No. 142, Original

In the

Supreme Court of the United States

STATE OF FLORIDA,

Plaintiff,

v.

STATE OF GEORGIA,

Defendant.

Before the Special Master

Hon. Ralph I. Lancaster

PRE-FILED DIRECT TESTIMONY OF FLORIDA WITNESS DR. SAMUEL A. FLEWELLING, PH.D.

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I. INTRODUCTION

1. I, Samuel Flewelling, am a hydrologist with a Ph.D. in environmental sciences. I study the movement of water as it moves across and through the earth, as well as the atmosphere. Water moving across the surface of the earth is called surface water, while water moving underneath the earth is called groundwater. I work as a scientist at the consulting firm, Gradient, on a wide range of hydrology projects.

2. I was retained by the State of Florida to evaluate the hydrology of the Apalachicola-Chattahoochee-Flint River Basin, or ACF Basin.

3. Based on the research and analysis I performed, as well as my scientific training and experience, I reached certain conclusions about the hydrology of the ACF Basin.

4. Before describing those conclusions, I provide an overview on how hydrologists measure the flow of water in a stream or river using the "cubic feet per second" (cfs) unit of measurement. This unit measures the amount of cubic feet of water that passes a specific point on the river within one second.

5. The consumption of water due to human activity in the Georgia portion of the ACF Basin has increased dramatically since the 1970s, when monthly use in the summer was no more than about 440 cfs.

6. In recent years, peak summer consumption of water due to human activity in the Georgia portion of the ACF Basin has reached peaks of over 5,000 cfs.

7. Agricultural water use in the Georgia ACF Basin is the single largest use. Large amounts of water in the Georgia ACF Basin are also consumed for municipal and industrial purposes, and by evaporation from man-made impoundments (*e.g.*, farm ponds). In addition, Georgia exports water from the ACF Basin to locations outside the basin, from which that water does not return. (These are called inter-basin transfers.)

8. My estimates of water use in the Georgia portion of the ACF Basin are conservative. These conservative estimates are useful for understanding the temporal and spatial patterns of consumptive water use in the ACF Basin, but are known to understate total water consumption. That is, although they represent a substantial portion of Georgia's actual use, my estimates certainly understate actual usage, for reasons that I explain in this testimony.

9. Generally speaking, I added up the estimates of consumptive use from various sources, such as readings from meters on center-pivot irrigation systems, none of which purport to capture all water use. I refer to this as a bottom-up approach.

10. The bottom-up approach is a different approach from using rainfall/runoff computer models to simulate the overall water budget, which is a system-wide accounting of all the changes in the amount of water that enters and leaves a particular area. Rainfall/runoff computer models estimate the portion of the overall water budget attributable to human activities. In contrast to my work to develop bottom-up estimates, Dr. Hornberger and Dr. Lettenmaier used rainfall/runoff models to provide what is called a top-down estimate of the amount of water missing from the water budget due to human consumption.

11. Georgia's consumptive water use in the ACF Basin is projected to increase substantially over the coming decades.

12. I also conclude that relatively little water use occurs in the Florida and Alabama portions of the ACF Basin.

II. PROFESSIONAL BACKGROUND

13. I am a scientist at Gradient with 15 years of experience on various topics related to hydrology and geology. I earned a Bachelor of Arts degree in environmental sciences in 2001 and a Ph.D. in environmental sciences in 2009, both from the University of Virginia. I have evaluated the hydrological water balance and effects of human water extractions on multiple

occasions.

14. My Ph.D. dissertation focused on the water balance of an agricultural watershed in the Coastal Plain of Virginia, which is contiguous with the Coastal Plain region that extends throughout much of the Atlantic and Gulf Coast regions, including southwest Georgia. A water balance is an accounting of the inflows (*i.e.*, precipitation), outflows (*i.e.*, evapotranspiration and stream/river flow), and storage of water in a specific area (*e.g.*, a watershed or reservoir). Although the basic accounting of water in a water balance is akin to balancing a check book, the individual components of a water balance (*i.e.*, inflows, outflows, and storage) are related to physics that control the routing of water through the environment.

15. My education includes graduate-level courses where I calculated evapotranspiration demand for crops and forests, and measured evapotranspiration directly with specially instrumented atmospheric monitoring towers. Evapotranspiration is the combination of evaporation of water from soils/open water bodies and from plant leaves. I subsequently taught the laboratory section of a graduate-level watershed hydrology course, where I led students in measuring evapotranspiration over vegetated surfaces, such as turf grass.

16. As a consultant, I conducted an extensive compilation of groundwater and surface water supply information throughout the contiguous United States, as well as an analysis of the Global Reservoir and Dam (GRanD) database and the entire U.S. Geological Survey (USGS) database of stream monitoring data (thousands of locations with daily flow data stretching back in time more than a century). I compiled county-by-county data on irrigated and un-irrigated acreage of corn, sorghum, and sugarcane for the entire United States from the 1960s to present, as part of an assessment of groundwater-stream interactions and agricultural chemical transport throughout the U.S. This work also included an evaluation of the effects of tile-drained

agricultural lands on groundwater-surface water interactions and an assessment of groundwater baseflow to streams throughout the Midwest.

17. Also as a consultant, I have applied my knowledge of hydrology to solve a range of complex challenges associated with the oil and gas, electric power, chemical manufacturing, pharmaceutical, mining, agrichemical, and waste disposal sectors.

18. I have published peer-reviewed papers on a variety of topics ranging from the natural controls on agricultural chemical migration through the landscape, to the potential for hydraulic fracturing fluid to migrate through fractures and faults to shallow drinking water resources. A complete list of my publications is included in my curriculum vitae, which is Appendix A of my expert report. (Expert Report of Dr. Samuel A. Flewelling (February 29, 2016) ("Flewelling Report"), FX-786.)

