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

UPDATED PRE-FILED DIRECT TESTIMONY OF FLORIDA WITNESS ADELBERT "DEL" BOTTCHER

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I. INTRODUCTION

1. My name is Adelbert ("Del") Bottcher, and I am an irrigation specialist who has spent more than 40 years working with farmers in Georgia and Florida.

2. I am a registered professional Agricultural Engineer in the states of Florida, Georgia, and North Carolina, and the president of Soil and Water Engineering Technology, Inc. ("SWET"), a consulting firm focused on, among other things, designing and optimizing irrigation systems.

3. My work as an Agricultural Engineer has involved the study and design of irrigation systems and agriculture water management controls, as well as the environmental assessment and management of watersheds. Specifically, I have practical experience helping farmers design and optimize their center pivot irrigation systems using the most advanced commercially available technologies to achieve the optimal irrigation efficiency. Irrigation efficiency is a term agricultural engineers use to describe the relationship between quantity of irrigation applied to field and amount water that is actually used by the crops to grow. I have also developed irrigation consumptive use computer models to access regional impacts of irrigation on local water resources.

4. Agricultural irrigation has dramatically increased in Southwest Georgia since the 1970s and constitutes the majority of agricultural water use in the Georgia portion of the Apalachicola-Chattahoochee-Flint River Basin (the "ACF" or "Basin"). I have personally observed the growth of irrigation and have been involved with the development of technologies that improve irrigation efficiency since the 1970s, both as a professor at the University of Florida and as president of SWET.

5. Based on my research and professional experience, I conclude that there are a variety of technologies and management practices that can meaningfully reduce agricultural

water use in the Georgia portion of the ACF by improving agricultural irrigation efficiency and reducing or eliminating the need for the irrigation of some crops. These technologies and management practices are commercially available and designed to be used by farmers.

6. In this testimony, I evaluate a variety of commercially available agricultural equipment, technologies, and practices that would reduce agricultural water use, improve irrigation efficiency, and limit the impact of agricultural water use from the waters of the ACF. I conclude that adoption of these technologies and practices is imminently feasible and, if adopted broadly by farmers in Georgia's portion of the ACF, could significantly reduce agricultural water consumption.

7. I also conclude that drilling deeper wells for irrigation is practically and economically feasible. In addition, I conclude irrigation water use meters rarely over-estimate water use.

8. My opinions are more fully laid out in my expert report. (Expert Report of Adelbert Bottcher, FX-783).

II. PROFESSIONAL BACKGROUND & EXPERIENCE

9. I received a Ph.D. in Agricultural Engineering from Purdue University in 1978 and an M.S. in Agricultural Engineering from the University of Florida in 1974. Since 1986, I have been the president of Soil and Water Engineering Technology, Inc., a consulting firm that focuses on, among other things, agricultural irrigation systems and agricultural water use reduction strategies. Prior to this position, I served as a professor for 15 years in the Department of Agricultural and Biological Engineering at the University of Florida. I have spent more than three decades researching and consulting on agricultural water resource management issues including irrigation efficiency and have worked with farmers that have implemented many of management practices and systems discussed in this testimony.

III. OVERVIEW OF AGRICULTURAL WATER USE AND IRRIGATION EFFICIENCY

10. The use of water for irrigation constitutes a substantial portion of total agricultural water use. In total, according to the United States Department of Agriculture, irrigated agriculture accounts for the largest share of agricultural consumptive water use in the United States.[1] Agricultural irrigation in Georgia's ACF Basin has increased dramatically since the 1970s. The primary increase has been in the use of center pivot irrigation systems and to a lesser degree traveling guns and micro-irrigation systems. Figure 1 shows a high pressure center pivot that is typical of the first systems installed. Figure 2 shows a more modern pivot with low pressure drop nozzle technology, which has significantly improved application efficiencies over the earlier high pressure systems. I have added notations to these photographs, which I did not take but which are fair and accurate representations of these types of center pivots, to provide the Court with a reference on the different parts of the center pivots.

