No. 142, Original

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In the

Supreme Court of the United States

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STATE OF FLORIDA,
*Plaintiff,*
v.
STATE OF GEORGIA,
*Defendant.*

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Before the Special Master
Hon. Ralph I. Lancaster

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# UPDATED PRE-FILED DIRECT TESTIMONY OF FLORIDA WITNESS DAVID SUNDING, PH.D.

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## I. BACKGROUND AND QUALIFICATIONS

1. My name is David L. Sunding, and I am the Thomas J. Graff Professor of Natural Resource Economics at UC Berkeley, where I have been on the faculty of the Department of Agricultural & Resource Economics since 1992. I am the founding director of the Berkeley Water Center, and have served as the chairman of my department for the past four years.

2. My research areas include agricultural economics, natural resource economics, environmental economics, water resources, land use, regulation and law and economics. I have won numerous awards for my research, and have received grants from the National Science Foundation, the U.S. Environmental Protection Agency, the U.S. Department of Agriculture, the Bureau of Reclamation, and private foundations.

3. My work on the Clean Water Act was cited by the U.S. Supreme Court in its decision in the *Rapanos* case. I have testified before Congress on numerous occasions on subjects including water quality and water resource allocation, agricultural water use, and the effects of environmental regulation on investment and economic activity. I also served on panels of the National Academy of Sciences and the Environmental Protection Agency's Science Advisory Board. During the Clinton Administration, I was a senior economist at the Council of Economic Advisors where I was responsible for the areas of agriculture, energy, natural resources and the environment.

4. I have extensive experience in the economics of agricultural and municipal water use. I have worked with agricultural water districts and farmers in California, Nevada, Texas, Nebraska and other locations. I have authored peer-reviewed academic articles on the subject of agricultural and urban water conservation, and on the design of efficient policies for water conservation. Earlier in my career, I directed a major research project sponsored by the Bureau of Reclamation to implement and test the effectiveness of policies to encourage agricultural

water conservation. This project resulted in the successful adoption of water trading systems and conservation pricing regimes in two of the largest agricultural water districts in California. I have worked with urban water districts such as the Metropolitan Water District of Southern California and the San Francisco Public Utilities Commission on topics including the cost and effectiveness of urban water conservation programs, consumer response to water rate changes, and short- and long-term forecasting of urban water demand.

5. Working with the U.S. Fish and Wildlife Service, the Bureau of Reclamation, the Environmental Defense Fund and The Nature Conservancy, I helped design and assess a program to retire agricultural water rights in Nevada. The purpose of the program was to enhance streamflows and habitat in a wildlife refuge managed by the FWS. Later, I was a member of the team negotiating the Colorado River Quantification Settlement Agreement on behalf of the San Diego County Water Authority. The centerpiece of the agreement was a water transfer between the Imperial Irrigation District and San Diego. This transfer is the largest such water reallocation in the history of the United States, and continues to provide significant benefits to residents of both the Imperial Valley and San Diego County.

6. I am currently the chief economic adviser to the State of California in its development of the California WaterFix, a $15 billion effort to modernize the state's water conveyance infrastructure and restore more natural streamflows in the Sacramento-San Joaquin Delta Estuary. In this role, I am responsible for assessing the benefits of capital investments made as part of the program, and for a host of issues related to cost allocation and financing.

7. I have extensive experience testifying in litigation concerning breach of contract, takings and the impact of regulation of water resources. I am currently serving as an expert witness for the U.S. Department of Justice in the *Klamath Basin* litigation, and recently testified for the United States in the *Stockton East* case. I have been retained as an expert in other water

resource disputes of original jurisdiction between states before the U.S. Supreme Court, including *Kansas v. Nebraska*; *North Carolina v. South Carolina* and *Texas v. New Mexico*.

## II. INTRODUCTION AND SUMMARY OF MY TESTIMONY

8. Florida is seeking a consumption cap remedy in this case with two principal elements: (1) a cap on Georgia's annual average consumption of water in the ACF basin; and (2) a cap specifically reducing the amount of water that can be consumed in drought years. In this testimony, I evaluate Georgia's water uses from an economic perspective, relying on testimony by other Florida experts on hydrologic and certain other issues. I then identify and explain a number of feasible and low-cost water conservation and drought mitigation steps that Georgia can take to satisfy the consumption caps. In particular, I show how Georgia can choose from an array of measures that have been successfully employed in other states to materially reduce its depletions of river flows in the ACF in key months, including by 1,500 to over 2,000 cubic feet per second (cfs) in peak summer months of drought years.

9. I explain that the consumption-related problems that have led to this case are the result of Georgia government policies that incentivized high levels of water use. For example, Georgia's groundwater withdrawal permits place no practical limit on the amount of water a farmer can withdraw, and were issued without regard for the downstream environmental effects of groundwater extraction. Such a system incentivizes farmers to use water up to the point at which it provides no incremental private benefit. Because the marginal economic value of water in Georgia is so low, I show that the Georgia government can reasonably fund numerous workable solutions to this problem.

10. I show that Georgia can comply with the consumption caps in a way that minimizes their impact on Metro Atlanta so that the economic growth of that area is not restrained. Likewise, the costs to the farm economy in Southwest Georgia of complying with the

consumption caps need not be large in relation to the size of the agricultural economy in the Basin. Indeed, if Georgia is concerned about the agricultural impacts of the consumption caps, it can choose to compensate farmers for reducing their water consumption. This approach to water reallocation has been successfully implemented in other states facing conditions of scarcity.

11. In addition to explaining how Georgia can comply with a consumption cap remedy, I address certain specific arguments recently made by Georgia's experts, and explain why their predictions of doom are not warranted here.

## III. OVERVIEW

### A. Georgia ACF Municipal Water Use

12. Municipal water supply is used by commercial and industrial businesses, governments, and by households.

13. Whereas virtually all agricultural water use is consumptive, a percentage of municipal water is returned to the source via the wastewater treatment system. Water withdrawn but then returned to the ACF has little impact on streamflows, so the magnitude of return flows in the municipal sector is critical. As described in my February 29, 2016 expert report submitted in this case, a true and accurate copy of which is FX-784, in the City of Atlanta, with its particularly old pipelines, return flows are likely approximately 60 percent of withdrawals. Other municipalities in the ACF report similar or even lower return flows. According to FX-285, a true and accurate copy of a report by the Flint Riverkeeper (an organization working to restore and preserve the habitat, water quality, and flow of the Flint River) and American Rivers, only approximately 25 percent of the public water supply in the Upper Flint River Basin is returned directly to the Flint River or its tributaries. The report is entitled "Running Dry: Challenges and Opportunities in Restoring Healthy Flows in Georgia's Upper Flint River Basin," and it was published in April 2013. The report is available at: http://www.americanrivers.org/wp-content/uploads/2016/05/running-dry-flint-river-report.pdf.

In its 2013 Water Supply Request, JX-86, Georgia admitted that it was possible to achieve a much higher return flow percentage in the Chattahoochee region in the future – roughly 78%.

a. Exhibit JX-86 is a true and accurate copy of what I believe is Georgia's January 11, 2013 Water Supply Request to the Army Corps of Engineers. This is a letter from Georgia Governor Nathan Deal to Jo-Ellen Darcy, the Assistant Secretary of the Army for Civil Works, and it includes an affidavit from the EPD Director, Judson Turner, and an analysis by who I understand to be EPD's chief hydrologist, Dr. Wei Zeng. I reviewed this document to inform my opinions in this case.

14. The primary consumptive uses of water in the municipal sector are outdoor use and losses due to leaks from aging water supply infrastructure. According to the 2009 Water Supply and Water Conservation Management Plan of the Metropolitan North Georgia Water Planning District, JX-37, which accounts for the majority of urban use in the ACF, system losses are approximately 15 percent of the district's water use. Residential use accounts for over half of water demand. Among single-family residences, approximately 20 percent of demand is accounted for by outdoor uses, such as lawn watering. There is also an outdoor component to multi-family, commercial, and public water use.

a. I understand that the Metropolitan North Georgia Water Planning District is a statutorily-created entity that is responsible for water management in the Metro Atlanta region, in particular. JX-37 is a true and accurate copy of what I know to be the District's publicly available 2009 Water Supply and Water Conservation Management Plan. You can see the name of the District at the bottom of the document. I reviewed this document to inform my opinions in this case. Experts in my field generally rely on such formal public reports for information regarding water supply and conservation projects in municipalities.

15. Municipal water use includes a number of outdoor water uses such as lawn watering and car washing. These outdoor uses are much smaller in the winter months and larger in the summer months, and account for the seaonal pattern of municipal water withdrawals revealed in Georgia Environmental Protection Division (EPD) data. Municipal water withdrawals reached their peak in the critically dry summer of 2011, indicating the absence of an adequate drought response.

16. Georgia has adopted drought response strategies to restrict outdoor water use that may be called on according to the severity of drought in a given year. In the most extreme drought scenario, no outdoor watering of non-food plants is allowed. However, the last drought that Georgia declared severe enough in the Metropolitan Atlanta Area to mandate the ban occurred in 2007 and 2008. While the 2011 drought was as severe in terms of dryness during the peak water use season in the ACF overall, it was more pronounced in the southern portion of the state. Neglecting to account for the external impacts of consumptive water use downstream, Georgia failed to implement its own additional outdoor water use restrictions in the Metro Atlanta Area in 2011 or 2012.

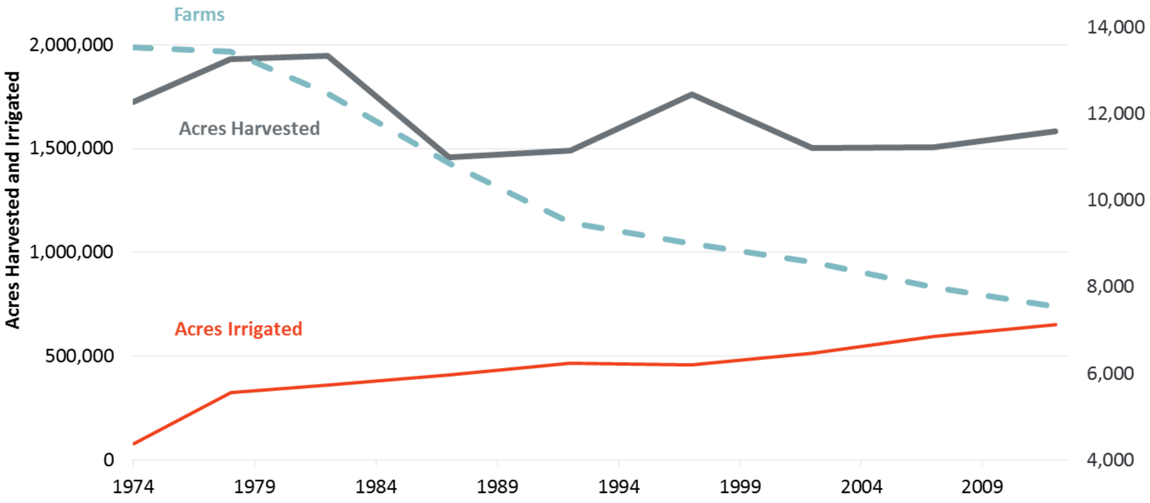
17. Additionally, in 2009 the Water Contingency Task Force Report recommended a number of conservation measures for Metro Atlanta. I understand from the deposition of Ms. Anna Kathryn Kirkpatrick that while Georgia has adopted some of the measures, discussed in this Report, others, such as expanding or building reservoirs have not been implemented.

### **B.** Agricultural Water Use in the ACF in Georgia

18. The agricultural sector is responsible for the largest share of consumptive water use in the ACF in Georgia. Crop irrigation constitutes a substantial portion of this consumptive

use. Georgia farmers historically grew their crops with only rainfall and little use of supplemental irrigation. In recent decades, however, because of Georgia government policies, Georgia farmers in the ACF basin have chosen to irrigate roughly half their farmland to improve and stabilize yields. Figure 1 illustrates this trend with USDA Census data, showing that the area of irrigated farmland increased sevenfold in ACF counties over the past 40 years even as total harvested area decreased slightly. The figure also suggests increasing concentration in ACF agriculture in large commercial farming enterprises – with the number of farms falling by approximately half.

**Figure 1: Recent Trends in ACF Agriculture**



Notes: Sixteen counties withheld data in 1978, fifteen in 1982, nine in 1987, seven in 1992, nine in 1997, one in 2002, and three in 2012.

a. Figure 1 was provided in my February 29, 2016 expert report, FX-784. It was created at my direction, and is a true and accurate representation of my analysis of publicly available data from the U.S. Department of Agriculture ("USDA") National Agricultural Statistics Service's ("NASS") "Desktop Data Query Tool." NASS conducts hundreds of surveys every year and prepares reports covering virtually every aspect of U.S. agriculture. It also conducts the Census of Agriculture every five years, which is the most detailed set of agricultural data for every county in America. Data from USDA/NASS is generally relied upon by other experts in my field, and is the most reliable set of information that I know of for this agricultural information.

b. Irrigation in 63 Georgia ACF Counties (2012), FX-270, is a true and accurate copy of a table that I created using USDA Agricultural Census data for Georgia. FX-270 shows the number of farms and irrigated acres that are irrigated and, conversely, not irrigated. The USDA Agricultural Census data is from the 2012 Census Volume 1, Chapter 2: County Level Data and was compiled pursuant to "Census of Agriculture Act of 1997," Public Law 105-113 (Title 7, United States Code, Section 2204g). It can be found at the following website: https://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1,_Chapter_2_County_Level/Georgia/. The 2012 Census was the 28th Federal census, and the fourth conducted by USDA-NASS.