III. BACKGROUND ON WATER USE ESTIMATES IN THE ACF RIVER BASIN

A. Overview of Methodology

19. For my work, I drew on multiple sources of data, including previous studies, databases of individual water users, and my own analysis based on established scientific principles, to examine the primary water uses in the ACF Basin. I analyzed historical water use data in the ACF Basin and used that data to reconstruct a historical record of annual and monthly water use in the basin. I also analyzed the information available to develop an estimate of future water use in the Georgia portion of the ACF Basin.

20. I primarily relied on Georgia's own data. I recognize that this approach is conservative, meaning that my estimates of Georgia's water use are low, including for the many reasons I explain in Sections IV to IX below. I also recognize that the methodology I used to sum up consumptive use estimates for the various categories of Georgia's water use understates total use, because inevitably some water use falls outside those categories and the specific

resources Georgia has available to compile the data.

21. My approach is therefore conservative, although it represents a substantial portion of the water that people in the Georgia portion of the ACF Basin use. I understand that other hydrologists, such as Dr. George Hornberger, will testify that basic hydrologic data and the results of rainfall/runoff modeling indicate that actual water use in the Georgia portion of the ACF Basin is higher. My conservative consumptive water use estimates for the Georgia portion of the ACF Basin are presented in detail in the Georgia Consumptive Use Spreadsheet, which I created using generally scientifically accepted principles and methodology in February 2016. FX-641 is a true and accurate copy of the Georgia Consumptive Use Spreadsheet.

22. Water withdrawals and consumptive use in all categories described below are dominated by human activities in Georgia's portion of the ACF Basin. Based on my analysis, Florida's water use is a small fraction of the basin total and is not a significant contributor to water use in the ACF Basin.

B. Key Terminology and Concepts

23. Prior to detailing the research and analysis I performed in this matter, understanding particular basic hydrological concepts is helpful.

24. Water *withdrawals* (which are also called *demands*) are the amount of water extracted for a given end use. Water withdrawn from a source can be returned (called a *return flow*) or it can be consumed (referred to as *consumptive use*).

25. A *return flow* is the amount of water that returns to a water body after being withdrawn for use. For example, when a city withdraws water from the Chattahoochee River for use for municipal and industrial purposes, the amount of water that the city returns through a sewer system to the river, after treatment, is called the *return flow*. Rainwater that enters a city's sewer systems should not be counted as part of the return flow for determining the rate of water

return because it was not withdrawn from the surface water in the first place.

26. *Consumptive use* is when water evaporates or is transported out of the basin. Any water lost from a basin through consumptive use is not available to sustain river flow in the basin. For example, water used to irrigate crops may be lost to evaporation (*e.g.*, water that evaporates from barren soil), or to transpiration (a term used to describe the process whereby plants transport water from their roots to their leaves where the water can evaporate into the air). Another example of *consumptive use* is the water supplied to a business minus the amount of water that users return to the surface waters via a sewer system.

27. I use the following standard consumptive water use categories to classify water use described in my testimony:

28. *Agricultural*—water used to irrigate crops and farmland;

29. *Municipal and industrial (M&I)*—including, for example, water used for domestic purposes, urban and suburban landscape irrigation, use of water to generate power at power plants and other industrial processes (*e.g.*, pulp and paper processing);

30. *Evaporative water loss from man-made impoundments*—When people create reservoirs or ponds (often referred to as 'surface water impoundments') to store water, they increase the surface area of open water, which increases evaporation of water. When temperatures rise, evaporation rates increase further. As I use it, the term 'man-made impoundments' can be broken down into sub-categories including the water lost to evaporation from small man-made impoundments throughout the basin and evaporative water loss from federal and non-federal (large) reservoirs; and

31. *Inter-basin transfers*—The net amount of water (exports minus imports) that is transported out of the ACF Basin into other watersheds. For example, water withdrawn from the

Flint River Basin for municipal and industrial purposes that is processed after its use by people and returned to a water body *outside* the ACF Basin constitutes an interbasin transfer.

32. Consumptive use, as this term is used in my testimony, is different from a *streamflow depletion*, which is the amount of water that is no longer in or never reaches a surface water body. My testimony focuses on consumptive uses, and the testimony of other Florida experts, including Dr. George Hornberger, analyzes how these consumptive uses translate into streamflow depletions at a given time.

33. Water withdrawals may occur from surface water or groundwater. *Surface water* is the water that collects on the surface of the earth and includes water in streams and rivers. *Groundwater* is the water that exists below the surface of the earth and includes the water that exists in underground aquifers.

34. Surface water withdrawals are drawn directly from streams or rivers. Groundwater withdrawals can occur in the following two ways: (1) water can be pumped directly from the ground and then routed through an irrigation application system; or (2) water can be pumped out of the ground and into a pond (such as a small man-made impoundment), where the water is stored prior to being routed through an irrigation application system (well-to-pond systems).

35. *Cubic feet per second* (cfs) is a unit of measurement for the volume of water flow over time, and can be used to describe the amount of water that is consumed.

36. Consumptive use amounts in cfs can be described as an average over different periods of time, such as annual averages or monthly averages. *Peak monthly* consumptive use amounts will be higher, and under some circumstances substantially higher, than the annual consumptive use amounts. For example, because most agricultural water use occurs during the

growing season, generally in the summer months, *peak monthly* agricultural consumptive use estimates will be much higher than annual average agricultural consumptive use estimates.

IV. TOTAL CONSUMPTIVE WATER USE IN THE ACF BASIN IN GEORGIA, FLORIDA, AND ALABAMA

37. FX-641 (Flewelling, Georgia Consumptive Use Spreadsheet, FX-641) is a true and accurate table I created in February 2016 that summarizes Georgia's overall consumptive water use from 1970 to 2013 across several categories of consumptive use: agricultural, municipal and industrial (M&I), inter-basin transfers, and evaporative loss from small impoundments, and federal and state reservoirs. The datasets I relied upon were either produced by Georgia during discovery or were available publicly from academic institutions, such as Georgia's National Environmentally Sound Production Agriculture Laboratory (NESPAL). It is a generally accepted practice by scientists in my field to rely on consumption data compiled by state agencies and academic institutions. I also used generally accepted scientific principles and methodologies to translate the compiled estimates for months and years across the period I examined, extrapolating based on the data sources I relied on. Detailed explanations of my calculations can be found in my Expert Report at 13-14, 19-23, 25, 29, 30.