11. Key to understanding opportunities for water savings from irrigation is how much water is lost during application. Known as an irrigation system's "irrigation application efficiency," this measurement is the percentage of water used in irrigation that actually makes it into the soil to become available for uptake and use by the plant. A number of factors influence irrigation application efficiency, including the type of system used, weather conditions, the time of day when water is applied, and cropping conservation measures that are in effect. Improving the irrigation application efficiency in Georgia's ACF Basin is vital to reducing the impact of agricultural water use on streamflow and aquifer depletion in Georgia's ACF Basin.

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[1] *See* USDA, Economic Research Service, Irrigation and Water Use, Background, http://www.ers.usda.gov/topics/farm-practices-management/irrigation-water-use/background.aspx.

Figure 1 – A high pressure center pivot irrigation system with sprinklers on top.

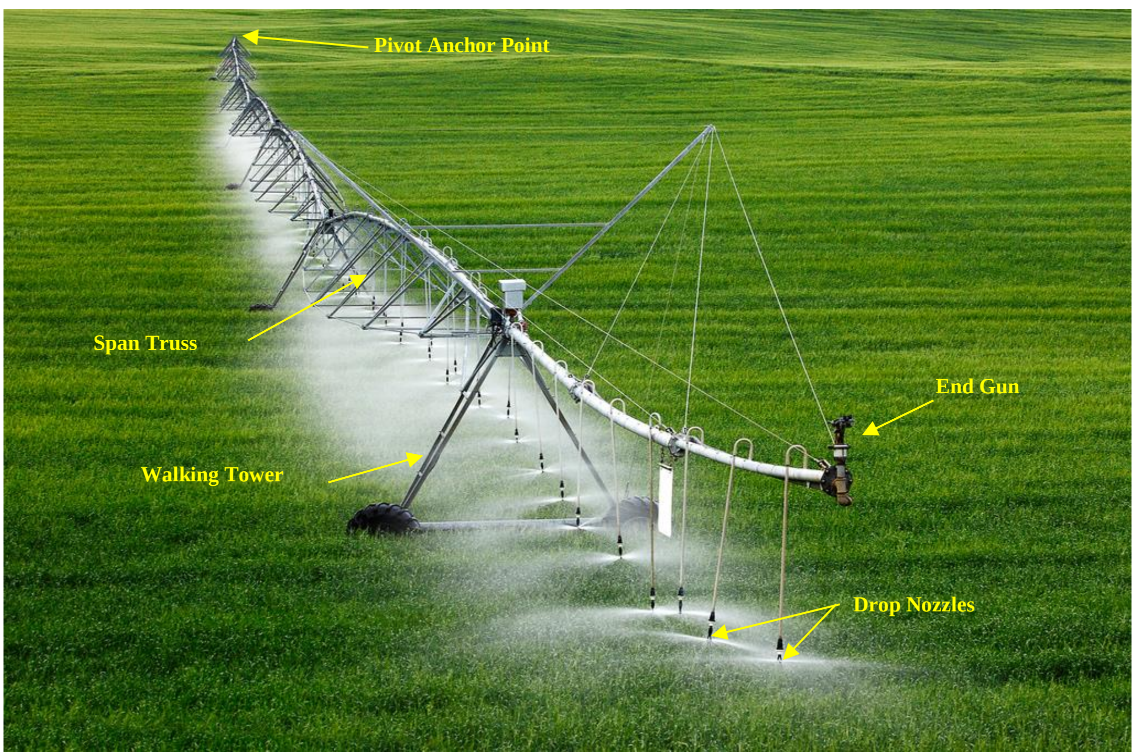

Figure 2 – A low pressure center pivot irrigation system with drop nozzles.

IV. GEORGIA FARMERS CAN ACHIEVE GREATER THAN 90% IRRIGATION EFFICIENCY

12. Georgia farmers can reduce agricultural water use by converting the older technology center pivot systems to newer higher-efficiency systems and thus improving irrigation application efficiency. However, simply converting to newer, more efficient systems does not guarantee improved efficiency and is only the first of many measures that Georgia farmers must take to improve their irrigation efficiency enough to meaningfully reduce agricultural water consumption in the Georgia ACF Basin.