19. Despite the extent of irrigation in the ACF in Georgia, agriculture remains relatively low in value on a per acre basis, or when compared to the size of the Georgia economy, or the size of other agricultural economies in the United States. The three primary crops grown by ACF farmers (cotton, peanuts and corn), which account for 85 percent of irrigated acreage in the region, generate substantially lower revenues per acre than numerous other crops grown in Georgia, such as pecans, produce, and sod. The 2014 Georgia Farm Gate Value Report, for example, showed that the total value of pecan production was almost $2,000 per acre, while corn, cotton, and peanuts had farm gate values of substantially less than $1,000 per acre.

20. Due to the relatively low value of the primary crops grown in the ACF in Georgia, the total value of agricultural activity in the region is small compared to major agricultural areas

in the United States. According to the report of one of Georgia's experts, Dr. Robert Stavins, the commercial value of all row crops in the ACF Basin (principally corn, cotton, peanuts and soybeans) was approximately $1.3 billion in 2013. These row crops are grown over almost 700,000 acres in the Georgia ACF. For comparison, the farm gate value of grapes grown in a single California county (Kern County, which has approximately 100,000 acres devoted to this crop) was $1.8 billion in 2013. Overall, I conclude that the State of Georgia is not in the top ten agricultural producing states in the country.

a. The 2014 Kern County Agricultural Report, FX-329, is an official government record created by the Department of Agriculture and Measurement Standards of Kern County, California. I have reviewed this report, which contains statistical information on acreage, yield, and gross values of Kern County agricultural products. It is common for experts in my field to rely upon reports such as these.

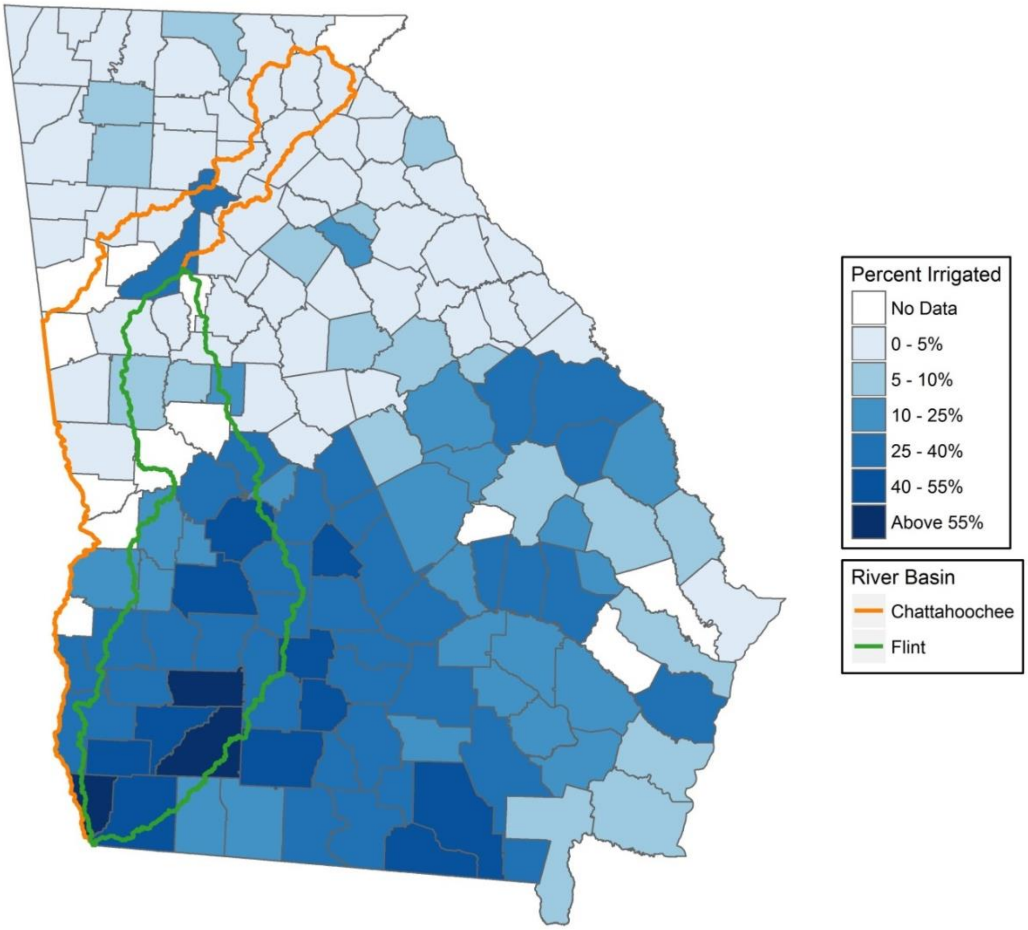
21. Moreover, the value of row crop production in the ACF in Georgia is small compared to the overall size of the ACF agricultural economy, and nominal in comparison to the economy as a whole. According to Dr. Stavins, the commercial value of all agricultural production in the ACF in Georgia is $4.7 billion. But row crops account for less than one third of that amount. Dr. Stavins also reports that the gross regional product of the entire ACF region is over $280 billion. The farm gate value of all row crop production is therefore less than *one half of one percent of the overall economy of the ACF in Georgia*.

22. The low value of agriculture, and particularly of row crop agriculture, means that the water applied to irrigate these crops is not highly productive in terms of revenue in larger economic terms. This observation is confirmed by the fact that while irrigation has increased substantially in the ACF in Georgia, over half of all harvested farmland in the region is still in purely rainfed cultivation. Agricultural irrigation is therefore clearly discretionary in the ACF,

as many farmers (spanning the range of farm sizes from ten acres to over 2,000 acres) have continued growing crops without it. For farmers choosing rainfed cultivation, the benefits of crop irrigation are not worth the extra costs incurred to purchase, install and maintain irrigation equipment.

23. The share of harvested acres that are irrigated is even lower elsewhere in the state. The map in Figure 2 depicts the portion of cropland that is irrigated in each Georgia county in 2012, ranging from zero to over 55 percent. Irrigated agriculture is clearly most common in the southwestern portion of the state, and in particular in the lower Flint River Basin, where groundwater use has the most direct impact on Apalachicola River streamflow.

**Figure 2: Fraction of Irrigated Cropland by County, 2012**



a. This figure is a slightly modified version of a map that was included in my February 29, 2016 expert report, FX-784. This figure was generated at my direction using data from the USDA Agricultural Census, 2012 Census County Level Data for Georgia, which lists the amount of irrigated cropland by county. FX-327 is a true and accurate copy of that document, which the USDA makes publicly available. FX-328 is a true and accurate copy of Appendix A to the 2012 Census of Agriculture, detailing its methodology. This version of the Fraction of Irrigated Cropland by County was modified to include the boundaries of the Flint and Chattahoochee Basins.

24. For farmers who do opt to irrigate their cropland, a number of factors determine how much water they apply in any given year, including the amount of rainfall and the characteristics of their farmland. Higher irrigation depths are expected in drier years, all else equal. Land characteristics, such as slope and soil composition, also affect crops' irrigation needs and therefore applied water depths. Irrigation tends to be higher on coarser soils.

25. A primary driver of irrigation depths is the crop that the farmer is growing. An acre of pecans, for instance, uses almost six times the amount of water as an acre of soybeans in an average year. For the three primary crops grown in the ACF in Georgia, namely cotton, peanuts, and corn, I estimated average irrigation depths in each year through measurements of farmers' water use captured in Georgia's Agricultural Metering Database, JX-138.

a. Georgia's Agricultural Metering Database, JX-138, is a true and accurate copy of the Agricultural Metering Database that was provided by the State of Georgia during the discovery process. I have reviewed the Agricultural Metering Database, which is a database of the kind regularly used by experts in my field.

26. Since 2003, agricultural water use under a new permit has required installation of a meter on the pump to monitor groundwater or surface water withdrawals. Georgia's Agricultural Metering Database, JX-138, contains records of agricultural water pumping

generated through Georgia's Agricultural Metering Program. Under the Agricultural Metering Program, approximately 5,000 unique meters have been read in the ACF Basin one or more times between 2004 and 2013. The majority of these are read on an annual basis, with 4,600 meter readings taken in 2013, the last year for which data was provided. For reference, approximately 8,000 agricultural permits have been issued in the Georgia ACF. So while the metering program certainly does not provide complete coverage of agricultural water use in the ACF, it nonetheless provides valuable information on farmers' actual behavior over a range of conditions.

27. As described in detail in Technical Appendix A to my February 29, 2016 report, FX-784, I matched the data from the Agricultural Metering Database, JX-138, to spatial datasets to assess irrigation patterns on corn, cotton, and peanut farms across soil and weather conditions. Specifically, I overlaid the locations of the meters and the reported irrigated areas with the USDA Cropland Data Layer to determine land use and cropping patterns in each year, and with USDA's SSURGO soils database to determine land characteristics. I then undertook several data cleaning steps to remove clearly erroneous observations from the metering data.

a. The Cropland Data Layer (CDL) is an annual publication by the Research and Development Division of the USDA's National Agricultural Statistics Service, which provides fine-resolution geospatial data on land use types, including more than 100 different crops. The CDL is developed from satellite imagery, validated by comparison with other USDA sources. It is available annually from 2008 to 2014 for the entire state of Georgia.

b. The SSURGO database is maintained by the USDA Natural Resources Conservation Service (USDA-NRCS). It contains information about soil as collected by the National Cooperative Soil Survey over the course of a century, and can be displayed in tables or as maps. The SSURGO database is a reliable source for determining land characteristics and is generally accepted and used by experts in my field. The SSURGO database map data, tabular data, and information about how the maps and tables were created. The data can be downloaded through several sources, including the Web Soil Survey. FX-177 is a true and accurate copy of a description of the SSURGO database by the USDA-NRCS, which explains how it was compiled. FX-171 is a true and accurate copy of the USDA-NRCS Geospatial Data Gateway webpage I used to access the SSURGO database, available at https://gdg.sc.egov.usda.gov/. FX-174 is a true and accurate copy of a screenshot of the webpage for downloading SSURGO data, available at https://gdg.sc.egov.usda.gov/GDGOrder.aspx.

28. Table 1 below combines the observed irrigation depths from the Agricultural Metering Database, JX-138, with estimated depths for other crops in drought and non-drought years produced by the National Environmentally Sound Production Agriculture Laboratory (NESPAL) at the University of Georgia. It also shows the total irrigated area planted in each crop in the ACF in Georgia, based on NESPAL's aerial imagery data. I adjusted the acreage estimates up by 10 percent to account for the growth in irrigated area since the NESPAL data collection effort was made. My estimate of growth is inferred from comparison of 2007 and 2012 USDA Agricultural Census data. As the NESPAL data was collected in the 2007 to 2008 time frame, my irrigated acreage estimates therefore represent irrigated area in 2012 to 2013. To the extent that more acreage has been brought into irrigation since 2013, my estimates are conservative.

29. I rely on NESPAL irrigated area estimates because the underlying methodology is clearly documented and was designed to provide complete coverage to aid Georgia in

understanding its agricultural water use. I performed a comparison of irrigated areas in NESPAL to reported irrigated areas in geospatial files relating to the Wetted Acreage Database that were received as support to a July 29, 2016 memorandum from one of Georgia's experts, Dr. Irmak. I found that a number of irrigated areas included in NESPAL were omitted from the Wetted Acreage Database, which was an irrigated acreage mapping effort carried out by the Georgia Water Planning & Policy Center at Albany State University through a contract with the State of Georgia. The omitted acres tended to be rectangular fields likely served by non-center pivot irrigation systems. FX-309 and FX-310 are maps of two separate areas in the Flint River Basin I created that show irrigated areas included in NESPAL only, and not the Wetted Acreage Database. I created these maps using generally accepted principles and methodology, and they accurately represent the outcome of my analysis. The Wetted Acreage Database is a database of irrigated fields, with accompanying additional geospatial files, compiled by the Albany State University through a contract with the State of Georgia. JX-129.

30. Multiplying the irrigation depths in each type of year with irrigated acreage generates the estimates of drought and non-drought year irrigation demand also presented in Table 1. Irrigation demand is the total volume of water used in irrigation of each crop on the recorded acreage. It is given in units of acre-feet, where one acre-foot is the volume of water required to cover one acre of land in a depth of one foot of water.

**Table 1: Irrigation Depths and Demand in the ACF in Georgia, by Crop**

| | | Non-Drought Year | | Drought Year | |
|---|---|---|---|---|---|
| Crop | Irrigated Acreage | Average Irrigation Depth (in) | Total Irrigation Demand (AF) | Average Irrigation Depth (in) | Total Irrigation Demand (AF) |
| cotton | 279,313 | 6.2 | 144,785 | 10.7 | 248,995 |
| peanuts | 194,132 | 7.5 | 120,530 | 12.2 | 197,021 |
| corn | 152,030 | 11.5 | 145,771 | 16.7 | 212,134 |
| pecan | 49,153 | 25.7 | 105,167 | 40.3 | 165,105 |
| soybean | 48,381 | 4.3 | 17,158 | 9.3 | 37,452 |
| produce | 42,644 | 13.0 | 46,190 | 25.3 | 89,917 |
| sod | 14,907 | 12.5 | 15,572 | 24.1 | 29,940 |
| pasture | 8,063 | 2.6 | 1,739 | 4.1 | 2,731 |
| other | 4,991 | 13.4 | 5,564 | 23.7 | 9,868 |
| **Total** | **793,613** | **9.1** | **602,476** | **15.0** | **993,163** |

31. While the above table presents only average irrigation depths, the Agricultural Metering Database, JX-138, also reveals that different farmers apply vastly different amounts of irrigation, even when growing the same crops under the same environmental conditions. In particular, many farmers apply more water than can actually be used by their crops, due to faulty irrigation equipment, lack of information, outdated management practices, or simply the absence of any incentive to use water efficiently. Simply put, the Agricultural Metering Database shows that there are a number of Georgia farmers whose irrigation practices waste water.