38. Georgia's overall consumptive water use in the ACF Basin has increased dramatically since 1970, even when using my conservative estimates. Figure 1 presents the total of Georgia's consumptive use categories in the ACF Basin, that I estimate exceeded 5,000 cfs during the summer months in drought years, using the conservative assumptions.

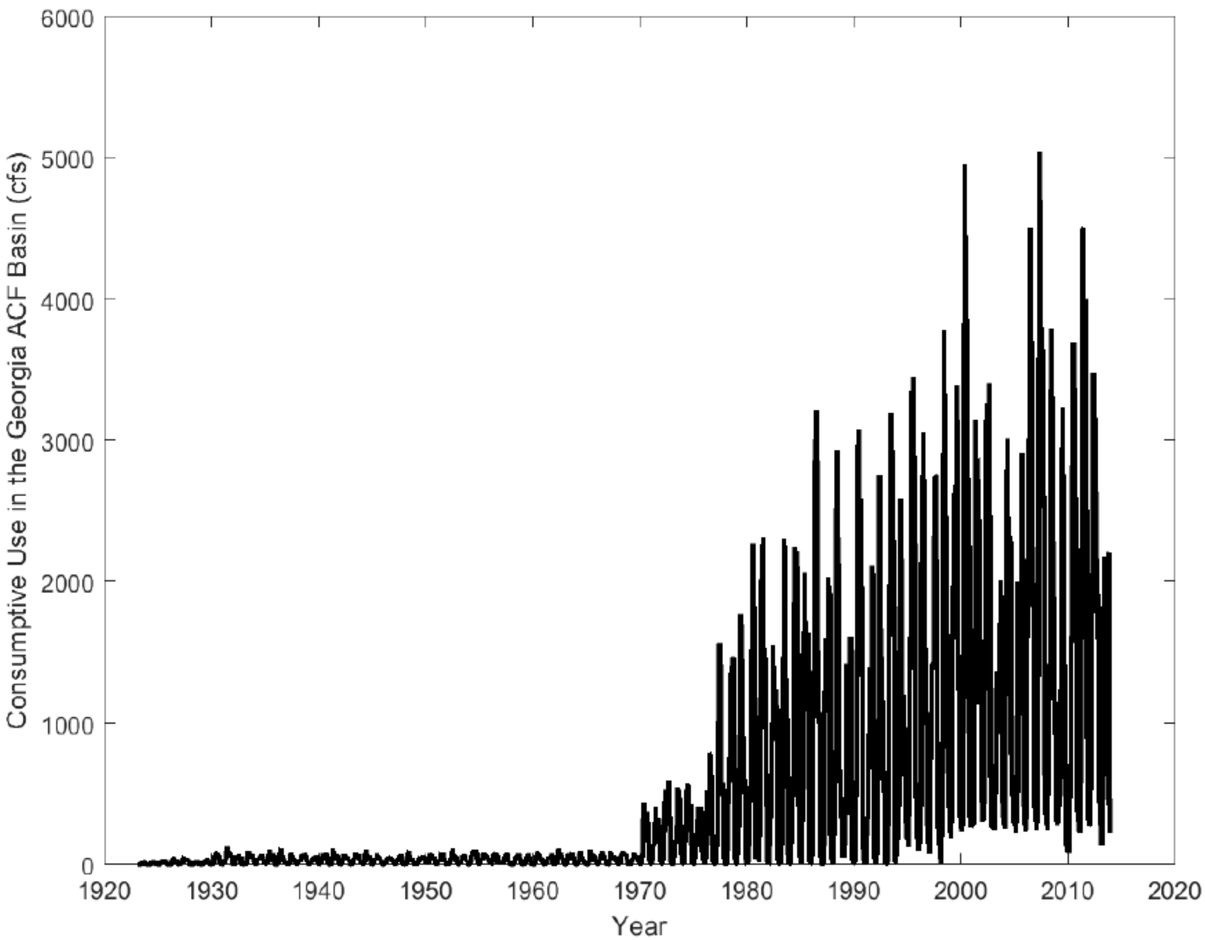

Figure 1. Total Consumptive Use in the Georgia ACF Basin Using Conservative Assumptions and Excluding Federal Reservoir Incremental Evaporation (This Figure was created using the data provided for in FX-641 that was compiled using generally accepted scientific principles. This same Figure was presented as Figure C.4 in my Expert Report at C-3.)

39. Figure 2 is a true and accurate table I created in February 2016 that illustrates estimates of Florida's, Alabama's, and Georgia's total withdrawals on an annual average basis from 1970 to 2013 in the entire ACF Basin over all consumptive use categories. It is a generally accepted practice by scientists in my field to rely on consumptive use data compiled in government reports and databases, as described in my Expert Report (Flewelling Report, FX-786 at 32-33). Figure 2 illustrates that the total water use in the Alabama and Florida portions of the ACF Basin is much lower than in the Georgia portion. Based on my analysis, Florida's water use is a small fraction of the basin total and is not a significant contributor to water use in the

ACF Basin. The total water withdrawals in Figure 2 do not include water used for power plants, often called thermoelectric water use. Water withdrawals for power plants tend to be large, but only a small fraction becomes consumptive use as the vast majority of this water use is returned to the surface waters.