13. I will first explain the center-pivot retrofit process, a vital first step in improving older, less efficient systems. After that, I will describe a host of commercially available technologies, such as variable rate irrigation ("VRI"), drop nozzles, and micro-irrigation technologies, that can achieve irrigation efficiencies greater than 90%. I will then discuss the need for an expansion of Georgia's Mobile Irrigation Lab program to ensure that the higher efficiency systems are set up and being operated in a manner that actually achieves increased irrigation efficiency. Finally, I will discuss the need for Georgia to better study and monitor the efficiencies of existing irrigation systems.

A. Retrofits of Existing Systems Are An Important First Step

14. Center pivot systems account for over 75% of irrigation systems in the Georgia ACF Basin.[2] Many of these irrigation systems are either several decades old or not optimized to achieve maximum irrigation application efficiency. As a result, many of these older or poorly optimized systems achieve an irrigation application efficiency of 70% or below. Even modern, low-pressure center pivots can have efficiencies well below 80% if not properly designed, optimized, and operated.

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[2] Hook, J. *et al*. "2008 CES Survey Irrigation Systems". NESPAL. June 1, 2009. Available online at: http://www.nespal.org/sirp/waterinfo/state/awd/background/agwaterdemand_ gairrdevelopment.htm; *see* JX-33.

15. Over the past two decades, irrigation system manufacturers have developed higher efficiency systems and upgrade packages to existing systems. These basic retrofits can improve irrigation efficiency from 70% or below to 80% efficiency by upgrading from high pressure nozzles, as shown in Figure 1, to low pressure nozzles as shown in Figure 2. Low-pressure systems irrigate with larger droplets of water that are more resistant to being blown away by high winds or evaporated.

16. Retrofits of center pivot systems upgrade the irrigation system from a high-pressure, low efficiency system to a low-pressure, high efficiency system and can be done on a cost-effective basis and achieve long-term water and economic savings. The conversion of existing pivots from high pressure, low efficiency systems with 65% to 70% efficiency to low pressure sprinklers or even higher efficiency drop nozzles to achieve 80% efficiency will range from $115 to $150 per acre, and the cost to achieve a 90% efficiency will range from $150 to $200 per acre.

17. A number of federal, state and local programs exist to assist farmers with the cost of such retrofits, such as the federal Natural Resource Conservation Service's Environmental Quality Incentive Program. For an 85 acre pivot, energy costs saved as a result of a retrofit would be about $15 per acre per year for systems achieving an 80% efficiency after conversion, and about $30/acre/year for systems achieving a 90% efficiency after conversion. Retrofits to 80% and 90% efficiency would save about 45,000 gallons per acre per year and 90,000 gallons per acre per year respectively.

B. Current Center-Pivot Efficiency Technologies Can Achieve 90% Efficiency or Greater

18. While low pressure center pivot systems are an improvement over high pressure systems, the upgrade and retrofit packages that are commercially available today can include a

number of technologies that can achieve irrigation efficiencies of 90% and greater and reduce ET. The commercially available technologies I will describe are available for use today and are vitally necessary to ensuring that Georgia farmers meaningfully reduce their irrigation water consumption.

- ***End gun shutoffs***. Higher pressure sprinkler guns at the end of a center pivot system are used to irrigate acreage not directly underneath the center pivot system and typically have lower application efficiencies and often irrigate non-cropped areas. Requiring end-gun shutoffs, combined with automated control systems that I will describe next, would improve efficiency because it would avoid water that is completely wasted since it is sprayed outside the cropping area (*See* Figure 3).

- ***Automated Control Systems***. Mechanical and GPS/computer-based automatic control systems, including variable-rate irrigation ("VRI") systems, are available to automatic react to variable weather conditions as well as accurately turning the end guns on and off as needed. User-friendly and reliable VRI systems were developed by the University of Georgia. These systems have end gun control and the ability of turning various sprinkler/nozzle zones along the pivot on and off to optimize irrigation rates throughout a field due to variable soil and crop conditions. University of Georgia Agricultural Extension irrigation specialist Calvin Perry stated at his deposition that use of VRI systems can achieve at least 15% water savings without any other change to the center pivot system.