## **C.** Externalities and the Inadequacy of Georgia's Water Use Policy

32. The concept of an externality is central to modern environmental economics and is taught to every undergraduate studying the subject. It is also a critical concept for understanding the economics of this case. An externality is an impact that is experienced by a third party as a result of a consumption or production activity. The classic example of an externality is a factory that emits pollution from a smokestack. Absent government regulation or some other kind of arrangement between the parties, the factory owner does not have an incentive to take the pollution he causes into account when choosing a level of output since the

harm from the pollution does not increase his cost of production, but rather is borne by someone else.

33. Uncontrolled externalities usually result in economic inefficiency. To continue with the factory example, absent government intervention, the factory owner recognizes only one cost of production, namely the cost of the production inputs that must be purchased to generate output. In actuality, however, there is another cost of production: the cost of the environmental harm suffered by downwind residents. If the factory owner sets the level of output to maximize his private profit, which will usually be the case absent government intervention, then the factory owner produces until the marginal revenue from increasing output equals the marginal cost of purchasing more production inputs. The external effects of generating pollution are not counted in the factory owners' economic decision making.

34. Like the factory owner in the above example, Georgia's water use permitting system fails to account for the external impacts of water use in the ACF Basin. As a result, current water use patterns in Georgia are economically inefficient in the sense that they do not consider or account for the impact of water use downstream in Florida, or even in multiple areas of Georgia which I understand have suffered environmental harm themselves. Because the State of Georgia does not properly regulate this activity, these upstream uses of water, on the margin, create more environmental damage than economic benefits. These fundamental insights are important in a case that requires a balancing of equities.

35. Environmental externalities are often more difficult to quantify than changes in economic activity. Whereas the value of economic activity such as business output or individual consumption decisions can be monetized in terms of profit or consumer surplus, environmental externalities are often far-reaching and complex, and more difficult, if not impossible, to reliably monetize using accepted methods in environmental economics. This observation is especially

true when externalities impinge on undeveloped areas and habitats. The Apalachicola, for example, is a large ecosystem, and changes in streamflows will impact this ecosystem in ways that are complex and multifaceted, and thus difficult for people to comprehend, let alone monetize. Nonetheless, Florida's experts have articulated a range of harms from Georgia's excessive water consumption that can be weighed against the impacts to Georgia from capping its consumptive use.

36. Georgia's current permitting system imposes no meaningful restraints on the vast majority of permit holders in the ACF Basin. In the agricultural sector, restrictions associated with permits, if any, are mostly non-binding or unenforced. Around 60 percent of permits were "grandfathered" into the system, and currently have almost no restrictions. Across all permits, whether grandfathered or not, farmers can use as much water as they can physically pump. As farmers do not run pumps constantly throughout the day and the year, these allowances likely rarely—if ever—present any binding constraint. Georgia has already permitted pumping in the Georgia ACF that would equate to approximately 17,000 cfs of water per year. In other words, there are no current practical limits on how much water a Georgia ACF farmer can use.

a. FX-267 is a true an accurate copy of a table I created that shows the total number of permits issued by EPD for the Chattahoochee and Flint Basins and the entire state of Georgia and the corresponding acreage compared to the number of permits applied for the same areas on or before July 1, 1991 and the corresponding acreage. The permits applied for on or before July 1, 1991, and the permits issued on or before December 31, 1993 are the "grandfathered" permits. I created this table using data from EPD's Agricultural Permitting Database.

b. Average Irrigation Depth of Surface Water Users, FX-707, is a true and accurate copy of a table I created that shows the difference between the average irrigation depth for surface water users with non-grandfathered permits compared to those with grandfathered permits. The table was created using data I obtained from Georgia's Agricultural Permitting Database and the Agricultural Metering Database.

c. Permits Containing Low-Flow Provisions, FX-709, is a true and accurate copy of an Excel spreadsheet I created that shows the irrigation permits that contain low-flow restrictions, the water source, the location of the permitted acreage, and the low-flow restrictions. The spreadsheet was created using data obtained from Georgia's Agricultural Permitting Database.

37. As explained in a study of agricultural water use in Georgia, co-authored by a University of Georgia faculty member, the state's agricultural water use permits "convey an almost unlimited right to use water on permitted acreage, effectively bounded only by pumping capacity… There is no component of the cost [of water use] that reflects any inherent scarcity of water."[1] On the margin, farmers pay only the cost of pumping water to their field, and nothing for the water itself; no significant economic incentives are in place to encourage farmers to conserve water and internalize externalities. Farmers are thus allowed to extract water until or past the point where it is simply not worth extracting any more from a profit standpoint. This result is economically inefficient since there are real consequences in Florida of Georgia's water use in the ACF Basin.

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[1] Gonzalez-Alvarez, Y., Keeler, A. G., & Mullen, J. D. (2006). *Farm-level irrigation and the marginal cost of water use: Evidence from Georgia*. J. Envtl. Mgmt., 80(4), 311-317. A true and accurate copy of this article, which I relied upon in formulating my opinions, is contained in FX-62. The Journal of Environmental Management is of a type of publication regularly relied upon by experts in my field.

38. Thus, basic economic theory indicates that economic welfare (that is, the combined well-being of Florida and Georgia) is reduced by these last units of Georgia's consumption.

## IV. CONSERVATION MEASURES TO CAP GEORGIA'S CONSUMPTIVE USE OF WATER IN BOTH DROUGHT AND NON-DROUGHT YEARS

39. Georgia can implement any number of conservation measures to reduce its consumptive use of water and offset future growth from the municipal and agricultural sectors. In particular, it can implement and enforce the policies it already has in place, and take advantage of other minimal-cost conservation opportunities. Such actions would enable Georgia to cap its annual consumptive use of water at current levels at minimal incremental cost, and would provide substantial environmental benefits to Florida in both drought and non-drought years.

40. If no new limits are put in place, water consumption in the Georgia ACF could grow dramatically in both the agricultural and municipal and industrial sectors over the coming decades. First, in addition to the lack of restraints on permit-holders, EPD has issued permits so freely that approximately 30 percent more farmland is permitted to be irrigated in the ACF than is currently irrigated, as estimated by Georgia's own experts. Georgia EPD also continues to issue new backlogged permits in areas of the Flint River Basin subject to their own recent permit moratorium. Moreover, on many farms the actual irrigated area often exceeds the permitted irrigated area. I estimate that up to 90,000 of the irrigated acres in the ACF in Georgia are in excess of individual permit terms. To date, Georgia has not enforced permit terms to eliminate irrigation on those acres. Further, increases in commodity prices could also incentivize existing permitholders to begin irrigating where they have not already.

41. Second, according to the State of Georgia's most recent Water Supply Request to the U.S. Army Corps of Engineers, there is expected to be significant growth in demand for

water in the Metro Atlanta Area between now and 2050. Annual average withdrawals are expected to increase by over 110 million gallons per day, equivalent to 120,000 acre-feet per year. If Georgia in fact increases return flows to 78% as projected in its 2013 Water Supply Request to the U.S. Army Corps of Engineers, JX-85, then this growth in withdrawals is limited to approximately 30,000 acre feet of consumptive use. There are numerous measures, described below, that Georgia could take to offset this growth in municipal and industrial and agricultural water consumption. It is important to note that preventing growth in the agricultural sector is in many cases economically preferable to reducing existing water use, as investments in irrigation equipment have not yet been made.

### **A.** Municipal Measures

42. One means of achieving Georgia's pledged increase in return flows to 78% would be to increase leak abatement efforts. Much of the municipal water infrastructure in the Metropolitan North Georgia area is old, with most of the conveyance and treatment facilities in Fulton, Gwinnett, DeKalb, Cobb, and Clayton counties constructed over 50 years ago. To minimize the consumptive use of water associated with leaks from aging pipelines, Georgia can undertake leak abatement programs on a sustained year-by-year basis. Leak abatement measures include the rapid detection and repair of leaks, exercising valves to mitigate the volume of water lost during pipeline breaks, and pressure sustaining valves to prevent breaks during low usage hours.

43. In 2009, Georgia's Water Contingency Planning Task Force evaluated options to improve the water supply and reduce consumptive use in the event that Lake Lanier was not reauthorized for municipal use. The Task Force estimated potential water savings from leak abatement programs of 27 million gallons per day (mgd), equivalent to 30,000 acre-feet of consumptive use. As most municipal water is taken from surface sources, this decrease in

consumptive use would translate to an equivalent increase in streamflow of 42 cfs in every year, assuming that leaks occur evenly throughout the year. Leak abatement programs could also be undertaken in municipalities outside the Metro North Georgia area for greater water savings.

a. Georgia's Water Contingency Planning Task Force Report, JX-41, is a true and accurate copy of the Water Contingency Planning Task Force – Findings and Recommendations, which was published in December 2009 and is publicly available on the Georgia government's website at http://sonnyperdue.georgia.gov/vgn/images/portal/cit_1210/59/57/154449884Water%20Contingency%20Planning%20Task%20Force%20Final%20Report.pdf. Experts in my field regularly rely on such government reports regarding water supply and conservation projects, and I relied upon this work in forming my opinions.

44. The Task Force estimated the cost of this measure for Metro Atlanta at approximately $16 million per year. While there are costs associated with the implementation of leak abatement programs, Georgia could benefit economically from such measures because water leaks themselves are costly to municipal utilities. Indeed, the Task Force favored undertaking greater leak abatement even if Lake Lanier was reauthorized for Atlanta's use. Moreover, as noted above, Georgia has already committed to increasing its return flows. The costs of leak abatement attributed to this case therefore are not incremental to Georgia's own plan.

45. An additional means of increasing municipal return flows would be the elimination of net exports of water from the ACF basin to other basins. "Exports" in this context means discharges or conveyance of water to other basins. Data on these inter-basin transfers are available for 1990 and from 2001-2013, and show that net transfers out of the ACF Basin have

exceeded 120 cfs. In the last severe drought year of 2011, eliminating net exports of water outside the ACF basin would have been equivalent to reducing consumptive water use by 48,000 acre-feet. Again, these savings would translate directly to a 66 cfs reduction in streamflow depletions. Leak abatement and curtailing exports of water out of the ACF would be more than sufficient in themselves to offset anticipated growth in municipal consumptive use in the Metro Atlanta Area.

## **B.** Agricultural Measures

### **1.** Stopping Irrigation on Unpermitted Acreage

46. Georgia has even more substantial opportunities for conservation in the agricultural sector, where again significant reductions in consumptive water use can be achieved through existing policies. First, Georgia could enforce its own permitted irrigated acreage limits. As I noted above, a large number of farms in Georgia are currently irrigating more land than is allowed by EPD agricultural water withdrawal permits. By comparing irrigated acreage data from the Wetted Acreage Database with EPD permit records, I calculated that there are up to 90,000 acres of irrigated land that are unpermitted. NESPAL irrigated acreage data could not be linked to individual permits as needed for this analysis, so I relied on the Wetted Acreage Database, which explicitly lists the permits associated with each irrigated field.

a. Unpermitted Acres, FX-708, is a true and accurate copy of a list of unpermitted acres in Georgia by permit number. I created this table comparing reported irrigated acreage in Georgia's Wetted Acreage Database with EPD permit records in Georgia's Agricultural Permitting Database, JX-132. Georgia's Agricultural Permitting Database, JX-132, was provided to Florida during discovery. Experts in my field generally rely on such databases and information to evaluate agricultural water permitting practices, and I reviewed and relied on JX-132 in formulating my opinion.

b. Examples of Unpermitted Irrigated Acres in Wetted Acreage Database, FX-311, is a true an accurate copy of a table I created in the same manner as FX-708.

47. To estimate how much consumptive use Georgia could save by actually enforcing its permit terms, I first adjusted the irrigated area inclusive of center pivot overthrow reported in the Wetted Acreage Database downwards by adopting NESPAL's more conservative approach to estimating overthrow. I then combined the total unpermitted area with the average irrigation depths summarized in Table 1. I estimate that eliminating unpermitted irrigation would reduce average annual consumptive use across the Georgia ACF by 54,000 acre-feet in a non-drought year and 89,000 acre-feet in a drought year relative to current levels. The declines in consumptive use would achieve increases in streamflow in the important peak summer month of 76 to 91 cfs in a non-drought year and 125 to 151 cfs in a drought year, depending on the assumption made about the underlying hydrological connectivity of groundwater.