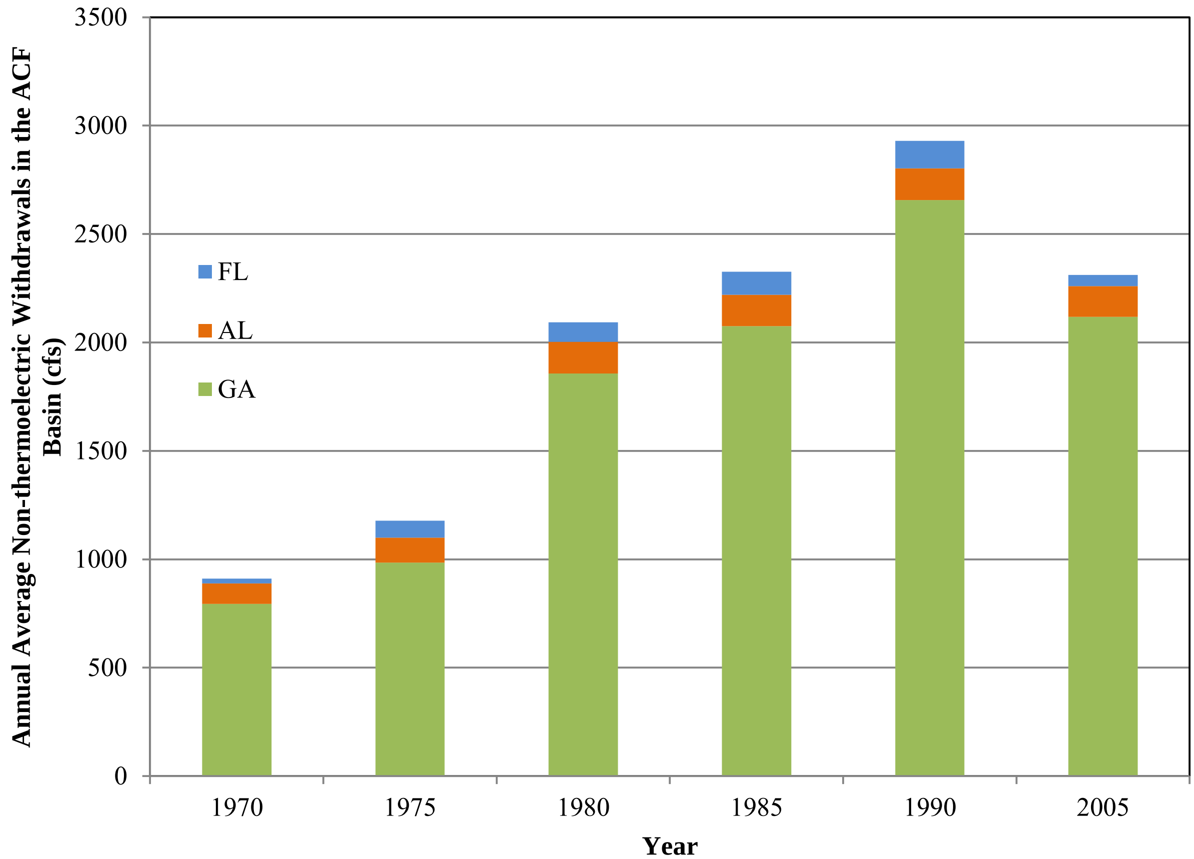

Figure 2. Annual Average Total Water Use (Withdrawals) in the Florida, Alabama, and Georgia Portions of the ACF Basin Using Conservative Assumptions (Figure 7.3 from Flewelling Expert Report). (Flewelling Report, FX-786 at 33.)

40. For example, in two recent years when water use data were available for the Alabama, Florida, and Georgia portions of the ACF Basin, Georgia accounted for over 90% of total non-power plant water use in the basin. (Flewelling Report, FX-786 at 32.)

V. AGRICULTURAL WATER USE IN THE ACF BASIN

41. Figure 3 is a graph I created using generally accepted scientific principles and methodologies in February 2016. It is a true and accurate representation of my estimates of agricultural withdrawals calculated from reconstructed irrigation depths and irrigated area, derived from Georgia's Agriculture Metering Database (JX-138), NESPAL irrigated acreage estimates, and U.S. Department of Agriculture (USDA) Cropland Data Layers, described in my Expert Report in Section 2.3, Dr. Sunding's Expert Report, and in my testimony below. I found that agricultural water use in the Georgia portion of the ACF Basin has increased dramatically since the 1970s. It is the single largest consumptive water use in the basin, reaching nearly 4,000 cfs in peak months using conservative assumptions, as described below (Figure 3).

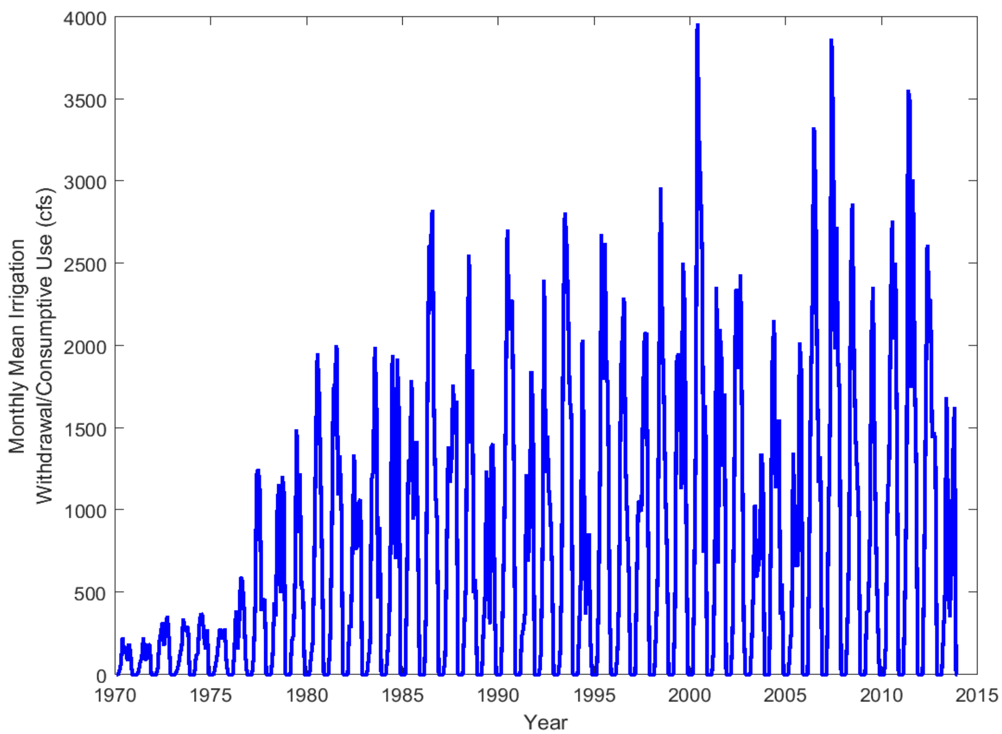

Figure 3. Monthly Irrigation Withdrawals/Consumptive Use in the Georgia ACF Basin for Conservative Withdrawal Estimates (Figure ES.1 from Flewelling Expert). (Flewelling Report, FX-786 at S-2.)