- ***Low Pressure Drop Nozzles***. Low pressure sprinklers/nozzles can significantly reduce evaporative loss during irrigation application and achieve irrigation efficiencies of 95% by producing larger droplet sizes that are closer to the ground, and reducing the wetting of the plant canopy. The following specific systems have been designed to maximize application efficiencies:

    - ***Low-Energy, Precision Application (LEPA) Systems***. This system spaces very low pressure nozzles along the pivot to match the circular crop row pattern under a pivot so that water may be applied directly to ground next to the crop, thus eliminating any water evaporation from the plant canopy and concentrating the wetted area around the crop roots. LEPA systems can achieve 95% or greater application efficiencies.

    - ***Low-Elevation, Spray Application (LESA) Systems***. This system places low pressure drop nozzles as close to the top of the plant canopy as possible to minimize evaporative losses compared to typical low pressure center pivot systems. Efficiencies of 80-95% are achievable with the LESA systems.

    - ***Low-Pressure, In-Canopy (LPIC) Systems***. This system places low pressure nozzles below the plant canopy, achieving similar benefits to the LEPA system described above. This method is used for certain crop types where the drop nozzles can be easily dragged through the canopy. A 95% or greater application efficiencies can be achieved by this method.

Figure 3 – A center-pivot system in Georgia's ACF Basin irrigating during a rain storm and an end-gun spraying the road.

19. Figure 3 is a true and accurate copy of FX-115, which I understand was a photograph taken by personnel in Florida's Northwest Florida Water Management District on July 15, 2016, at 3:06 PM. The photograph depicts a center-pivot system in the Flint River Basin. I first saw this photograph in July 2016.

20. To achieve even higher application efficiencies for certain vegetable and orchard crops, alternative micro-irrigation systems should be considered. Micro-irrigation systems use very low pressure water application devices, such as driplines and micro-jet nozzles, that limit the application area to just the plant root zones, which can further reduce water applications. Micro-irrigation are non-mobile systems where in-ground pipelines are installed to deliver water to either microjets, small directional spray nozzles close to the ground surface, or driplines that

run allow a crop row either above or just below the ground surface to wet only the root zone of the crop.

21. Micro jets and drippers will typically have application efficiencies of 80 and 85%, respectively, but when drippers are used under plastic mulch their efficiency can exceed 95%. When adding the benefit that these systems can reduce the wetted areas to just the root zone of the crops, these systems can reduce net water application rates by 30% to 60% compared to full coverage irrigation, such as a center pivot, thus reducing pumped by these percentages as compared to center pivot.

C. Expansion Of Georgia's Mobile Irrigation Lab Program Is Vital To Achieving Greater Irrigation Efficiency

22. Simply upgrading the low pressure, higher efficiency systems is not sufficient to ensure that a center-pivot irrigation system will achieve its potential efficiency improvement because the pump system and management protocols need to properly reflect these changes. One of the best ways to ensure the proper performance of a system is to have it evaluated using a mobile irrigation laboratory ("MIL"). Georgia currently has an extremely limited MIL program *that has only evaluated approximately 3% of center pivot irrigation systems throughout the entire state*. To ensure that farmers dramatically improve irrigation efficiency, the Georgia MIL program must be expanded. Florida's MIL program provides an excellent example of how this is possible.

23. Florida has a robust MIL program with 17 MILs in operation throughout the state. The MIL program was developed by the Florida Department of Agriculture and Consumer Services, in cooperation with the U.S. Department of Agriculture, Florida's water management districts, and the local Soil and Water Conservation Districts. Within Florida's Apalachicola River basin, *over 80% percent of the irrigation systems have been tested using the MIL*. The

MIL program includes the physical testing of the application uniformity under the system to identify problems as well as inspecting the various irrigation system components for functionality, such as the irrigation pump, end gun shut offs, rainfall detectors, and control systems. Training on irrigation scheduling and other water conservation and water quality practices are also provided. MIL testing ensures that a center pivot achieves its maximum irrigation application efficiency.