48. Unlike the municipal measures I discussed first, decreases in consumptive use in the agricultural sector do not translate directly to reductions in peak monthly streamflow depletions in drought years. First, agricultural water use is highly seasonal, so I use an annual average to peak month conversion factor calculated by Dr. Hornberger. Second, a majority of agricultural withdrawals are taken from the Floridan Aquifer rather than from rivers and streams directly, and the extent to which groundwater use shows up as streamflow depletion depends on the underlying hydrological connectivity of the land. For all of my agricultural analyses, I use the hydrological map produced by Dr. Langseth with an average connectivity of 0.43 on irrigated acreage as a conservative baseline. I understand that this number is highly conservative and underestimates the hydrological connectivity between the Floridan Aquifer and surface water. As such, I also use adjusted connectivity values averaging 0.6 across the Georgia ACF, provided

by Drs. Langseth and Hornberger to represent a more middle-of-the road estimate of hydrological connectivity.

### **2.** Curbing Non-Productive Irrigation

49. In addition to curtailing unpermitted irrigation, Georgia could also curb farmers' excessive water use. I found through my analysis of the Agricultural Metering Database that some ACF Georgia farmers apply much more water than can be productively used by their crops, effectively wasting water. The excessive irrigation provides no benefit in terms of crop yield and thus no additional revenue to the farmer. Eliminating this excessive irrigation is therefore a near costless conservation opportunity, particularly in very dry and drought years when irrigation is most heavily applied.

50. I estimated the amount of water that may be saved by curtailing excessive irrigation on the primary row crops in the ACF in Georgia by comparing actual irrigation depths from the Agricultural Metering Database, JX-138, to the maximum amount of water the crops could productively use under given weather and soil conditions. Examples are illustrated for cotton and peanuts respectively in Figure 3 and Figure 4, where all meter readings to the right of the depth marked by the dashed red line indicate excessive, non-productive irrigation. I created Figure 3 and Figure 4 with data from Georgia's Agricultural Metering Database, JX-138. The figures show how many farms are irrigating to a given irrigation depth expressed in inches. As I discussed earlier, Georgia's Agricultural Metering Database, JX-138, is a true and accurate copy of the Agricultural Metering Database that was provided by the State of Georgia during the discovery process. As discussed in detail in my May 20 report, a true and accurate copy of which is FX-801, I estimated these maximum productive irrigation depths from the crop simulation results provided by Dr. Hoogenboom. Excessive irrigation is then calculated as the actual irrigation depth applied by a farmer beyond the maximum productive depth.

Figure 3: Actual vs. Maximum Productive Irrigation Depths, Cotton on Coarse Soils 2011

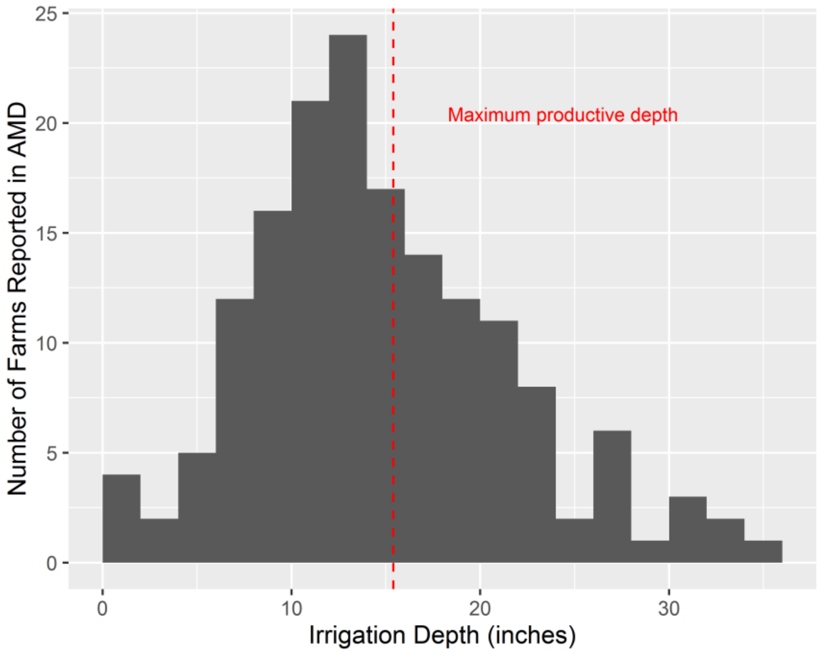
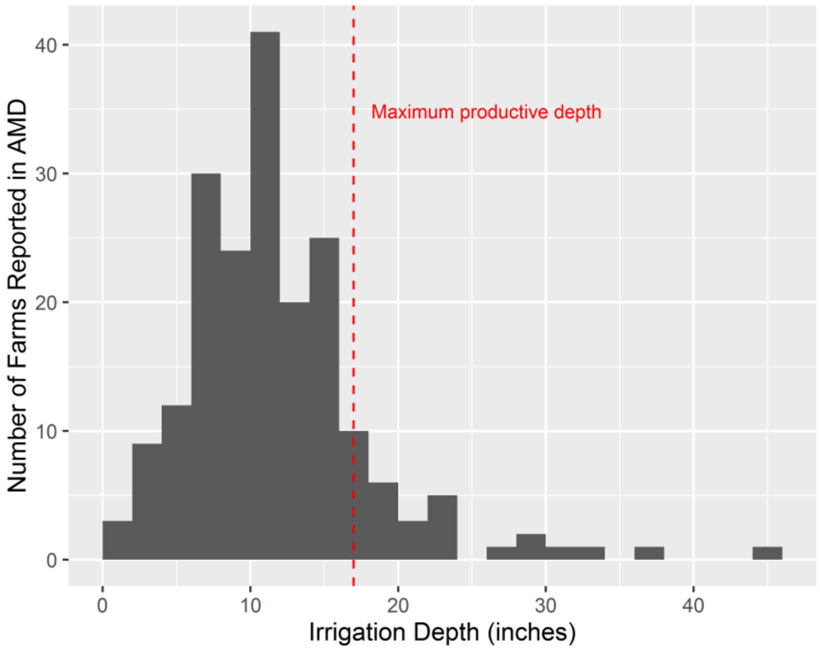


Figure 4: Actual vs. Maximum Productive Irrigation Depths, Peanuts on Fine Soils 2011



51. This analysis allowed me to estimate the average amount of excessive irrigation applied to fields of each crop type on each soil type, which I then scaled up by my estimates of irrigated area described above. Excessive irrigation on row crops across the ACF basin in Georgia averages 54,000 acre-feet in a non-drought year and 98,000 acre-feet in a drought year such as 2011. The impact on peak summer month streamflow depletions of just eliminating this wasteful water use would be 90 to 106 cfs in a non-drought year and 162 to 192 cfs in a drought year. Since such a measure would have no necessary impact on crop yields, farmers could reduce their consumptive use without incurring significant economic costs. In fact, they would save the costs associated with pumping that excessive water from the source to their fields.

52. Although the Agricultural Metering Database, JX-138, lacks sufficient data on high-value crops such as pecans, produce and sod, thereby currently precluding an equivalent analysis of excessive irrigation for those crops, there may nonetheless be potential to similarly reduce the amount of water applied to them without affecting yields. In particular, a 2015 study published in a peer-reviewed academic journal (HortScience) by Lenny Wells, a University of Georgia Extension expert on pecan production and irrigation, concludes that irrigation schedules for pecans may be redesigned to reduce early season irrigation by 38 percent without a statistically-significant impact on yields. The study, a true and accurate copy of which is at FX-699, was based on an experiment conducted from 2012 to 2014 on a commercial pecan orchard in Berrien County, GA, close to the Lower Flint River Basin. The results of the study have been featured in presentations given to Georgia pecan growers advising them on management practices, at true and accurate copy of which is at FX-700. It is common in my field to rely on these types of analyses by horticultural experts regarding potential water savings achieved through changes in water management techniques. I reviewed these two analyses in formulating my opinions in this case.

53. To calculate the reduction in consumptive use and streamflow impacts of such a change in pecan irrigation management, I rely on NESPAL's estimated irrigation depths reported in Table 1. These estimates are based on a combination of crop simulations using the same agronomic model Dr. Hoogenboom relied on in his expert report, agronomic engineering calculations, and farmer irrigation surveys conducted by the University of Georgia. The projected irrigation depths were prepared using sound scientific methodology and were done under contract with EPD for use by Georgia's Water Planning Regions and Counties. According to NESPAL, the irrigation depth for pecans would be approximately 40 inches in a drought year such as 2011. Note that this projected depth is based on simulation and not actual usage, the latter of which may be higher or lower and surely varies across users.

54. Combining this depth with the amount of irrigated pecan acreage, I estimate that a 38 percent reduction in pecan irrigation across the Georgia ACF would reduce annual consumptive water use by 40,000 acre-feet in a non-drought year and 63,000 acre-feet in a drought year like 2011. This measure alone would reduce peak monthly streamflow depletions in a non-drought year by 65 to 76 cfs and in a drought year by 102 to 119 cfs. Again these savings would be near costless, as the reduction in irrigation is not associated with any loss in crop yield.

55. In addition to curbing excessive irrigation, improvements in the efficiency of irrigation equipment would reduce consumptive use without affecting crop yields. Depending on the type of irrigation equipment used, only some portion of the amount of water dispersed makes it to the crop's root zone where it can be used for plant growth. Even among center pivot systems, the efficiency can vary greatly from 70 to 90 percent, or more.

56. As described in my February 29 report, FX-784, based on information provided by Dr. Bottcher and my estimates of row crop irrigated acreage and average irrigation depths, I

calculated the water savings and costs associated with efficiency upgrades that increase average irrigation efficiency on half of center pivot systems to 80 percent and half of center pivots to 90 percent. I estimate that improving the efficiency of center pivot irrigation systems in the ACF in Georgia, used primarily for cotton, peanuts, and corn, could reduce annual consumptive use by 39,000 acre-feet in a non-drought year to 63,000 acre-feet in a drought year like 2011. The resulting increase in peak summer streamflows would be 107 to 127 cfs in such a drought year and 66 to 78 cfs in a non-drought year, at an annual cost of less than $4 million.

57. There are various ways Georgia could encourage efficiency improvements, and there are indeed already some such programs in place. One notable example is the Mobile Irrigation Lab (MIL), which travels to farms around the state and provides efficiency testing and equipment upgrades to farmers. MIL services are provided at no cost and generally improve system efficiency by increasing the application uniformity of center pivot systems and installing end gun shutoff devices. According to data provided by Dr. Irmak, MIL testing and upgrades on several hundred center pivot systems have saved approximately 1,200 million gallons per irrigation season, representing water savings of approximately 26 acre-feet per center pivot per year. But, an analysis of pages 64-65 of Dr. Irmak's report shows that only a small percentage of Georgia ACF farms been served by the MIL program thus far. According to Dr. Irmak, Georgia has conducted a total of "over 450" irrigation system retrofits, but many of those were outside of the Georgia ACF, and in any case that is a small fraction of the total center pivots in the Georgia ACF. Scaling these savings to all center pivot systems in the Georgia ACF would imply reductions in peak streamflow depletions in drought years of 330 cfs, more than double my estimates above.

58. As described in Dr. Irmak's expert report and documents produced in support of his opinions, which I reviewed, Georgia farmers could more broadly utilize variable rate

irrigation (VRI) systems and intelligent irrigation scheduling to reduce their irrigation demand. VRI systems allow farmers to more precisely control the center pivot irrigation systems by controlling end gun sprinklers to avoid irrigation of non-cropped areas. User-friendly and reliable VRI systems were developed by the University of Georgia but, according to Dr. Irmak's expert report, have only been used in 22 pilot projects covering 3,500 acres in Georgia. These pilot projects found that VRI systems can reduce water use by 15% and save 5 million gallons of water per field in a dry year. Georgia farmers could also benefit from expanded use of intelligent irrigation scheduling. This technology, described by Dr. Irmak, allows farmers to utilize real-time soil moisture and crop water data to avoid irrigation at unnecessary or inefficient times. The Flint River Soil and Water Conservation District (FRSWCD) implemented an automation project that developed tools to allow for farmers to automate the incorporation of relevant data into their irrigation schedule. Per Dr. Irmak's expert report, the initial FRSWCD automation project was only deployed on several farms but saved more than 15 billion gallons of water in total. Expanded use of VRI and intelligent irrigation scheduling to a meaningful number of farms in the Georgia ACF Basin could result in significant reductions in agricultural water use.

### **3.** Permanent Buyback of Irrigation Permits

59. In a short-lived effort to reduce irrigated acreage in the Flint River Basin in critical years, Georgia passed the Flint River Drought Protection Act (FRDPA) in 2000 to automatically trigger an auction process when EPD declared a severe drought. Farmers would place voluntary bids on the amount of money for which they would agree to stop irrigating acres of their land in that year. EPD would then select the lowest bids until the target number of acres was withdrawn. However, the FRDPA auction has been implemented only twice since its introduction, in 2001 and in 2002 when 33,000 and 40,000 acres were removed from irrigation respectively. The auction process was never funded thereafter, and was not invoked despite

severe droughts in 2007-2008 and 2011-2012. In fact, amendments to the FRDPA in 2014 made both the severe drought declaration and the auction discretionary.

60. In addition to the FRDPA, Georgia itself has considered alternatives to temporarily reducing irrigated acreage in the Flint River Basin. In particular, the 2006 Flint River Basin Regional Water Development and Conservation Plan (Flint River Plan), published by EPD, assessed the impacts of stopping irrigation on 40% of corn, cotton, and peanut acreage in the Spring Creek and Ichawaynochaway sub-basins in dry years. The Flint River Plan, which is publicly available online and a copy of which is at JX-21, was developed by EPD to promote and facilitate the conservation, efficient use, and reuse of water in Georgia and avoid water shortages. It was developed in response to prolonged droughts and increased agricultural irrigation in the Flint River Basin. The Flint River Plan describes the 40% irrigation reduction scenario modeling and results in detail on pages 152-159. I reviewed the Flint River Plan as part of my preparation for this testimony.