42. In my field it is appropriate to look at state records to determine how state

officials estimate how much water withdrawn for irrigation is consumptively used, meaning it is not returned. As discussed in my Expert Report at 13-14, reports produced on behalf of Georgia's Environmental Protection Division (EPD), statements made by Georgia EPD officials, and the USGS have acknowledged that water used for irrigation in the ACF Basin is virtually all consumptively used. For instance, I reviewed the September 2011 Lower Flint-Ochlockonee Regional Water Plan, an official government water planning document in Georgia. The Lower Flint-Ochlockonee Regional Water Plan included the assumption that agricultural water use is all consumptive, stating, "[b]ased on the recommendation of the Technical Ad Hoc committee, the Council decided to proceed . . . on the 100 percent consumptive use assumption for irrigated agriculture" in order to develop its water management plan. (FX-24, 3-3.) This means that water is completely lost through evaporation or transpiration by crops and no material amount of irrigation water returns to the water bodies from which the water is withdrawn.

43. My estimates of Georgia's agricultural water use are based on an evaluation of data on the two key variables for making agricultural water use estimates: (1) irrigated area—the total number of acres on which farmers in the Georgia ACF Basin are actually irrigating; and (2) irrigation depth—the amount of water those farmers use to irrigate their crops per unit of area, which is often presented as an amount in inches per year.

44. To determine irrigated acreage in the Georgia portion of the ACF Basin, I performed a thorough review of the data sources available, and reconstructed acreage estimates for each year from 1970 to 2014 based on the best information available. A key data source in that review is the irrigated acres mapping work conducted by the University of Georgia's National Environmentally Sound Production Agriculture Laboratory (NESPAL), using aerial imagery and a compilation of prior irrigation mapping efforts by the Georgia Environmental

Protection Division, Georgia Soil and Water Conservation Commission, and Albany State University. This data source is available on NESPAL's website at http://www.nespal.org/SIRP/waterinfo/State/AWD/AgWaterDemand_IrrArea.htm. I accessed this data source in February 2016. FX-269 (Flewelling, Irrigated Agricultural Area Spreadsheet, FX-269) is a true and accurate copy of a chart I prepared using generally scientifically accepted principles and methodology in February 2016 which summarizes my review of numerous irrigated acreage data sources and the annual irrigated acreage estimates from 1970 to 2014, which are described in detail in my Expert Report (Flewelling Report, FX-786 at 7-9). For years prior to the NESPAL mapping, I scaled statewide irrigated acreage down to the ACF Basin and interpolated between reported values of acreage to get an acreage estimate for every year.

45. I personally reviewed the irrigated acreage totals in the Georgia ACF Basin in the Wetted Acreage Database produced by Georgia (Georgia Wetted Acreage Database, JX-129). JX-129 is a true and accurate copy of the database detailing irrigated parcels in the Georgia ACF Basin, which I reviewed and relied upon in forming my opinion. It is a generally accepted practice by scientists in my field to rely upon this type of data. The irrigated acreage estimates contained in FX-269 (Flewelling, Irrigated Agricultural Area Spreadsheet, FX-269) are generally consistent with the number of irrigated acres in the Georgia ACF Basin in recent years as provided in the Wetted Acreage Database.

46. Based on my experience with interpreting these types of datasets, I conclude that the Georgia portion of the ACF Basin's irrigated acreage has increased from less than 75,000 acres in 1970 to more than 825,000 acres in 2014, as summarized in FX-269.

47. Georgia produced its Agricultural Metering Database which compiles the data Georgia collected on the total amount of water those farms use, principally on an annual basis

(Georgia Agricultural Metering Database, JX-138). JX-138 is a true and accurate copy of the database detailing the amount of water used by Georgia farms. This database is maintained by the Georgia Soil and Water Conservation Commission, a state agency. It is a generally accepted practice by scientists in my field to rely upon water use data compiled by state agencies, and I reviewed and relied upon it in forming my opinion. The amount of agricultural water withdrawals are directly measured on a portion of the land irrigated in the Georgia ACF Basin using meters installed on the irrigation systems. Data from Georgia's Agricultural Metering Database (JX-138) were available to calculate irrigation depth from 2008-2013, based on meter readings from about 60-70% of recorded irrigated acreage. In years without Agricultural Metering Database data, I reconstructed irrigation depth based on the relationship between irrigation depths in the database (available for only recent years) and the evapotranspiration deficit (available for all years). The evapotranspiration deficit is a metric of how much water plants may use in addition to that supplied naturally by rainfall. An average irrigation depth was derived from this data, and in low rainfall years is often 12 to more than 17 inches per year.

48. Another Florida expert, Dr. David Sunding, used Georgia's Agricultural Metering Database to calculate irrigation depths that I incorporated into my analysis. After I submitted my February 29, 2016 expert report, Georgia provided new information regarding irrigated acreage data associated with the Agricultural Metering Database. Based on this new information, Dr. Sunding adjusted the irrigation depths calculation (*see* Testimony of Dr. Sunding). I evaluated those irrigation depth values and found that they would only reduce my agricultural consumptive use estimates by 6 to 7%. This change is not material and it does not change my opinions or conclusions regarding Georgia's consumptive use in the ACF Basin, in particular because my estimates are highly conservative.