D. Georgia Must Better Survey and Analyze the Use of Efficient Systems

24. The overall potential water savings within the Flint River Basin available as a result of conversion to more efficient irrigation systems and better management practices depends on the types of irrigation systems currently being used in the ACF Basin and how those systems are being used. Georgia's inventory of irrigation systems and management practices is outdated and it is not known with precision the application efficiency of most systems in Georgia's ACF Basin, but it is likely that less than 50% of the center pivots are high efficiency systems that achieve 80% efficiency in practice. The limited scope of Georgia's MIL program means that it is not known how many of the 80% efficient systems are actually operating at maximum efficiency.

25. To fully understand the potential regional water savings from converting to higher efficiency systems and better management practices, an updated inventory of the irrigation systems and management practices is recommended. A similar recommendation has been made by Georgia's Upper Flint and Lower Flint Ochlocknee Regional Water Councils.

V. BETTER MANAGEMENT PRACTICES AND CROPPING PRACTICES WILL REDUCE AGRICULTURAL WATER CONSUMPTION

26. In addition to substantially improving the efficiency of irrigation systems, Georgia farmers can reduce agricultural consumptive water use by implementing better irrigation management practices and cropping practices.

27. Regardless of the type of irrigation system being used, the lowest application efficiencies occur during warmer, lower humidity, and windier conditions. Irrigation during or immediately after rainstorms often results in over-irrigation regardless of the system used. Commercially available computerized irrigation control systems can employ farm-level weather data and/or in-field moisture probes to ensure that irrigation is used only in the most optimal situations. This can reduce consumptive water use by up to 25% or more. These computer systems are designed to be easily usable by farmers but have not been widely adopted in Georgia. Simply avoiding irrigation between 10 AM and 4 PM, when the temperatures are highest, humidity the lowest, and winds the strongest, can significantly reduce consumptive water use.

28. Georgia farmers can also dramatically reduce agricultural water use by converting to less water-demanding crops or non-irrigated (dryland) crops. Dr. Sunding has proposed as part of his remedy that the purchase of irrigation rights for acreage that has a high impact on stream flows. The remedy would require no further investment in irrigation equipment or its operation for covered acreage, meaning that that farmers would need to use dryland farming techniques. While yields for dryland farms are often lower than for irrigated farms so are the production costs, dryland farming is feasible in Georgia and is currently practiced widely.

29. Data from the USDA 2012 Census of Agriculture indicates that in the counties of the Lower Flint River Basin, dryland farming is utilized for corn, cotton, and peanuts, some of

the most widely farmed crops. In Baker County, for example, 8,399 acres of corn are under cultivation; of this, 2,213 acres are not irrigated. Baker County also included 5,341 acres of dryland cotton cultivation and another 10,355 acres of dryland peanut cultivation. In fact, in the entirety of Georgia's ACF Basin, only 26% of farms and 44% of total harvested acres are irrigated.[3] Converting irrigated acreage to non-irrigated acreage would eliminate irrigation water use for those acres and significantly impact overall agricultural consumptive water use for Georgia's ACF Basin.

30. Georgia's dryland farmers could further improve yields, and the stability of those yields using the following techniques. For example, Georgia farmers could convert some acreage to crops that are better suited to dryland farming, including corn. They could also use dryland farming techniques that preserve soil moisture, including using wider spacing between crops to give each plant a larger area from which to pull moisture or "no-till" or "zero-till" techniques that leave plant residues on the ground surface to create a mulch layer that reduces soil evaporation.