61. Similar to the buyback contemplated in the Flint River Plan, a buyback of irrigation permits could also be implemented to reduce irrigated acreage on a permanent basis and limit consumptive use in all years. Such a program would be straightforward to implement, and would not need to be repeated in each drought year. I understand that Mr. Judson Turner, who was until recently the director of EPD, testified in his deposition that Georgia has considered instituting a permanent buyback in key areas of the Flint River Basin.

62. The cost of an irrigation buyback program depends on the value to farmers of their access to irrigation, or the amount they would have to be paid to be willing to give up their irrigation permits. One way of estimating this value is to compare the sales prices of farm land with and without access to irrigation. As detailed in Appendix B to my February 29 report, I conducted a hedonic analysis to estimate the average value of irrigation permits within the EPD

moratorium as components of the sales price of the farmland to which they were attached. Hedonic analysis is an established approach used to estimate the value of individual characteristics of a good when sold in a competitive market, and is often used to assess the economic value of environmental goods. Based on data on individual sales records of agricultural parcels, I found that the average premium for access to irrigation water in the Flint River Basin is around $860 per acre.

63. This estimate is consistent with two prior studies I reviewed that were authored in part by faculty at the University of Georgia, as summarized in Table 2 below. Spurgeon and Mullen (2005) estimated the value of agricultural water withdrawal permits under moratorium in Sumter County by considering land sales from 1977 to 2003, and find a premium of around $1,220 per acre. Spurgeon, Kyle C. and Mullen, Jeffrey D. "Estimating the Value of Irrigation Water in Georgia." Proceedings of the 2005 Georgia Water Resources Conference, held April 25-27, 2005, at the University of Georgia, https://smartech.gatech.edu/bitstream/handle/1853/47758/SpurgeonK-MullenJ%20paper.pdf?sequence=1. Presentations such as those given at the annual Georgia Water Resources Conference are the types of sources upon which those in my field generally rely. I reviewed and relied on this study in formulating my opinions in this case.

64. Petrie & Taylor (2007) estimated the value of permits under moratorium in Dooly County by considering land sales from 1993 to 2003, and find they add an average of $550 to $780 per acre to farmland sale prices. Petrie, Ragan A., and Taylor, Laura O. "Estimating the value of water use permits: A hedonic approach applied to farmland in the southeastern United States." Land Economics 83.3 (2007): 302-318, http://le.uwpress.org/content/83/3/302.short. Land Economics is a peer-reviewed journal and the type of source upon which those in my field generally rely. I relied on this report in formulating my opinions in this case.

65. Both studies also note that their estimates are in the range of permit values approximated by farm real estate agents in the region.

**Table 2: Estimates of the Value of Access to Irrigation in the ACF in Georgia**

| Analysis | Study Area | Number of Sales Included | Average Permit Value (2012 $ per acre) |
|---|---|---|---|
| Sunding Analysis | Flint River Basin | 1,010 | $860 |
| Petrie & Taylor (2007) Analysis | Dooly County | 324 | $620 |
| Reported Real Estate Agent Valuation | | -- | $550 - $780 |
| Spurgeon & Mullen (2005) Analysis | Sumter County | 42 | likely less than $1,220 |
| Reported Real Estate Agent Valuation | | -- | $1,020 - $1,280 |

66. To translate the purchase of an irrigation permit for one acre into savings in consumptive use, I again rely on the basin-wide average irrigation depths reported in Table 1. The per acre consumptive use savings, as well as the costs per acre, can then be scaled up by the number of acres Georgia removes from irrigation. For example, Georgia may purchase 100,000 acres of permitted irrigation at a one-time cost of $86 million, achieving reductions in annual consumptive use of 76,000 to 125,000 acre-feet depending on weather conditions. In an average non-drought year, buyback of 100,000 acres would reduce peak streamflow depletions by 128 to 157 cfs, depending on the underlying hydrological connectivity of the basin. In a drought year like 2011, buyback of 100,000 acres would reduce peak summer month streamflow depletions by 211 to 259 cfs relative to current levels. On an annualized basis, the cost of this measure would amount to just over $4 million per year. Purchase of 50,000 acres would achieve half the water conservation at half of the cost.

67. The permanent and temporary buyback of irrigation rights has featured in resolutions to a number of other water conflicts. In the Klamath Basin in Southern Oregon and Northern California, the Bureau of Reclamation implemented a water bank program similar in

approach to the FRDPA to reduce demand for their irrigation water supply on a year by year basis. In its dispute with Texas over the Pecos River Compact, New Mexico achieved compliance by short-term leasing of irrigation water rights.

68. To prevent further disputes between Colorado, Kansas, and Nebraska regarding the water of the Republican River Basin, the Nebraska Department of Natural Resources (DNR) and the three Natural Resources Districts within the Nebraska portion of the Republican River Basin agreed on a basin-wide management plan. For years forecast to be dry, DNR requires each district to reduce consumption in proportion to its contribution to streamflow depletions. The districts may choose a variety of conservation measures to achieve the required reductions in depletions, including leasing water rights or the retirement of irrigated acreage. Georgia could employ a similar range of measures here.

a. FX-867 is a true and accurate copy of a map showing, among other things, the irrigation water allocation and annual precipitation for each Nebraska Natural Resource District (NRD) as of September 10, 2015. I downloaded the from: https://www.nrdnet.org/sites/default/files/ubbnrdgroundwater_quantity_map2015.pdf. An earlier version of this map is FX-183, a true an accurate copy of the allocations in 2014. I downloaded that map from: http://cpnrd.org/wp-content/uploads/2015/11/2014-STATE-MAP-WATER-MANAGEMENT-STATUS.pdf. The information detailed on these maps was gathered and published by the Upper Big Blue Natural Resources District. The NRDs are local government entities. I relied upon these documents in formulating my opinions in this case.

b. Cornhusker Economics – Republican River Dry-Year Pans, FX-184, is a true and accurate copy of an article published by the University of Nebraska-Lincoln

Extension office in August 2013. FX-184 describes the dry year water allotment plans for the Republican River NRD. I downloaded Cornhusker Economics directly from the webpage for the University of Nebraska-Lincoln Extension office at http://agecon.unl.edu/cornhusker-economics/2013/republican-river-dry-years-plans.pdf. This type of university publication is generally relied upon by those in my field, and I relied upon in formulating my opinions in this case.

c. FX-185, is a true and accurate copy of the Integrated Management Plan for the Republican River NRD prepared by the Board of Directors for the Upper Republican Natural Resources District and the Nebraska Department of Natural Resources (DNR), in accordance with the Nebraska Ground Water Management and Protection Act, Neb. Rev. Stat. §§ 46-701 to 46-754. I downloaded Cornhusker Economics directly from the webpage of the Nebraska DNR at http://dnr.nebraska.gov/Media/iwm/PDF/URNRD_IMP_0910.pdf.

### **4.** Automatic Reductions in Farm Pond Evaporation

69. Reducing row crop irrigation by any of the means I have discussed has the additional benefit of reducing evaporation from farm ponds. Small man-made ponds – often referred to as water "impoundments" – occur throughout the Georgia portion of the ACF Basin, and are highly concentrated in agricultural areas where they are often used to serve center pivots. These ponds are filled with either surface or groundwater to provide irrigation on demand in large volumes. Prior estimates of total small impoundment storage show that they can hold the equivalent of over half of the volume of conservation storage in Lake Lanier (the largest federal reservoir on the Chattahoochee River) at peak times. Water is lost from these impoundments through evaporation, particularly in the hot summer months, contributing further to consumptive use and peak season streamflow depletions in the agricultural sector.

70. According to estimates provided by Dr. Flewelling, evaporation off small agricultural impoundments in the ACF amounted to nearly 400 cfs of peak monthly streamflow depletions in 2011. It is reasonable to assume that reliance on small impoundments, and therefore the evaporation associated with them, would automatically decline in proportion to reductions in center pivot irrigation overall, providing additional streamflow benefits at minimal extra cost. In addition to reducing irrigated row crop acreage and curtailing wasteful irrigation, the amount of center pivot irrigation (and therefore the amount of farm pond evaporation) can also be reduced via the drought-year limits on irrigation depths described in the following section.

## V. ADDITIONAL DROUGHT-YEAR MEASURES TO REDUCE ENVIRONMENTAL HARM

71. The measures described above are examples of how Georgia could reduce consumptive use in both drought and non-drought years, enabling Georgia to cap its consumptive use of water taken from the ACF Basin. Since the externalities associated with Georgia's water consumption are most severe in drought years, Georgia can and should increase its conservation efforts in those critical times.

### **A.** Implementing Urban Outdoor Watering Restrictions

72. As noted above, Georgia already has a drought year policy in place in the municipal sector, namely a ban on non-essential outdoor water uses. However, this ban was not invoked in the 2011 and 2012 droughts. Restrictions on outdoor water use are common policies that numerous other municipalities have enacted in drought years. Among others, cities in California, Texas, Colorado, and Florida have all faced mandatory outdoor use restrictions during drought.

73. Urban outdoor water use is primarily for landscape watering, which, unlike crop irrigation, is not directly associated with the production of any economic output. Curbing this

use in very dry and drought years thus entails only relatively small fiscal costs to administer and enforce the program. Reducing urban outdoor use in certain years would also require only minimal additional equipment or investment. And, changes in the appearance of lawns would be temporary. According to EPD's WaterWise Landscape Guide, "[d]uring drought periods, a healthy turfgrass will wilt and turn brown, but then regain normal color and growth when it rains or environmental conditions become favorable for growth." *See* https://epd.georgia.gov/sites/epd.georgia.gov/files/MDC_WaterWise_Landscape_Final-7MB.pdf. According to the Cobb County Water Authority, "more Georgia lawns were damaged from over-watering than from lack of water during recent droughts in Georgia." *See* http://watersmart.net/conserve/outdoor.

74. The total amount of urban outdoor use in the ACF in Georgia can be inferred from the seasonal pattern of municipal demand. As outdoor water use varies throughout the year, while indoor uses remains relatively constant, a common method for estimating outdoor use involves the comparison of usage across months within each year. Using this approach with EPD's municipal and industrial withdrawals database, on a permit-holder by permit-holder basis, I estimated the total annual outdoor water use of all permitted municipal users withdrawing from the Chattahoochee and Flint River basins. I have reviewed this database, entitled "permits.mdb," which I received through the discovery process. JX-139. It is typical for experts in my field to rely on databases of this type. Aggregate outdoor water use in the ACF in Georgia resulted in over 130,000 acre-feet of consumptive use in 2011. As landscape watering follows a similar seasonal pattern to agricultural irrigation, streamflow impacts during the peak month are much higher than they would be if outdoor use was distributed evenly throughout the year.

75. A 50 percent cutback in urban outdoor use would thus lead to a reduction in peak month streamflow depletions of 207 cfs, and a 30 percent cutback to a reduction in depletions of

124 cfs, in a drought year like 2011. For context, a peer-reviewed study of various mandatory outdoor water use scheduling restrictions implemented by Colorado municipalities during its 2002 drought found that the restrictions reduced outdoor water use by 18 to 56 percent. The 56 percent reduction was achieved with a one day per week watering restriction, still less stringent than the full ban specified in Georgia's drought response plan.

76. Restricting outdoor water use to one or two days per week, or banning it altogether during drought periods, may cause an aesthetic impact in urban areas. Consumers would rather purchase water for lawn watering at prevailing rates, and so preventing this transaction from occurring results in some loss of economic welfare. To estimate this welfare loss, as described in my February 29, 2016 report, FX 784, I conducted an econometric analysis of municipal water users' demand for outdoor water at the different prices that they have been charged over recent years, taken from the Georgia Water and Wastewater Rates Dashboard provided by the University of North Carolina. The prices that municipal users are willing to pay for outdoor water represent the welfare loss they incur from foregoing that water. For the 50 percent cutback described above, I estimate that welfare losses would be approximately $78 per service connection per year, only in years in which the restriction is implemented. If this is once every three years, the annualized cost per service connection is $26, or $2 per month. Again, these are welfare losses, not fiscal costs imposed on water users or Georgia.

77. However, prohibiting lawn watering may also create what economists refer to as welfare gains since urban consumers may care about downstream ecological impacts in Florida. In a later section of this testimony, I show that urban consumers in Georgia have exactly these preferences, and a majority express support for mandatory or voluntary lawn watering restrictions in drought conditions if the conserved water is allowed to make its way to Florida.

78. Likewise, as an outdoor watering ban would be only a temporary measure, and given that lawns and landscaping would continue to grow in Georgia without supplemental watering even in a drought year, such a measure would not entail significant job losses in the landscaping industry. Consistent with this expectation, according to Georgia's Bureau of Labor Statistics Quarterly Census, FX-710, employment for landscaping services in the Atlanta area did not fall dramatically during the last outdoor watering ban in 2007 and 2008. The total number of jobs in the sector fell 3 percent from 2006 to 2007, and a further 6 percent in 2008. In fact, landscaping jobs fell by a larger percent in 2009 and 2010, when no outdoor watering restrictions were in place.

a. FX-710 is a true and accurate copy of Georgia's Quarterly Census of Employment and Wages Program for the Landscaping Services Sector. This data is publically available at https://explorer.gdol.ga.gov/vosnet/Default.aspx, which is maintained by the State of Georgia.