49. Irrigators in the Georgia ACF Basin withdraw water from both surface water and groundwater sources. I used the estimate that 78% of agricultural withdrawals in the Georgia ACF Basin were from groundwater and 22% were from surface water, which is based on the U.S. Geological Survey's summary of Georgia's Agricultural Metering Database from 2010 to 2014 (USGS Georgia Agricultural Water Conservation and Metering Program Website, JX-104, which is publicly available at http://ga.water.usgs.gov/projects/agwater/, which I accessed in February 2016). JX-104 is a true and accurate copy of the database summarizing Georgia's Agricultural Metering Database from 2010 to 2014, which I reviewed and relied upon in forming my opinion. It is a generally accepted practice by scientists in my field to rely upon consumption data and associated information compiled by federal agencies.

50. As a hydrologist I often review statements made by government officials and university scientists and professors while forming the assumptions that guide my calculations. I reviewed true and accurate copies of the deposition transcripts of the following Georgia officials.

51. Clifford Lewis, the program manager for agricultural water withdrawal permitting at the Georgia Environmental Protection Division, testified that no regulatory groups in the Georgia government keep track of the volumes of agricultural water withdrawals below the 100,000 gallon-per-day threshold below which a state permit is not required. (Lewis Dep. Tr. (November 4, 2015), 12:25–13:4; 26:6-24.)

52. David Eigenberg, deputy director of the Georgia Soil and Water Conservation Commission, testified that there have been reports of tampering with the meters on irrigation systems in the field in Georgia. One example of tampering that has been reported is the removal of meters. He also testified that the Commission does not take steps to protect against tampering with the meters and that he was not aware of any circumstances where Georgia penalized a

farmer for tampering with one of the meters. (Eigenberg Dep. Tr. (November 13, 2015), 14:20-22; 52:4-6, 9-13; 52:22-53:1, 55:8-11.)

53. Mr. Eigenberg testified that some farmers have added irrigation capacity in a way that is not metered, thereby bypassing the meter for those withdrawals. (Eigenberg Dep. Tr. (November 13, 2015), 55:12–56:16.) He also testified that the Commission does not have any means of knowing if the meter has been removed or replaced on the site, or any ability to recover water use data if a meter fails during the course of a year (between the annual meter readings). (Eigenberg Dep. Tr. (November 13, 2015), 65:3-7; 67:3-6.)

54. Mark Masters, director of the Georgia Water Planning and Policy Center at Albany State University in Georgia, testified that there are irrigation sources that are not fully metered. (Masters Dep. Tr. (January 6, 2016), 12:3-18, 265:10-12.) For example, sometimes the source water to a farm serves multiple center pivots, but only one of those center pivots is metered, such that the water to the other center pivots supplied by that source goes unmetered. (Masters Dep. Tr. (January 6, 2016), 265:13-25.) Another example of a source that is not fully metered is when pipes that carry water from the source to the field may be split to send water in different directions, but the meter is on one of the pipes downstream of the split—not on the main pipe. (Masters Dep. Tr. (January 6, 2016), 266:11-19.)

55. Dr. Jim Hook, former professor at the University of Georgia, testified that he found that approximately 20% of water usage for irrigation was done with temporary irrigation equipment that was not stationary, and therefore was not monitored through the metering program. (Hook Dep. Tr. (February 23, 2016), 10:14-18, 152:2-18.)

56. Florida's and Alabama's agricultural consumptive use in the ACF Basin is very small. For example, in the drought year 1990, Florida and Alabama each had about 50 cfs of

annual average agricultural consumptive use compared to 1,060 cfs annual average agricultural water use by Georgia, using highly conservative estimates, as explained in my expert report (Flewelling Report, FX-786 at 17-18).

VI. MUNICIPAL AND INDUSTRIAL WATER USE IN THE ACF BASIN

57. Municipal and industrial (M&I) water use, as I refer to it, can include the following categories: public supply (*e.g.*, water supplied to residents and businesses in metropolitan areas); self-supplied, including domestic (*e.g.*, homeowner wells) and commercial and industrial (*e.g.*, businesses that operate their own wells or surface water intakes); and thermoelectric power generation (*e.g.*, water used for cooling or for potable uses at power generation facilities).

58. It is a generally accepted practice by scientists in my field to rely upon consumption data compiled by state agencies. My analysis focused largely on the M&I consumptive use spreadsheet database produced by Georgia in this case (JX-165). JX-165 is a true and accurate copy of the database detailing monthly water withdrawals and returns, which I reviewed and relied upon in forming my opinion. Georgia's data provided withdrawals and returns on a monthly basis, even though that database did not have data farther back than 1994. Monthly (rather than only annual) data is important because consumptive use peaks in the summer due to outdoor water use, such as landscape irrigation.

59. I recognized that this database understates Georgia's M&I consumptive use in the ACF Basin, and therefore my estimates based on that database are low. For example, this database only includes M&I surface water use, not groundwater use. Data from Georgia's M&I consumptive use database is also biased low due to it understating power plant consumptive use, failing to account for withdrawals from homeowner wells, and counting rainwater as a return flow from combined sewer discharges in parts of Atlanta. Stormwater should not be credited as

a return flow as it was never withdrawn from surface or groundwater in the first place.

60. Even with all of these conservative assumptions and estimates drawn from a database that understates Georgia's M&I water use, the M&I consumptive water use in the Georgia ACF Basin (based on that database, JX-165) is substantial, reaching nearly 650 cfs in a peak month (August 2007). Figure 4 is a graph I created using generally accepted scientific principles and methodologies in February 2016. It is a true and accurate representation of Georgia's monthly record of M&I consumptive use as represented in its M&I consumptive use database (JX-165), which does not include all categories of M&I consumptive use and does not include groundwater M&I withdrawals.

