculation was repeated using the same aquifer parameter ranges, but using the 2007 Memphis aquifer potentiometric surface by Schrader (2008) (Figure 5). The groundwater gradient in 2007 is primarily west to northwest from Mississippi into Shelby County except along the western edge where a groundwater divide is present (Figure 5). The range of gradients is 0.000132-0.00170. The estimated quantity of flow crossing into Shelby County from

Mississippi using Schrader's (2008) potentiometric surface is on average 186,000 m^3/day with a range of approximately 132,000-249,000 m^3/day. Without information from Schrader (2008) on the spatial and vertical error of their water levels an analysis of error cannot be performed.

DISCUSSION

The State of Mississippi claimed that pumping in Shelby County, Tennessee caused groundwater from the Memphis aquifer to reorient its original, pre-development direction from east-to-west to northwest across the state line; hence, water that was once the property of the State of Mississippi was now being withdrawn for use in Tennessee. Mississippi based its claim on the pre-development potentiometric surface map presented by Criner and Parks (1976) that was estimated using four control points with no southern control proximal to the state line border. The validity of the downtown control point used by Criner and Parks (1976) is questionable as it was not taken from an actual well screened within the Memphis aquifer, but was a water level extracted from an underground network of tunnels that collected and conveyed groundwater as it rose under pressure into the tunnel network. The three remaining control points are in the northern part of Shelby and Fayette counties. The water levels used for these controls are at least 68 years post-pre-development, which is considered to be 1886. Although Criner and Parks' (1976) map was useful for illustrating the overall pre-development water levels in Shelby County, Tennessee, for the scope of their study, the map is clearly inappropriate for supporting the State of Mississippi's claims.

In cases of transboundary groundwater quantity disputes, such as that between the State of Mississippi and MLGW, preparation of a well constrained water level map based on data approaching pre-development conditions is essential. The pre-development water level map of groundwater conditions in the Memphis aquifer presented in this study uses 27 control points whose latest water level records are only eight years post-pre-development (1886). Six control points are within Shelby County with the remainder scattered throughout the adjoining counties of which three are in Mississippi. This improved pre-development map indicates that groundwater naturally flowed from Mississippi into Tennessee prior to major pumping within Shelby County. The estimated average quantity of flow from Mississippi into Shelby County around the time of pre-development was approximately 220,000 m^3/day as compared to zero or no flow according to Criner and Parks (1976). Accounting for uncertainty in the data, the volumetric flow crossing from Mississippi into Shelby County, Tennessee is still much greater than zero where the range is approximately 139,000 and 331,000 m^3/day with an average rate of 221,000 m^3/day.

Schrader (2008) indicated that in 2007 the Memphis aquifer water levels were oriented toward the pumping centers, causing a large cone of depression under downtown Memphis. Groundwater gradients along the Shelby/Desoto County lines were primarily northwestward into Shelby County. Along the state line near the eastern edge of Shelby County, the gradient (see Figure 5) had a more westward orientation as compared to the northwest direction shown in Figure 3; hence, less groundwater would pass from

Mississippi into Tennessee at this location. Given that urban growth in northwestern Mississippi has increased greatly over the past 20 years and is fastest growing urban area in the State of Mississippi, it is likely that groundwater may in the future move from Tennessee to Mississippi. The lack of well control and thus contours along the southwest corner of Shelby County limits the accuracy of our average estimate crossing the Mississippi state line (186,000 m^3/day) into Shelby County. Adding greater control near the two southern corners of Shelby County on future groundwater level mapping efforts will improve our ability to better estimate the amount of groundwater flowing across the state line.

The results of this study raise concern in the State of Mississippi's claim that MLGW altered a zero-gradient flow condition along the Shelby County to now unrightfully pull groundwater across the county line due to excessive pumping in Shelby County. This study demonstrates the utility of accurate reconstruction of early groundwater conditions in assessing the validity of transboundary water disputes. This research also amplifies the importance of retaining historic groundwater level records and the need for additional groundwater level control along political boundaries that may separate regional groundwater resources.

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U.S. Department of the Interior
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Basic Ground-Water Hydrology

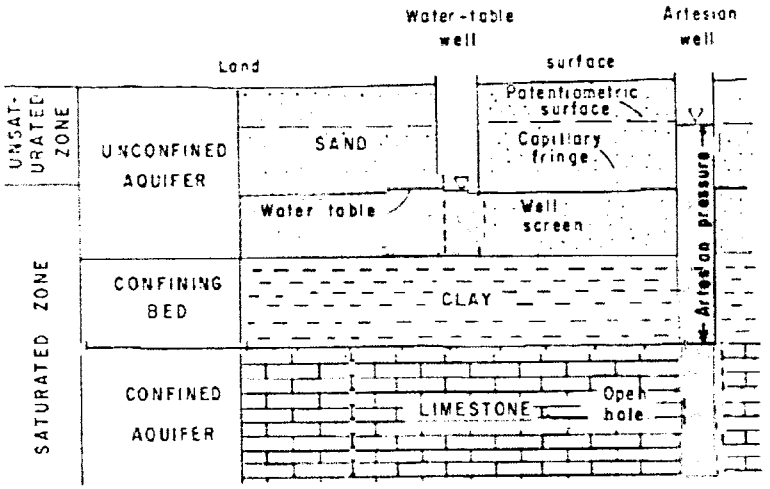
Water-Supply Paper 2220

By RALPH C. HEATH

Prepared in cooperation with the
North Carolina Department of Natural Resources
and Community Development

* * *

[p. 6; pdf p. 11 of Joint Exhibit 40]



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[p. 35; pdf p. 40 of Joint Exhibit 40]