79. Because a reduction in outdoor water use is not associated with any fiscal costs, and the welfare costs of such a reduction would largely or entirely be offset due to the preference of urban Georgia consumers to minimize downstream impacts to Florida, I do not include the welfare cost from my February 29, 2016 report in the possible combinations of measures to reduce streamflows presented later in my testimony.

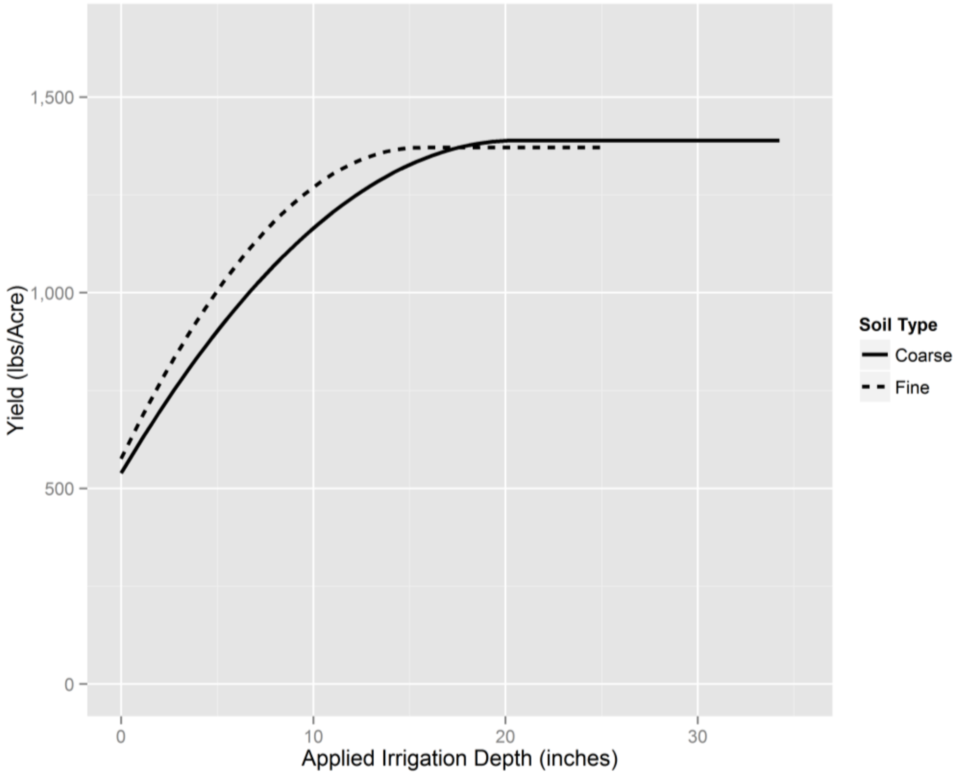
### **B.** Reduced Irrigation Depths on Irrigated Acreage

80. Consumptive use can also be further reduced in drought years in the agricultural sector by limiting the amount of water applied on the irrigated acreage remaining after any permit buybacks. This practice is commonly known as deficit or limited irrigation. In contrast to the Flint River Plan measure described above, partial reductions in irrigation depths could be imposed on a broader set of Georgia ACF farmers. Partial reductions in irrigation depths are

generally less costly because, for any given crop and soil, an additional inch of water has less of an impact on crop yield if more water has already been applied. The first inch of water applied to a crop provides a bigger boost in yield and farmer revenue than the second, the second a bigger boost than the third, and so on. Eventually, an additional inch of water provides no yield gain at all and may even damage the crop.

81. An example of the relationship between irrigation and crop yield is illustrated in Figure 5, for cotton under dry year conditions. The lines are based on crop simulation results provided by Dr. Hoogenboom, as described in Technical Appendix A to my February 29 report. They show the average cotton yield for any given irrigation depth, with the maximum possible yield per acre reached at approximately 14 inches of irrigation on fine soil and 17 inches on coarse soil. In contrast, as shown in Figure 3 above, some cotton farmers in the ACF in Georgia irrigate upwards of 30 inches in a drought year.

**Figure 5: Irrigation-Yield Relationship for Cotton in Dry Years**



82. The costs of reducing irrigation depths are simply the revenue losses farmers incur due to the lower crop yield in each year when such a conservation measure is put in place. The last units of water applied on a given acre are therefore cheapest to conserve, while the first units are most costly. Spreading a given cutback in consumptive use across a larger acreage base is therefore more economically efficient in the short run, all else equal.

83. Lower irrigation depths could be achieved most simply by specifying a cap as a percentage of the maximum amount of water a crop can productively use. The Northwest Florida Water Management District imposes irrigation caps in this manner, as described in the testimony of Mr. Brett Cyphers. Table 3 below reports incremental reductions in consumptive use and corresponding peak month streamflow depletions from ratcheting down irrigation depths to 90%, 80%, and 50% of the maximum productive irrigation depths for cotton, peanuts, and corn across the ACF in Georgia in a drought year such as 2011. I also present the water savings that would occur from equivalent caps in non-drought years, and the incremental costs of imposing these tiers of restrictions in all years. The water savings and cost estimates presented are relative to current irrigation patterns in the Georgia ACF.

**Table 3: Costs and Water Savings of Basin-wide Percentage Limits on Row Crop Irrigation**

| | Drought Year | | | Non-Drought Year | | | |
|---|---|---|---|---|---|---|---|
| | | Peak Streamflow (cfs) | | | Peak Streamflow (cfs) | | |
| **Row Crop Depth Limit** | **Cons. Use (AF)** | **0.43 Conn** | **0.60 Conn** | **Cons. Use (AF)** | **0.43 Conn** | **0.60 Conn** | **Annual Cost ($ million)** |
| Limit to 90% of Maximum | 120,087 | 205 | 243 | 67,622 | 117 | 138 | $3 |
| Addl. Limit to 80% of Maximum | 29,146 | 56 | 68 | 14,397 | 28 | 33 | $5 |
| Addl. Limit to 50% of Maximum | 136,452 | 263 | 314 | 69,996 | 135 | 162 | $36 |
| TOTAL | 285,686 | 525 | 625 | 152,015 | 280 | 333 | $44 |

84. Alternatively, Georgia could reduce irrigation depths by imposing total irrigation volume restrictions on specific areas, according to their hydrologic connectivity, and allowing trading across water uses to minimize costs. Under such a policy, water conservation can be

optimized by targeting reductions to locations that contribute most to streamflow, to water users that benefit the least from additional irrigation, and to the lowest value crops. As a general principle, conservation of a resource is most cost-effective when it targets the lowest value uses of water first. The same applies to agricultural water conservation in the ACF in Georgia.

85. If total pumping volumes are limited and a market-based policy is used to allow farmers to undertake deficit irrigation in an economically optimal manner, Georgia can achieve drought year reductions in streamflow depletions at lower cost. Assuming that Georgia calls on such a policy in drought years, under an average hydrological connectivity of 0.6, a reduction in peak depletions of 300 cfs would cost $2.1 million per year. A reduction of 500 cfs could be achieved at a cost of $9.1 million per year. Under an average connectivity of 0.43, those same cutbacks in consumptive use would amount to 259 cfs and 438 cfs respectively at the same costs.

### **C.** Switching High-Value Crop Irrigation to Alternative Water Sources

86. For the relatively higher-value crops grown in the ACF in Georgia such as pecans and fruits and vegetables, where crop yield losses would be more costly on a per acre basis, Georgia could shift to deeper groundwater irrigation water sources that do not affect Apalachicola River streamflows. The lower aquifers do not connect directly to the Flint River or its tributaries in a large portion of the Flint basin. High value crop acreage that relies on surface water from the Flint River, or on groundwater taken from the Upper Floridan Aquifer, could move to groundwater drawn from the deeper Claiborne and Cretaceous Aquifers. Georgia has indeed considered this option itself – for example, in the Lower Flint Ochlockonee Regional Water Plan (LFO Plan), FX-24 – and there are already farms withdrawing water from the Claiborne Aquifer in certain portions of the lower Flint. The LFO Plan, released in November 2011, is publicly available and was developed by the Lower-Flint Ochlockonee Regional Water Planning Council, in cooperation with EPD, as part of the Georgia State-wide Water

Management Plan, adopted by the Georgia legislature in January 2008. That is, this is a government document maintained by the State of Georgia. As indicated by Table 1, relatively high-value crops account for 170,000 to 290,000 acre-feet of consumptive use in the Georgia ACF. To assess the potential reductions in streamflow depletions associated with shifting the Floridan and surface water portion of this consumptive use to alternative sources, I combined the irrigation demands of high value crops from Table 1 with the amount of relevant acreage. I estimate that just switching 75 percent of this acreage to deeper aquifers could save 321 to 376 cfs of peak streamflow depletions in a drought year. Deeper aquifer wells would also be available for use in non-drought years, providing 189 to 221 cfs of peak month streamflow savings.

87. As discussed in my February 29 report, the costs associated with this measure are largely the one-time expenses of drilling and installing new, deeper wells. As a conservative adjustment, I also increase the costs of pumping from deeper aquifers to accommodate an increase in required lift, although I understand that these deeper aquifers are pressurized and would not necessarily require more lift than pumping from the Floridan Aquifer. The total resulting costs of switching high value crops to deeper aquifers is approximately $10 million on an annualized basis if the wells are used only in drought years, and $12 million per year if they are used in every year.

## VI. COMBINATIONS OF MEASURES TO LIMIT CONSUMPTIVE USE

88. As previously discussed, Georgia could institute: (1) a cap on annual average consumption of water in the ACF basin; and (2) a cap specifically reducing the amount of water that can be consumed in drought years. Water consumption has the potential to increase greatly in the coming decades. For example, according to Dr. Stavins, current Metro Atlanta annual water use is approximately 110 million gallons per day less than projected in the year 2050.

There are many measures that could affordably offset that growth in Metro Atlanta, including increases in return flow rates. Additionally, agriculture could grow substantially even if Georgia issues no new permits. Georgia could take any number of the conservation measures discussed in my testimony to offset this growth. Again, preventing growth in the agricultural sector is in many cases economically preferable to reducing existing water use, as investments in irrigation equipment have not yet been made.

89. As demonstrated in Table 4, Table 5, and Table 6 below, Georgia could combine any of the conservation measures I have analyzed and discussed to provide reductions in peak streamflow depletions of 1,500 to 2,000 cfs in drought years. These tables also include estimates of the non-drought year water savings associated with the conservation measures I analyzed, in terms of peak month streamflow depletions for comparison, and the incremental fiscal costs of each of the measures on an annualized basis. These costs do not include the non-fiscal welfare losses associated with restricting urban outdoor water use, or costs associated with implementation of Georgia's own existing policies. Costs are calculated based on the assumption that a dry year occurs once every three years, where all dry year costs are represented by the full costs incurred in a drought year such as 2011. Water savings estimates are also based on a representative drought year, to illustrate the full potential of these measures in reducing peak streamflow depletions in years when they are most needed.

90. In combination, the water savings and costs for each measure depend on which other strategies are already being employed. For example, permanent buyback of irrigation permits reduces the amount of acreage on which irrigation depth limits can provide additional reductions in streamflow depletions. The testimony of Dr. Hornberger and other hydrologists will explain how the conservation measures I propose will cause reductions in streamflow depletions and increases in Apalachicola River streamflow, and how drought can be reliably

predicted. In particular, I refer the Court to Dr. Hornberger's testimony on streamflow impacts at Section VII for an explanation of the .43 and .60 impact factors in the charts below.

### Table 4: Possible Combinations of Measures to Reduce Streamflow Depletions by 2,000 cfs

| Conservation Measure | Non-Drought Year (peak cfs) 0.43 Conn | 0.60 Conn | Drought Year (peak cfs) 0.43 Conn | 0.60 Conn | Incremental Fiscal Cost per Year ($ millions) |
|---|---|---|---|---|---|
| **Existing Policies and Minimal-Cost Measures** | | | | | |
| Municipal Leak Abatement | 42 | 42 | 42 | 42 | -- |
| Reduce Municipal Outdoor Use by 50% | -- | -- | 207 | 207 | -- |
| Eliminate Net Basin Exports | 66 | 66 | 66 | 66 | -- |
| Eliminate Unpermitted Acreage | 76 | 91 | 125 | 151 | -- |
| Eliminate Excessive Irrigation of Rotation Crops | 82 | 98 | 150 | 178 | -- |
| **Additional Agricultural Measures** | | | | | |
| Irrigation Permit Buyback (20% of Total Acreage) | 186 | 228 | 306 | 375 | $6.9 |
| Deficit Irrigation to Reach 2,000 cfs | -- | -- | 430 | 480 | $20.7 |
| Reduced Evaporation from Farm Ponds | 135 | 135 | 279 | 271 | -- |
| Switch High Value Crops to Deeper Aquifers | 116 | 136 | 198 | 232 | $7.6 |
| **TOTAL** | **704** | **796** | **1,802** | **2,000** | **$35.2** |

Note: Irrigation permit buyback is implemented here as permanent buyback of 160,000 acres of irrigation, but temporary buyback is another option, as in the FRDPA. Deficit irrigation reduces annual consumptive use by 170,000 acre-feet in drought years.