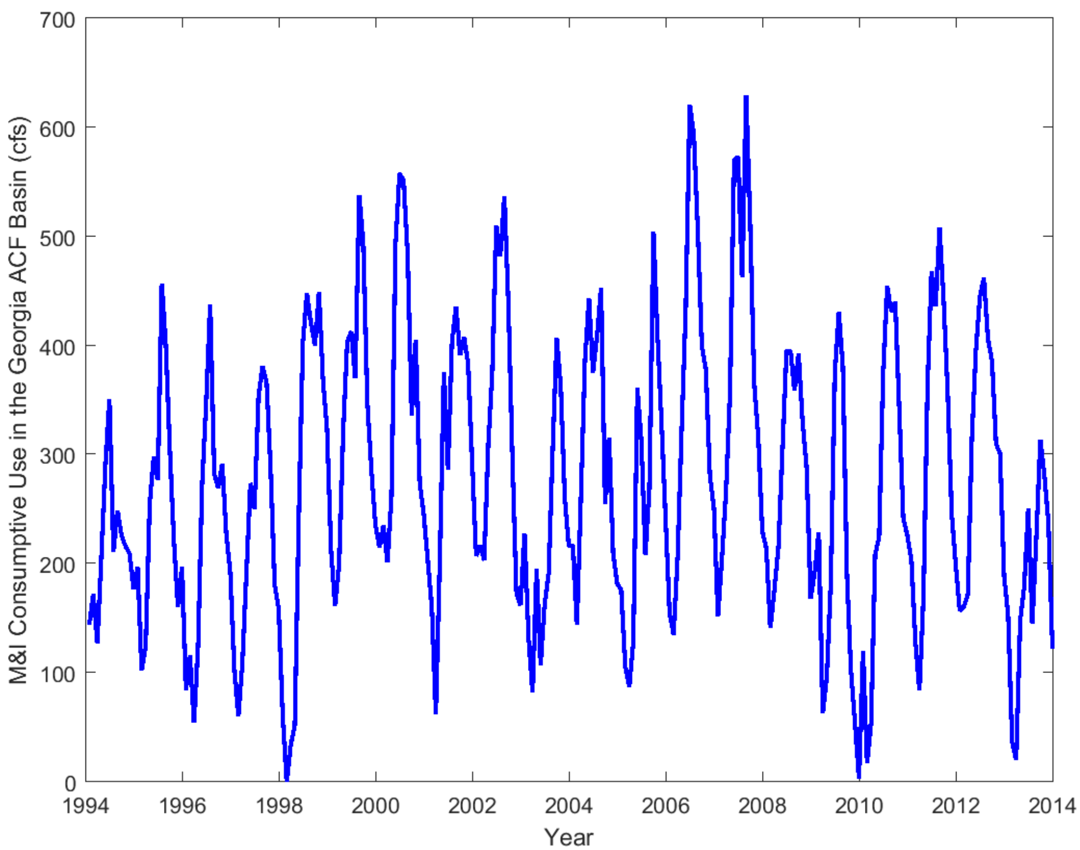

Figure 4. Monthly Record of Surface Water M&I Consumptive Use in Georgia from 1994-2013 as Report by Georgia EPD. (Figure 3.2 from Flewelling Expert Report). (Flewelling Report, FX-786 at 23.)

61. Florida's and Alabama's municipal and industrial consumptive use in the ACF Basin is very small. For example, on an annual average basis M&I consumptive use in Florida was only 24 cfs in 2014-2015 compared to 308 cfs by Georgia in 2012, using highly conservative estimates, as explained in my expert report (Flewelling Report, FX-786 at 23).

VII. EVAPORATION FROM MAN-MADE IMPOUNDMENTS THAT STORE WATER

62. Water is lost from man-made impoundments by evaporation and this contributes to consumptive water use in the ACF Basin. I examined the incremental evaporation from these man-made water bodies, meaning the evaporation that otherwise would not have occurred if these impoundments had not been created and filled.

63. I have classified man-made impoundments into three categories: small impoundments; non-federal reservoirs; and federal reservoirs.

64. Small impoundments (*e.g.*, farm ponds) are man-made ponds or lakes. In the ACF Basin, small impoundments are often used to store water for agricultural irrigation purposes. For example, farmers create ponds to store water pumped from the ground or diverted from a river, and then tap into the ponds to feed center pivot irrigation systems. There has been significant growth in the number and surface area of small impoundments in the Georgia portion of the ACF Basin in recent decades. In the Georgia portion of the ACF Basin, these impoundments collectively now store an amount of water equivalent to about half the conservation storage in Lake Lanier, the largest reservoir on the Chattahoochee River (Flewelling Report, FX-786 at B-5). I determined combined small impoundment surface area in the ACF Basin from satellite imagery. As of 2014, there were more than 20,000 small impoundments covering a combined area of more than 64,500 acres in the Georgia portion of the ACF Basin—a surface area from which evaporation occurs that is almost two times as large as

the surface area of Lake Lanier. My calculation of incremental evaporative loss from these impoundments showed consumptive use in the Georgia ACF Basin that approaches 400 cfs in some summer months in drought years. For more detail on my analysis of small impoundments, see Appendix B of my expert report.

65. FX-534 (GWRI, Unimpaired Flow Assessment report, 2012) is a draft technical report created by the GWRI and the Georgia Institute of Technology (Georgia Tech), who studied the historical stream flows in the ACF Basin, absent human influence that would tend to inhibit streamflow. It is a true and accurate copy of the document produced by Georgia Tech in this case. This kind of report is regularly relied upon by experts in my field, and I reviewed and relied upon this document in forming my opinions in this case. This report estimates that evaporation from small impoundments is about 1,200 cfs in some months with a 12-month running average of over 600 cfs in recent years, (GWRI, Unimpaired Flow Assessment report, 2012, FX-534 at 166, 198-211), further demonstrating the high evaporative water loss from these water bodies.

66. In addition to causing substantial increases in evaporative water loss from the basin, small impoundments also severely hinder recovery from droughts due to their large storage volume. My final consumptive water use estimates for small impoundments in the Georgia ACF Basin are conservative because they do not include this captured water.