VI. DRILLING DEEP AQUIFER IRRIGATION WELLS IS FEASIBLE

31. An additional technique to reduce the consumption of water from the Upper Floridan Aquifer and surface water hydrologically connected to the Flint River would be to irrigate with water from wells drilled to deeper aquifers such as the Claiborne and Cretaceous aquifers. If these deeper aquifers are not materially connected hydrologically to surface flows, then tapping these deeper aquifers instead of using Upper Floridan or surface water sources could significantly benefit flows of the Flint River and its tributaries. To understand the average cost associated with a deeper well, I evaluated the cost of drilling a 12-inch well, the typical size

[3] *See* USDA 2012 Agriculture Census Vol. 1, Ch. 2 – Tables 9 and 10, available at https://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1%2c_Chapter_2_County_Level/Georgia/; *see* FX-327.

for a 125 acre pivot irrigation system, to a depth of 600 feet, which would be deep enough to tap into deeper aquifers. The cost to drill and install such a well would be between $120,000 and $140,000. If necessary, an upgrade of the pumping system to account for the deeper well would add approximately $35,000 to $40,000 to the overall cost. The range in costs accounts for slight variations in Basin geology, such as aquifer depth, that may impact costs.

VII. IRRIGATION METERS DO NOT OVER-ESTIMATE WATER USE

32. Dr. Sunding uses Georgia's Agricultural Metering Database ("AMD") to determine the volume of irrigation water that is applied beyond what the plant is capable of using. This water is effectively wasted. The AMD is a Georgia-administered database that measures irrigation depths as recorded by irrigation water-use meters on a majority of farms in the Georgia ACF. The meters are installed and monitored by the Georgia Soil and Water Conservation Commission, which provides the data for other agencies, such as the Georgia EPD and the USGS to build databases to gage water use and allow for the identification of potential irrigation management problems. Like any piece of equipment, the water-use meters are not perfectly accurate and over time become less reliable and therefore require routine maintenance/calibration to ensure accuracy. When these meters begin to fail, they *typically underestimate the amount of water being used and rarely overestimate*.

Figure 4. Propeller Driven Flow Meter

33. The tendency of meters to underestimate rather than overestimate water use is a result of their design. The meters are equipped with a propeller that is spun by water that passes through the pipe on its way from the pump to the center pivot for application, see Figure 4. I did

not create Figure 4, but it accurately depicts a typical flow meter used on center pivot irrigation systems. The meter measures the volume of water moving through the pipe by counting how many times the propeller spins around. Failure to accurately record the water flow is typically due to the malfunction of some part of the propeller equipment that prevents the propeller from moving freely. For example, a failure of the bearings in the propeller mechanism would increase friction; this inhibits the propeller's movement, reducing its speed and causing the meter to underestimate of the volume of water used. In order to over-estimate water use, the propeller would need to spin faster than the water moving through the pipe. However, I am not aware of any phenomenon that would cause the propellers to spin faster than the water. As a result, it is very rare that a malfunctioning irrigation flow meter would overestimate the water being used by the center-pivot being metered. Therefore, agricultural consumptive use calculations based on the AMD are likely underestimates.

VIII. EXHIBITS REFERENCED IN MY TESTIMONY

34. In my testimony, I referenced two documents and one photograph taken by personnel at the Northwest Florida Water Management District. True and accurate copies of those documents have been submitted into evidence. I describe the documents and my familiarity with each of them below.

a. FX-783: Expert Report of Adlebert (Del) Bottcher: This is a true and accurate copy of the expert report I produced for the State of Florida in this litigation, which I prepared using generally scientifically accepted principles and methodology.

b. FX-327: USDA 2012 Census of Agriculture – Georgia: State and County Data – Volume 1: This is a true and accurate copy of the USDA 2012 Census of Agriculture in Georgia. The USDA National Agricultural

Statistics Service conducted the Census of Agriculture every five years; this is the most detailed set of agricultural data for every county in America. It is the kind of report regularly relied upon by experts in my field, and I reviewed and relied upon it in forming my opinions in this case.

c. FX-115 (Figure 3): This is a true and accurate copy of a photograph of a center-pivot irrigation system, which I understand was taken in the Flint River Basin on July 15, 2016, by personnel from the Northwest Florida Water Management District. I am very familiar with these types of systems and irrigation practices, and this photograph is an accurate depiction of such a system. This kind of photograph is regularly relied upon by experts in my field, and I reviewed and relied upon this photograph in forming my opinions in this case.