### Table 5: Possible Combinations of Measures to Reduce Streamflow Depletions by 1,500 cfs

| Conservation Measure | Non-Drought Year (peak cfs) 0.43 Conn | 0.60 Conn | Drought Year (peak cfs) 0.43 Conn | 0.60 Conn | Incremental Fiscal Cost per Year ($ millions) |
|---|---|---|---|---|---|
| **Existing Policies and Minimal-Cost Measures** | | | | | |
| Municipal Leak Abatement | 42 | 42 | 42 | 42 | -- |
| Reduce Municipal Outdoor Use by 50% | -- | -- | 207 | 207 | -- |
| Eliminate Unpermitted Acreage | 76 | 91 | 125 | 151 | -- |
| Eliminate Excessive Irrigation of Rotation Crops | 82 | 98 | 150 | 178 | -- |
| **Additional Ag Measures** | | | | | |
| Irrigation Permit Buyback (15% of Total Acreage) | 139 | 171 | 229 | 281 | $5.2 |
| Deficit Irrigation to Reach 1,500 cfs | -- | -- | 181 | 200 | $5.5 |
| Reduced Evaporation from Farm Ponds | 114 | 114 | 191 | 182 | -- |
| Switch High Value Crops to Deeper Aquifers | 130 | 152 | 221 | 259 | $8.5 |
| TOTAL | 584 | 668 | 1,346 | 1,500 | $19.2 |

Note: Irrigation permit buyback is implemented here as permanent buyback of 120,000 acres of irrigation, but temporary buyback is another option, as in the FRDPA. Deficit irrigation reduces annual consumptive use by 70,000 acre-feet in drought years.

## Table 6: Possible Combination of Measures to Reduce Streamflow Depletions by 1,000 cfs

| | Non-Drought Year (peak cfs) | | Drought Year (peak cfs) | | Incremental Fiscal Cost per Year ($ millions) |
|---|---|---|---|---|---|
| **Conservation Measure** | **0.43 Conn** | **0.60 Conn** | **0.43 Conn** | **0.60 Conn** | |
| **Existing Policies and Minimal-Cost Measures** | | | | | |
| Municipal Leak Abatement | 42 | 42 | 42 | 42 | -- |
| Reduce Municipal Outdoor Use by 30% | -- | -- | 124 | 124 | -- |
| Eliminate Unpermitted Acreage | 76 | 91 | 125 | 151 | -- |
| Eliminate Excessive Irrigation of Rotation Crops | 82 | 98 | 150 | 178 | -- |
| **Additional Ag Measures** | | | | | |
| Irrigation Permit Buyback (13% of Total Acreage) | 116 | 142 | 191 | 234 | $4.3 |
| Irrigation Cap at 75% of Max Productive Depth | -- | -- | 103 | 123 | $4.6 |
| Reduced Evaporation from Farm Ponds | 104 | 104 | 148 | 148 | -- |
| TOTAL | 420 | 477 | 883 | 999 | $8.9 |

Note: Irrigation permit buyback is implemented here as permanent buyback of 100,000 acres of irrigation, but temporary buyback is another option, as in the FRDPA.

91. The costs of water conservation listed in the preceding tables focus on so-called direct impacts, which are defined as impacts to the entity (person or business) that is reducing its consumption. Echoing claims made in similar situations, Georgia's expert Dr. Stavins asserts that the regional economic impacts of agricultural water conservation in the Flint Basin are large. In particular, he claims that there are significant employment impacts from reductions in agricultural output that result from water conservation efforts. These claims are unfounded for several reasons. First, as demonstrated above, Georgia farmers currently use significant amounts of water that do not increase agricultural productivity at all in the sense that they are above amounts that enable crops to achieve maximum yield. Farmers can curb at least this amount of irrigation without any changes in farm output, and thus with no indirect effects. Second, deficit irrigation can be employed to reduce crop output by a modest amount by limiting, but not entirely reducing, irrigation depths. Dr. Stavins considers only the two most extreme possibilities in his analysis of employment effects: full irrigation and no irrigation. Third, Georgia farmers can reduce their water use by improving irrigation efficiency. Under this type

of intervention, it is possible that Georgia farmers could actually maintain or increase their crop yields from current levels (resulting in third-party regional benefits) while reducing their water use at the same time. Dr. Stavins does not consider this possibility.

92. Finally, Dr. Stavins' analysis of regional impacts fails to acknowledge the possibility that Georgia farmers could be compensated for their water conservation efforts. Such payments could occur through permanent or temporary programs to purchase irrigation rights such as have been implemented in other states, or through programs that would insure Georgia farmers against yield decreases resulting from drought-related limitations on water use. If Georgia farmers were paid to reduce their water use, then the stimulus effect of such payments would also need to be accounted for in a proper regional economic analysis.

93. It is important to remember that even a program to permanently purchase irrigation rights would not necessarily result in a reduction in the amount of land farmed in the Flint Basin since rain-fed agriculture is a viable alternative to irrigation. If farmers remain active in the Basin after receiving such payments, it is likely that they will spend the proceeds to pay down debt, invest in farm equipment, increase their personal consumption, or engage in some combination of these and other responses. These increased expenditures have a positive stimulus effect and can even increase the long-run productivity of agriculture in the region.

## VII. CRITIQUES OF GEORGIA EXPERTS

94. Georgia's experts have presented a number of other critiques of my analysis that are either incorrect or overstated. I will first discuss the technical issues that have been raised, and then address the more conceptual criticisms. First, Dr. Stavins states that I included in my analyses irrigation that draws from the Claiborne aquifer rather than the Floridan, thereby overstating the impact of reductions in groundwater withdrawals on streamflow. He fails to recognize, however, that most existing Claiborne acreage is outside the geographical boundary of

the hydrological model I relied on, and is therefore implicitly excluded from my analysis. The remaining acreage is disproportionately concentrated in model areas of low connectivity, and therefore plays a minimal role in my conservation measures.

95. Dr. Stavins' own removal of Claiborne acreage from the analysis was implemented incorrectly, as he simply removed the total amount of Claiborne acreage in the ACF proportionally across the Basin. This approach even cuts back surface water acreage, although only groundwater withdrawals may possibly come from the Claiborne Aquifer. Dr. Stavins' estimate of the impact of removing Claiborne acreage is further confounded by the fact that he ignores growth in irrigated area since 2008, and unjustifiably refuses to allow any degree of deficit irrigation other than switching entirely to rainfed production. The impact of removing existing Claiborne acreage correctly in itself is minimal, and is included in my analysis above with little quantitative significance.

96. Dr. Irmak's July 28, 2016 memorandum, prepared in collaboration with Mr. Mark Masters, the director of the Georgia Water Planning & Policy Center at Albany State University, presented an analysis suggesting that the irrigated acreages reported in the Agricultural Metering Database did not include the overthrow produced by center pivot end guns, thereby leading to overestimates of irrigation depths for corn, cotton, and peanuts. To adjust for this information, in estimating irrigation depths from the Agricultural Metering Database, I have divided the reported volume of water usage by 1.1 times the reported irrigated acreage to approximate the irrigated area inclusive of center pivot overthrow.[2] The irrigation depths for corn, cotton, and peanuts presented here are thus ten percent lower than in my expert reports, and represent more conservative estimates of irrigation water use. Again, this adjustment has minimal impact on the overall streamflow impacts and costs of conservation and no qualitative significance.

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[2] This 1.1 scaling factor was used by NESPAL.

97. As brought to my attention during my deposition, I overestimated outdoor use in my expert reports by not adding up the withdrawals of municipal water users with multiple permits in determining their baseline level of water use. The above analysis of outdoor water use aggregates all permits for each water user, leading to a 49 cfs smaller estimate of the streamflow savings associated with a 50 percent reduction in outdoor use, and a 30 cfs smaller estimate of the streamflow savings associated with a 30 percent cut. Contrary to Dr. Stavins' assertion, it is appropriate to use the same seasonal scaling factor for urban outdoor use and agricultural irrigation, as they follow similar seasonal patterns. I have adjusted the peak seasonal scaling factor for urban leak abatement reported above to reflect that leaks due to poor management may not be seasonally dependent.

98. In terms of more general arguments, Dr. Stavins and Dr. Irmak both claim that deficit irrigation is infeasible, although for different reasons. Dr. Irmak claims that deficit irrigation is impossible in Georgia due to the sandiness of Georgia's soils. He argues that Georgia soils do not hold enough water to allow crops to survive without full irrigation. In making this claim, Dr. Irmak ignores the existence of a large number of farmers in the ACF who continue to grow crops with no irrigation whatsoever, and the large number of farmers he himself identifies through the Agricultural Metering Database as applying less than the productive maximum amount of irrigation. Moreover, my analysis of deficit irrigation builds on the Decision Support System for Agrotechnology Transfer (DSSAT) modeling of Dr. Hoogenboom. DSSAT is an agronomic model that calculates growth, development, and yield (amount of production) of a particular crop under various circumstances, including weather, amount of water various soil types hold, crop management, and plant genetics. It is one of the most well-known and widely-used decision support system models. Dr. Hoogenboom's DSSAT model explicitly accounts for differences in soil quality, and contains expansive

modeling of plant growth across a range of environmental conditions. In this way, my deficit irrigation analysis explicitly takes Georgia's unique soil types into account.

99. As further evidence that Dr. Irmak's claim about the impossibility of deficit irrigation on Georgia soils is incorrect, I compiled data on the "available water holding capacity" (AWC) of soils in the ACF in Georgia (FX-165, FX-166 and FX-167), Nebraska (FX-186 and FX-187) and Florida (FX-181 and FX-182). AWC refers to the volume of water that is stored in a given unit of soil. Higher values indicate more water that can be stored and made available to plants. The data was compiled at my direction from USDA-NRCS sources, as I described earlier. This source generally is relied upon by other experts in my field.

a. FX-170 is a true and accurate copy of USDA-NRCS's webpage defining and explaining the importance of AWC. I reviewed this webpage in preparing my expert report and testimony.

b. The data I used to create FX-165, a distribution table showing the AWC values for irrigated parcels in the entire ACF basis in terms of cultivated acres, was pulled directly from the SSURGO database. Specifically, both exhibits combined tabular data ("horizon," "component," and "map unit" tables and spatial data in the form of a shapefile). The SSURGO data used is described at the following webpage: http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/geo/?cid=nrcs142p2_053631.

c. The data I used to create FX-166 and FX-167, a map of the AWC for Baker County, Georgia and distribution table showing the AWC values in terms of cultivated acreage for Baker County, Georgia respectively, were pulled directly from the SSURGO database. Specifically, both exhibits combined tabular data ("horizon," "component," and "map unit" tables and spatial data in the form of a shapefile). The SSURGO data used is described here: [http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/geo/?cid=nrcs142p2_053631](http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/geo/?cid=nrcs142p2_053631).

d. FX-172 is a true and accurate copy of an NRCS webpage describing the soil data available using the Web Soil Survey. I have reviewed water holding capacity data using the Web Soil Survey. FX-175 is a true and accurate copy of a screenshot of a Web Soil Survey webpage showing the types of data, information and mapping available for an "area of interest" in Baker County, GA. I created FX-175 by selecting the geographic "area of interest" to examine in Baker County using Web Soil Survey. FX-176 is also a true and accurate copy of a screenshot of a Web Soil Survey webpage showing average water holding capacity, or AWC, for soils in the selected area of interest in Baker County, Georgia. The AWC data in FX-176 was pulled directly from the SSURGO database by Web Soil Survey. I created FX-176 by selecting the geographic "area of interest" to examine in Baker County using Web Soil Survey.

e. The data I used to create FX-180, FX-181, and FX-182, a distribution table showing the AWC values in terms of cultivated acreage for Calhoun County, Florida, and two maps of the AWC for Calhoun County, Florida, respectively, were pulled directly from the SSURGO database. Specifically, both exhibits combined tabular data ("horizon," "component," and "map unit" tables and spatial data in the form of a shapefile). The SSURGO data used is described here: [http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/geo/?cid=nrcs142p2_053631](http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/geo/?cid=nrcs142p2_053631).

f. The data I used to create FX-186 and FX-187, a map of the AWC for Banner County, Nebraska and distribution table showing the AWC values in terms of cultivated acreage for Banner County, Nebraska, respectively, were pulled directly from the SSURGO database. Specifically, both exhibits combined tabular data ("horizon," "component," and "map unit" tables and spatial data in the form of a shapefile). The SSURGO data used is described here: http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/geo/?cid=nrcs142p2_053631.

100. As additional background on this analysis, SSURGO contains information about various soil parameters (for example, taxonomic information, water storage information, soil composition, elevation and slope data, etc.) for the majority of the United States. SSURGO data can generally be downloaded by county, where tabular and spatial information can be connected using specific identifiers.

101. For the purposes of the AWC calculations, I extracted data on water storage capacity for soil horizons included in the plant root zone (approximately extending from the ground surface to 48" below the surface) and plotted it for relevant counties in Georgia, Florida, and Nebraska. I weighted the raw AWC values reported for each soil layer in the SSURGO database according to depth to calculate a specific AWC value for each point on the landscape. These numbers correspond to the unique colors on the accompanying maps and the values plotted in the distributions charts.

102. Dr. Irmak asserts that soils typically found in southwestern Georgia are sandy and have AWC values of 0.6 inches per foot. I examined actual AWC values for irrigated land in the Georgia ACF using the USDA's SSURGO database, which is the result of extensive collection and analysis of soils across the United States. I found an average AWC value of 1.29 in the

Georgia ACF, or more than double what Dr. Irmak claims. Furthermore, these values are comparable to AWC values for soils in Nebraska, where even Dr. Irmak acknowledges that farmers have successfully coped with restrictions on consumptive use. Soils in the Florida ACF were sandier than soils in the Georgia ACF.