67. In addition to these small impoundments, non-federal reservoirs in the Georgia ACF Basin account for incremental increases in evaporation of over 100 cfs in many summer months (Flewelling Report, FX-786 at C-1).

68. Federal reservoirs in the ACF Basin include the five federally-operated reservoirs on the Chattahoochee River. The surface area of these reservoirs is predominantly in the state of

Georgia and accounts for incremental increases in evaporation that are at or near 1,000 cfs in some summer months (Flewelling Report, FX-786 at C-1).

VIII. INTER-BASIN TRANSFERS OF WATER OUT OF THE ACF BASIN

69. I relied upon data on inter-basin transfers compiled on an annual basis and produced by Georgia. In the absence of monthly data on inter-basin transfers, I assumed that the reported annual values were spread evenly throughout the year. I also reviewed the Georgia Water Resources Institute (GWRI) report which modeled the effect of removing inter-basin transfers on ACF Basin water resources and used it to form my opinions in my report and in this testimony. Assessments such as these are regularly reviewed by hydrologists and are considered scientifically reliable in my field.

70. Georgia exports a substantial amount of water from the ACF Basin to areas outside the basin, which significantly affects ACF Basin hydrology. Using Georgia's data, inter-basin transfers accounted for losses approaching 100 cfs on an annual average basis in recent years, such as 99 cfs in 2004 and 90 cfs in 2012 (Flewelling Report, FX-786 at 29).

71. The inter-basin transfer data from Georgia provides annual average values for the amount of water exported out of the ACF Basin in Georgia. As compared to annual average values, inter-basin transfers on a monthly basis are expected to be lower in the winter and higher in the summer relative to the annual average values, similar to the pattern of M&I consumptive use. As a result, the inter-basin transfer estimates I used are conservative with respect to summer time water use.

72. FX-524 (GWRI, First Round Scenario Assessments, 2013, FX-524 at 2, 9) is a draft report created by the GWRI and Georgia Tech. This report evaluates the effects of different Water Management Alternatives on ACF Basin water resources in order to identify performance sensitivities to changes in system operations, infrastructure, and water uses. It is a

true and accurate copy of the document produced by Georgia Tech in this case. This kind of report is regularly relied upon by experts in my field, and I reviewed and relied upon this document in forming my opinions in this case. The GWRI assessment found that the removal of inter-basin transfers had a generally positive effect on water resources through the increase of reservoir levels and river flows. (GWRI, First Round Scenario Assessments, 2013, FX-524 at 2, 9.) The Institute's modeling found that Flint River flows at all locations were sensitive to inter-basin transfer changes, particularly in dry years. For example, removal of inter-basin transfers increased flows in the Flint River Basin in Georgia during dry years at the Griffin gage by 20% and at the Carsonville gage by 7%. Elimination of interbasin transfers also increased minimum lake levels in Lake Lanier by 2 feet during drought years.

IX. GEORGIA'S PROJECTIONS OF INCREASED CONSUMPTIVE WATER USE IN THE ACF BASIN

73. I also evaluated Georgia's estimates of its own projected growth in consumptive water use in the ACF Basin in the future. If no additional conservation measures are put in place, Georgia's consumptive water use will increase substantially in the coming decades.

74. Through its Agricultural Permit Database (Georgia Agricultural Permit Database, JX-132) maintained by the Georgia EPD and produced by Georgia in this case, Georgia has acknowledged that it has already permitted approximately 986,000 acres and allows approximately 17,325 cfs of water withdrawals for agriculture in the ACF Basin (based on the pumping rata data stored in the Agricultural Permit Database). These values come from my February 2016 review of Georgia's Agricultural Permit Database using a search for permitted acres and withdrawals for all active permits (expired permits were excluded) that had a year recorded for the date issued. For comparison, average June through September flow through the Flint River at the USGS stream gage at Bainbridge, Georgia was 1,830 cfs in 2011 and 1,700 cfs

in 2012, and June through September flow through the Apalachicola River at the Chattahoochee gage (just below the Georgia state line) was 5,560 cfs in 2011 and 5,420 cfs in 2012. (JX-128, USGS Historic Gage Data.) Georgia has already allocated over nine times as much water for irrigation as flows through the Flint River and about three times as much as flows through the Apalachicola River during these dry summers. Recent trends from the USDA show that irrigated acreage in the Georgia ACF Basin continues to increase, driving consumptive water use upward (Flewelling Report, FX-786 at 9). JX-132 is a true and accurate copy of the database detailing Georgia's agricultural permits. JX-128 is a true and accurate copy of the database detailing historic gage data. These kinds of databases are regularly relied upon by experts in my field, and I reviewed and relied upon them in forming my opinions in this case.

75. JX-126 is a true and accurate copy of the Water Supply Request, which I reviewed and relied upon in forming my opinion. It is a generally accepted practice by scientists in my field to rely upon this type of data. Georgia submitted a M&I water supply request in 2015 that corresponded to a 57% increase in water demand for the water planning district of the Atlanta metropolitan area. (*See* Georgia Water Supply Request to U.S. Army Corps of Engineers, 2015, JX-126.)

76. The trend in small impoundment surface area has been increasing over time, indicating that it is likely to continue to increase in the future (Flewelling Report, FX-786 at 26).

77. Under conservative assumptions, monthly water use in the Georgia portion of the ACF Basin during a representative drought year could increase to over 7,700 cfs in a peak summer month by the year 2050 (Flewelling Report, FX-786 at 36).

X. CONCLUSION

78. In summary, it is my opinion that the amount of water consumed due to human activity in the Georgia portion of the ACF Basin has increased dramatically from the 1970s to

the present. Even using a conservative accounting approach of totaling up water use in the Georgia ACF Basin using Georgia data sources that underestimate water use, peak summer month consumptive water use estimates for this region are over 5,000 cfs. Agricultural water use is the dominant water use category in the Georgia portion of the basin. Significant amounts of water are also consumed in the Georgia ACF Basin for municipal and industrial as well as the other purposes I describe in my testimony.