103. Dr. Stavins argues that deficit irrigation is too complex of a conservation measure for Georgia to implement, and that no such policies have been implemented before. This is a puzzling statement, and in making these claims, it is clear that Dr. Stavins misunderstands the nature of deficit irrigation. Rather than a direct command-and-control policy, deficit irrigation is a means by which farmers can respond to water supply constraints that arise for any reason, including the system of water rights in place, conservation policy, or simply a natural water shortage. Rational farmers will handle water supply limitations in a cost-effective way, and the particular policy Georgia implements need only be flexible enough to allow them to do so.

104. Dr. Stavins also claims that agricultural water conservation measures will place an undue burden on ACF farmers and the ACF economy. As I noted earlier, however, rotation crop agriculture accounts for a small portion of the value of ACF agriculture, and a minimal portion of the ACF economy – less than one half of one percent. Irrigated row crop agriculture in the ACF in Georgia is smaller still. Also, as I discussed in my February 29 report, the costs of conservation may be distributed across the state, and farmers can be compensated for their revenue losses in drought years when conservation measures are implemented. Such compensation also produces regional economic benefits as farmers receiving conservation payments can spend the proceeds locally.

105. Perhaps the broadest critique Dr. Stavins levels against water conservation in the ACF in Georgia is that it does not pass a cost-benefit test. Comparing the costs and benefits of an

environmental policy is a standard means of evaluating whether it is socially desirable. However, a strict cost-benefit test – or apples-to-apples comparison – relying on monetized values for both costs and benefits, is often not appropriate or possible in a case of environmental conservation like this one, where benefits are far-reaching and complex and involve a myriad of species. Most economists have now concluded that available methods for estimating the intrinsic, nonuse values of natural and undeveloped areas are not sufficiently reliable to be used in strict cost-benefit analysis. It is beyond the bounds of mainstream economic science to estimate the monetary value of the purple bankclimber mussel, or salinity gradients in Apalachicola Bay, or disruption of longstanding cultural and social relationships in oystering communities – let alone to monetize the value of *changes* in these resources as Dr. Stavins would have us do. In situations like the one presented in this case, most environmental economists and scholars in the field of cost-benefit analysis recommend comparing incremental economic costs, most of which can be fairly readily monetized, to incremental benefits even if those benefits can only be expressed in non-monetary terms.

106. Indeed, in other settings, Dr. Stavins has argued for exactly this approach. Writing with a group of economists, Dr. Stavins lays out a set of principles for environmental cost benefit analysis.[3] One such principle is that “benefits and costs of proposed policies should be quantified wherever possible. But not all impacts can be quantified, let alone monetized. Therefore, care should be taken to assure that quantitative factors do not dominate qualitative factors in decision making.” I agree. Dr. Stavins and his co-authors go on to conclude that “[a]lthough formal cost-benefit analysis should not be viewed as either necessary or sufficient for designing sensible

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[3] Kenneth Arrow et al., “Is there a Role for Benefit-Cost Analysis in Environmental, Health and Safety Regulation?,” Science 272(12 April 1996): 221-222. Dr. Stavins reaffirmed his support for this article in a July 2009 web article titled “Is Benefit-Cost Analysis Helpful for Environmental Regulation?” Accessed at http://www.robertstavinsblog.org/2009/07/08/is-benefit-cost-analysis-helpful-for-environmental-regulation/

public policy, it can provide an exceptionally useful framework for consistently organizing disparate information, and in this way, it can greatly improve the process and hence the outcome of policy analysis." The approach of Florida's experts to understanding the incremental costs and benefits of changes in consumptive use and streamflows fulfills the spirit of cost-benefit analysis where one compares the incremental costs of an action to what it achieves, but does not go beyond the bounds of mainstream economic science by attempting to monetize effects that are not amenable to such quantification.

a. Guidelines for Preparing Economic Analyses (December 17, 2010), JX-47, is a true and accurate copy of guidance prepared by the National Center for Environmental Economics and the U.S. Environmental Protection Agency. I reviewed JX-47 as part of my research for how to value incremental costs in a scenario involving the intrinsic value of a natural resource.

107. It is commonplace in environmental policy making to engage in a cost-benefit analysis where incremental benefits and costs are compared while stopping short of monetizing benefits. A good example is the case of critical habitat designation under the Endangered Species Act. The ESA requires the U.S. Fish and Wildlife Service to designate critical habitat for listed species, and authorizes the Secretary of the Interior to exclude land from critical habitat if the costs of inclusion exceed the benefits. The costs of critical habitat designation are routinely monetized by the Service using standard economic methods since designation can result in restrictions on development and other types of economic activity. However, the Service is rarely, if ever, able to monetize the benefits of critical habitat designation since such monetization cannot be done reliably and scientifically. In a typical recent example, the Service declined to monetize the benefits of critical habitat for the Texas golden gladegrass because "while the designation may modestly influence the probability that the golden gladegrass will be

conserved, the published valuation literature does not support monetization of such changes for this species."[4] Instead, the Service has concluded that the benefits of critical habitat designation are best expressed in biological terms. Thus, when undertaking the critical habitat balancing test required by the ESA, the Secretary of the Interior does so by comparing monetary costs to biological benefits, and not by the approach advocated by Dr. Stavins in this case.

## VIII. PUBLIC SUPPORT FOR WATER CONSERVATION MEASURES

108. While it is impossible to reliably monetize the environmental benefits of consumption caps such as Florida has requested, there is ample evidence that the Apalachicola's natural resources are highly valued by residents of both Florida and Georgia. As discussed in the testimony of Mr. Jonathan Steverson, the Secretary of Florida's Department of Environmental Protection, the State of Florida has spent hundreds of millions of dollars on conservation in the Apalachicola River and Bay. This effort indicates that those resources are valued by the State of Florida. Those resources, as well as the rivers and streams of the Georgia ACF, are also valued by a much broader population than just local residents. Residents of Georgia visit the Apalachicola region for recreation, and may simply value its existence as a unique natural habitat. As described in my February 29, 2016 report, I conducted a survey of a random sample of Georgia residents to assess whether they valued the natural resources of the ACF, and to estimate their support for policies to protect these resources.

a. Recreational use survey, FX 800, is a true and accurate copy of Recreational Use of the Apalachicola River: A Survey of Residents of Alabama, Florida and Georgia - David Sunding. I created this document, which contains the results of

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[4] *Economic Analysis of the Critical Habitat Designation for Texas Golden Gladegrass and Neches River Rose-Mallow, East Texas*. Industrial Economics, Incorporated. Prepared for the U.S. Fish & Wildlife Service. March 14, 2013.

the survey. The survey was designed and conducted using accepted scientific principles, and it is typical for experts in my field to rely upon such surveys.

109. Approximately one-third of respondents from Georgia stated that they had visited the Apalachicola River for recreational purposes in the last 3 years. Almost two thirds had visited rivers in the broader ACF area during the same period. Such visits take time and resources, and thus indicate that Georgia households value ACF lakes and rivers. Although the Apalachicola River is located within Florida's boundaries, and is greatly valued by many Floridians, it also is used and valued by people across state lines.

110. Georgia survey respondents were also asked whether they would support mandatory water rationing during drought years in order to preserve either the Apalachicola River or the rivers of the ACF more broadly. As summarized in Table 1, support for mandatory rationing to preserve the Apalachicola alone was greater than opposition, at 50 to 11 percent. When asked about the broader ACF area, there were even fewer negative responses.

**Table 7: Survey Responses on Georgia Residents' Attitudes toward Conservation**

| | **Region** | **Responses from Georgia Residents** | | |
|---|---|---|---|---|
| **Policy Proposed** | **Preserved** | Support | Neither | Oppose |
| **Mandatory Water Rationing** | Apalachicola | 50% | 39% | 11% |
| | All ACF | 59% | 37% | 4% |
| **Outdoor Watering Restrictions** | Apalachicola | 60% | 23% | 17% |
| | All ACF | 70% | 29% | 1% |

Source: GfK Knowledge Networks Survey designed by The Brattle Group.

111. Georgia residents were also asked about a specific policy to restrict outdoor watering to two days a week during times of drought, similar to policies enacted in other metropolitan areas such as Los Angeles and Dallas. Generally these policies allow households to water lawns only on two specified days of the week, and only during cooler hours of the day.

Over 60 percent of respondents were either strongly or somewhat supportive of the policy, an even higher support rate than for mandatory water rationing during drought years.

112. The fact that a majority of Georgia residents would be willing to reduce their own water use on behalf of environmental preservation also serves as a rational basis for distributing the costs of conservation policy across a broad swath of the Georgia population. While cheaper opportunities for conservation may exist in particular areas or sectors, the economic impact may be distributed across the state to avoid placing burdens on those subject to conservation policy.

113. If the costs of achieving 2,000 cfs of reductions in streamflow depletions were spread across all 3.5 million households in the state, they would amount to approximately $10 per household per year. Compared to median Georgia household income of approximately $50,000 per year, and to the benefits of conservation to both Georgia and Florida residents, this cost is certainly reasonable. In total, the cost of the measures described above to reduce peak streamflow depletions by 2,000 cfs in drought years represents less than 0.2 percent of the State of Georgia’s $23 billion annual budget.

## IX. CONCLUSION

114. Georgia state policy has incentivized large increases in consumptive water use in the ACF Basin to the detriment of Florida's environment. These increases in consumptive use have been especially significant in the agricultural sector where Georgia's system of water withdrawal permitting has placed no meaningful limits on farmers’ water use. As a result, Georgia's farmers extract water to the point where it has little to no economic value on the margin. While there are certainly some agricultural uses of water in the ACF Basin of Georgia that are highly productive, there are ample opportunities to reduce farmers’ water use at little to no economic cost. These opportunities include permanent or dry-year buybacks of irrigation rights, limits on per-acre water use to eliminate irrigation above maximum productive amounts,

reducing irrigation depths, and improvements in irrigation efficiency.

115. In the urban sector as well, this testimony has shown that there are opportunities to reduce consumptive use to comply with Florida's requested consumption caps. Outdoor water use can be reduced by imposing one- or two-day a week lawn watering restrictions, or by imposing a ban on outdoor use in severely dry years such as Georgia state law already provides for. Metropolitan areas of Georgia can also undertake leak abatement to reduce consumptive use as indicated in the report of the state's Water Contingency Planning Task Force.

116. The fiscal cost of measures that would augment streamflows by 1,500 or even 2,000 cfs in dry years like 2011 were quantified in this testimony and shown to be modest in relation to Georgia state income and the size of the state's annual budget. Further, I demonstrated that Georgia residents themselves express broad-based support for conservation measures that improve Florida streamflows. In particular, a majority of Atlanta-area residents express support for voluntary or mandatory restrictions on outdoor water use assuming that the conserved water makes its way to Florida. Thus, the aesthetic and quality of life impacts of restricting outdoor water use in urban Georgia are economically counterbalanced by the corresponding improvements in Florida's ecosystems.

117. As a riparian rights state, Georgia has not grappled with the problem of water scarcity to nearly the same degree as western states like California, Nebraska, Arizona, Texas and others. The policies I considered in this testimony as a way for Georgia to better manage its water resources and comply with the requirements of Florida's requested consumption caps are routinely used in dry states to cope with scarcity and balance competing demands for water. There are numerous practical measures that Georgia could implement to reduce its consumptive use of water in the ACF Basin at a reasonable economic cost.

118. For the court’s convenience, I have listed the exhibits described and discussed in

my testimony in the table below in numerical order and noted the page on which the exhibit first appears. Authentication and foundational language are provided in the text of my testimony.

| Florida Exhibits | Florida Exhibits (cont.) | Joint Exhibits |
|---|---|---|
| FX-24 – Pg. 41 | FX-270 – Pg. 8 | JX-21 – Pg. 30 |
| FX-62 – Pg. 18 | FX-285 – Pg. 4 | JX-37 – Pg. 6 |
| FX-165 – Pg. 49 | FX-309 – Pg. 14 | JX-41 – Pg. 21 |
| FX-166 – Pg. 49 | FX-310 – Pg. 14 | JX-85 – Pg. 20 |
| FX-167 – Pg. 49 | FX-311 – Pg. 23 | JX-86 – Pg. 5 |
| FX-170 – Pg. 49 | FX-327 – Pg. 11 | JX-132 – Pg. 22 |
| FX-171 – Pg. 13 | FX-328 – Pg. 11 | |
| FX-174 – Pg. 49 | FX-329 – Pg. 9 | |
| FX-175 – Pg. 13 | FX-699 – Pg. 26 | |
| FX-176 – Pg. 13 | FX-700 – Pg. 26 | |
| FX-177 – Pg. 13 | FX-707 – Pg. 17 | |
| FX-180 – Pg. 50 | FX-708 – Pg. 22 | |
| FX-181 – Pg. 49 | FX-709 – Pg. 18 | |
| FX-182 – Pg. 49 | FX-710 – Pg. 38 | |
| FX-183 – Pg. 33 | JX-47 – Pg. 54 | |
| FX-184 – Pg. 33 | FX-784 – Pg. 4 | |
| FX-185 – Pg. 34 | FX-800 – Pg. 55 | |
| FX-186 – Pg. 49 | FX-867 – Pg. 33 | |
| FX-187 – Pg. 49 | FX-784 – Pg. 10 | |
| FX-267 – Pg. 17 | | |